



## **KINGSTON ENGINEERING COLLEGE**

**(An Autonomous Institution)**

**(Approved by AICTE & COA, New Delhi, Affiliated to Anna University, Chennai)  
Chittoor Main Road, Christianpet,  
Katpadi, Vellore-632059**

### **MASTER OF ENGINEERING IN POWER SYSTEMS ENGINEERING**

### **AUTONOMOUS CURRICULUM REGULATION 2026**

***Academic Year 2026-27 onwards***



## **INSTITUTE VISION**

To be a pioneer in engineering and management education by providing amicable ambience and being a centre for learning thereby perpetuating versatile professionals in engineering and management suitable for industry, higher education and research.

## **INSTITUTE MISSION**

- Developing, nurturing and building professionals with technical, research and managerial expertise, intellectual proficiency, right attitude and moral ethics.
- Building infrastructure that earmarks the institution to be the most preferred educational destination and provides the right ambience for creative and innovative teaching - learning process.
- Enabling learners to broaden their horizon and helping to meet global challenges.

## **QUALITY POLICY**

To establish and implement a robust quality system at Kingston Engineering College, encircling teaching, learning, research, and self-reliance, focusing on core and support functions to ensure accountability to stakeholders through continuous improvement and sustenance towards promoting holistic academic excellence.





**ME-POWER SYSTEMS ENGINEERING**  
**REGULATION-2026**  
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## **ME-POWER SYSTEMS ENGINEERING**

### **REGULATION-2026**

### **CHOICE BASED CREDIT SYSTEM**

#### **VISION:**

To build highly skilled, competent, ethical and versatile professionals with ability to design, develop, analyze and implement core engineering technologies to solve real time problems.

#### **MISSION**

**M1:** To Train students to become well balanced engineers taking into consideration society, safety and environment.

**M2:** To make the students suitable for industry.

**M3:** To import self-learning ability, and to drive the students for higher education and research.

#### **Program Educational Objectives (PEOs)**

**PEO1:** To prepare the students for successful career in electrical power industry, research and teaching institutions.

**PEO2:** To provide strong foundation in Power Engineering, necessary for day-to-day operation and planning of Power System.

**PEO3:** To develop the ability to design various controllers to enhance the stability and power transfer capability of the Power System.

**PEO4:** To provide knowledge in Renewable Energy Systems, Electric Vehicles and Grid Integrations using Power Converters.

**PEO5:** To develop a detailed understanding of various tools applied to the operation, design and investigation of modern electric power systems.

## PROGRAMME OUTCOMES (POs)

**PO1:**An ability to independently carry out research / investigation and development work to solve practical problems.

**PO2:**An ability to write and present a substantial technical report / document.

**PO3:**Students should be able to demonstrate a degree of mastery in power systems engineering.

## PROGRAMME SPECIFIC OUTCOMES (PSOs)

**PSO1:**Get elevated as technically competent Power Engineer to cater the needs of Electrical Power Industry, Research and Educational Institutions. Pursue career in core service sector of power system industry with lifelong learning and professional ethics.

**PSO2:**Become an entrepreneur in modern restructured power systems, proficient in application software packages used in the Power System industry.

## MAPPING OF PROGRAM EDUCATIONAL OBJECTIVES WITH PROGRAM OUTCOMES

| PRORAM<br>EDUCATIONAL<br>OBJECTIVES | PROGRAM OUTCOMES |     |     |
|-------------------------------------|------------------|-----|-----|
|                                     | PO1              | PO2 | PO3 |
| PEO1                                | 3                | 2   | 3   |
| PEO2                                | 2                | 1   | 3   |
| PEO3                                | 3                | 2   | 3   |
| PEO4                                | 2                | 1   | 3   |
| PEO5                                | 3                | 2   | 3   |

1 – Low, 2 – Medium, 3 – High, ‘-’ -no correlation

## MAPPING OF PROGRAM SPECIFIC OUTCOMES WITH PROGRAM OUTCOMES

| PROGRAM SPECIFIC OUTCOMES | PROGRAM OUTCOMES |     |     |
|---------------------------|------------------|-----|-----|
|                           | PO1              | PO2 | PO3 |
| PSO1                      | 3                | 2   | 3   |
| PSO2                      | 3                | 2   | 3   |

1 – Low, 2 – Medium, 3 – High, ‘-‘ -no correlation

## SUSTAINABLE DEVELOPMENT GOALS (SDG)



## ME-POWER SYSTEMS ENGINEERING

### REGULATION-2026

#### CURRICULUM SEMESTER I to IV

#### CHOICE BASED CREDIT SYSTEM

(For the Students admitted in the Academic Year 2026-27)

| Semester I                          |             |                                                |             |                 |           |          |          |           |          |
|-------------------------------------|-------------|------------------------------------------------|-------------|-----------------|-----------|----------|----------|-----------|----------|
| S. No                               | Course Code | Course Name                                    | Course Type | Contact Periods | L         | T        | P        | C         | SDG      |
| <b>Theory Course</b>                |             |                                                |             |                 |           |          |          |           |          |
| 1                                   | PS26M01     | Applied Mathematics for Power System Engineers | BS          | 4               | 3         | 1        | 0        | 4         | 9,7      |
| 2                                   | PS26101     | Computer Aided Power System Analysis           | PC          | 3               | 3         | 0        | 0        | 3         | 7,9      |
| 3                                   | PS26102     | Advanced Power System Operation and Control    | PC          | 3               | 3         | 0        | 0        | 3         | 7,13     |
| 4                                   | PS26103     | Research Methodology and IPR                   | PC          | 2               | 2         | 0        | 0        | 2         | 4,9,17   |
| 5                                   |             | Programme Elective I                           | PE          | 3               | 3         | 0        | 0        | 3         | -        |
| <b>Lab Integrated Theory Course</b> |             |                                                |             |                 |           |          |          |           |          |
| 6                                   | PS26104     | Analysis of Power Converters                   | PC          | 5               | 3         | 0        | 2        | 4         | 7,12     |
| <b>Practical Course</b>             |             |                                                |             |                 |           |          |          |           |          |
| 7                                   | PS26111     | Power System Simulation Laboratory             | PC          | 4               | 0         | 0        | 4        | 2         | 4, 9     |
| <b>TOTAL</b>                        |             |                                                |             | <b>24</b>       | <b>17</b> | <b>1</b> | <b>6</b> | <b>21</b> | <b>-</b> |



| Semester II                             |             |                                                                 |             |                 |           |          |          |           |          |
|-----------------------------------------|-------------|-----------------------------------------------------------------|-------------|-----------------|-----------|----------|----------|-----------|----------|
| S. No                                   | Course Code | Course Name                                                     | Course Type | Contact Periods | L         | T        | P        | C         | SDG      |
| <b>Theory Course</b>                    |             |                                                                 |             |                 |           |          |          |           |          |
| 1                                       | PS26201     | Power System Transients                                         | PC          | 3               | 3         | 0        | 0        | 3         | 7,9      |
| 2                                       | PS26202     | Power System Dynamics                                           | PC          | 3               | 3         | 0        | 0        | 3         | 7,9      |
| 3                                       |             | Programme Elective II                                           | PE          | 3               | 3         | 0        | 0        | 3         | -        |
| <b>Lab Integrated Theory Course</b>     |             |                                                                 |             |                 |           |          |          |           |          |
| 4                                       | PS26203     | Advanced Power System Protection                                | PC          | 5               | 3         | 0        | 2        | 4         | 7,9      |
| <b>Practical Course</b>                 |             |                                                                 |             |                 |           |          |          |           |          |
| 5                                       | PS26211     | Modern Power System Laboratory                                  | PC          | 4               | 0         | 0        | 4        | 2         | 4,7      |
| <b>Employability Enhancement Course</b> |             |                                                                 |             |                 |           |          |          |           |          |
| 6                                       | PS26S01     | Industry Oriented Course                                        | EE          | 1               | 1         | 0        | 0        | 1         | -        |
| 7                                       | PS26S02     | Mini Project /Industrial Training                               | EE          | 2               | 0         | 0        | 2        | 2         | -        |
| <b>Mandatory Course</b>                 |             |                                                                 |             |                 |           |          |          |           |          |
| 8                                       | PS26S03     | Self-Learning Course/Value added Course/Conference presentation | SL          | -               | -         | -        | -        | 2         | -        |
| <b>TOTAL</b>                            |             |                                                                 |             | <b>21</b>       | <b>13</b> | <b>0</b> | <b>8</b> | <b>20</b> | <b>-</b> |

| Semester III     |             |                                |             |                 |           |          |           |           |          |
|------------------|-------------|--------------------------------|-------------|-----------------|-----------|----------|-----------|-----------|----------|
| S. No            | Course Code | Course Name                    | Course Type | Contact Periods | L         | T        | P         | C         | SDG      |
| Theory Course    |             |                                |             |                 |           |          |           |           |          |
| 1                | PS26301     | Energy Management and Auditing | PC          | 3               | 3         | 0        | 0         | 3         | 7,9      |
| 2                |             | Programme Elective III         | PE          | 3               | 3         | 0        | 0         | 3         | -        |
| 3                |             | Programme Elective IV          | PE          | 3               | 3         | 0        | 0         | 3         | -        |
| 4                |             | Programme Elective V           | PE          | 3               | 3         | 0        | 0         | 3         | -        |
| Practical Course |             |                                |             |                 |           |          |           |           |          |
| 6                | PS26311     | Project Work – I               | EE          | 12              | 0         | 0        | 12        | 6         | -        |
| <b>TOTAL</b>     |             |                                |             | <b>24</b>       | <b>12</b> | <b>0</b> | <b>12</b> | <b>18</b> | <b>-</b> |

| Semester IV  |             |                   |             |                 |          |          |           |           |          |
|--------------|-------------|-------------------|-------------|-----------------|----------|----------|-----------|-----------|----------|
| S. No        | Course Code | Course Name       | Course Type | Contact Periods | L        | T        | P         | C         | SDG      |
| 1            | PS26411     | Project Work – II | EE          | 24              | 0        | 0        | 24        | 12        | -        |
| <b>TOTAL</b> |             |                   |             | <b>24</b>       | <b>0</b> | <b>0</b> | <b>24</b> | <b>12</b> | <b>-</b> |

### Credit Distribution

| S.No         | Subject Area                           | Credit Per Semester |           |           |           | Credits Total | Percentage |
|--------------|----------------------------------------|---------------------|-----------|-----------|-----------|---------------|------------|
|              | Semester                               | I                   | II        | III       | IV        |               |            |
| 1            | Basic Science Course (BS)              | 4                   | 0         | 0         | 0         | 4             | 5.63 %     |
| 2            | Employability Enhancement Courses (EE) | 0                   | 3         | 6         | 12        | 21            | 29.57%     |
| 3            | Professional Course (PC)               | 14                  | 12        | 3         | 0         | 29            | 40.84%     |
| 4            | Programme Elective (PE)                | 3                   | 3         | 9         | 0         | 15            | 21.12%     |
| 5            | Mandatory Course                       | 0                   | 2         | 0         | 0         | 2             | 2.81%      |
| <b>Total</b> |                                        | <b>21</b>           | <b>20</b> | <b>18</b> | <b>12</b> | <b>71</b>     | <b>100</b> |

**PROGRAMME ELECTIVE COURSES (PE)**

| S. No | Course Code | Course Name                                                     | Course Type | Contact Periods | L | T | P | C  | SDG       |
|-------|-------------|-----------------------------------------------------------------|-------------|-----------------|---|---|---|----|-----------|
| 1     | PS26001     | Power System State Estimation and Security Assessment           | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 2     | PS26002     | Computational Intelligence Techniques to Power Systems          | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 3     | PS26003     | IoT for Smart Systems                                           | PE          | 3               | 3 | 0 | 0 | 3, | 7,9,11,13 |
| 4     | PS26004     | Renewable Energy and Grid Integration                           | PE          | 3               | 3 | 0 | 0 | 3  | 7, 13,17  |
| 5     | PS26005     | Electrical Power Distribution System                            | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 6     | PS26006     | Wind and Solar Energy Systems                                   | PE          | 3               | 3 | 0 | 0 | 3  | 7,13      |
| 7     | PS26007     | Energy Storage Technologies                                     | PE          | 3               | 3 | 0 | 0 | 3  | 7,12,13   |
| 8     | PS26008     | Power Quality                                                   | PE          | 3               | 3 | 0 | 0 | 3  | 9,7,12    |
| 9     | PS26009     | Power System Reliability                                        | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 10    | PS26010     | EHV AC Transmission                                             | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 11    | PS26011     | Electromagnetic Interference and Compatibility in System Design | PE          | 3               | 3 | 0 | 0 | 3  | 9,11      |
| 12    | PS26012     | Industrial Power System Analysis and Design                     | PE          | 3               | 3 | 0 | 0 | 3  | 9,12      |
| 13    | PS26013     | Advanced Power System Dynamics                                  | PE          | 3               | 3 | 0 | 0 | 3  | 7,13      |
| 14    | PS26014     | Computer Relaying and Wide Area Measurement Systems             | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 15    | PS26015     | Application of DSP To Power System Protection                   | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 16    | PS26016     | High Voltage Technology                                         | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 17    | PS26017     | Smart Grid                                                      | PE          | 3               | 3 | 0 | 0 | 3  | 7,11      |
| 18    | PS26018     | Distributed Generation and Micro Grid                           | PE          | 3               | 3 | 0 | 0 | 3  | 7,13      |

**PROGRAMME ELECTIVE COURSES (PE)**

| S. No | Course Code | Course Name                                                     | Course Type | Contact Periods | L | T | P | C  | SDG       |
|-------|-------------|-----------------------------------------------------------------|-------------|-----------------|---|---|---|----|-----------|
| 1     | PS26001     | Power System State Estimation and Security Assessment           | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 2     | PS26002     | Computational Intelligence Techniques to Power Systems          | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 3     | PS26003     | IoT for Smart Systems                                           | PE          | 3               | 3 | 0 | 0 | 3, | 7,9,11,13 |
| 4     | PS26004     | Renewable Energy and Grid Integration                           | PE          | 3               | 3 | 0 | 0 | 3  | 7, 13,17  |
| 5     | PS26005     | Electrical Power Distribution System                            | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 6     | PS26006     | Wind and Solar Energy Systems                                   | PE          | 3               | 3 | 0 | 0 | 3  | 7,13      |
| 7     | PS26007     | Energy Storage Technologies                                     | PE          | 3               | 3 | 0 | 0 | 3  | 7,12,13   |
| 8     | PS26008     | Power Quality                                                   | PE          | 3               | 3 | 0 | 0 | 3  | 9,7,12    |
| 9     | PS26009     | Power System Reliability                                        | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 10    | PS26010     | EHV AC Transmission                                             | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 11    | PS26011     | Electromagnetic Interference and Compatibility in System Design | PE          | 3               | 3 | 0 | 0 | 3  | 9,11      |
| 12    | PS26012     | Industrial Power System Analysis and Design                     | PE          | 3               | 3 | 0 | 0 | 3  | 9,12      |
| 13    | PS26013     | Advanced Power System Dynamics                                  | PE          | 3               | 3 | 0 | 0 | 3  | 7,13      |
| 14    | PS26014     | Computer Relaying and Wide Area Measurement Systems             | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 15    | PS26015     | Application of DSP To Power System Protection                   | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 16    | PS26016     | High Voltage Technology                                         | PE          | 3               | 3 | 0 | 0 | 3  | 7,9       |
| 17    | PS26017     | Smart Grid                                                      | PE          | 3               | 3 | 0 | 0 | 3  | 7,11      |
| 18    | PS26018     | Distributed Generation and Micro Grid                           | PE          | 3               | 3 | 0 | 0 | 3  | 7,13      |

|    |         |                                              |    |   |   |   |   |   |        |
|----|---------|----------------------------------------------|----|---|---|---|---|---|--------|
| 19 | PS26019 | Python Programming for Machine Learning      | PE | 3 | 3 | 0 | 0 | 3 | 4,9    |
| 20 | PS26020 | Restructured Power System                    | PE | 3 | 3 | 0 | 0 | 3 | 7,12   |
| 21 | PS26021 | Electric Vehicles and Power Management       | PE | 3 | 3 | 0 | 0 | 3 | 7,13   |
| 22 | PS26022 | FACTS                                        | PE | 3 | 3 | 0 | 0 | 3 | 7,9,13 |
| 23 | PS26023 | Application of AI Techniques to Power System | PE | 3 | 3 | 0 | 0 | 3 | 9,12   |
| 24 | PS26024 | Cybersecurity of Smart Grids                 | PE | 3 | 3 | 0 | 0 | 3 | 9,16   |

  
**BOS Chairman/PSE**

**Chairman**  
Board of Studies  
M.E. Power Systems Engineering  
Kingston Engineering College  
Vellore - 632 059

  
**PRINCIPAL**

**PRINCIPAL**  
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# **SEMESTER-I**







|           |                                                 |   |   |   |   |
|-----------|-------------------------------------------------|---|---|---|---|
| PS26M01   | APPLIED MATHEMATICS FOR POWER SYSTEMS ENGINEERS | L | T | P | C |
| SDG:4,7,9 |                                                 | 3 | 1 | 0 | 4 |

### COURSE OBJECTIVES:

- To develop the ability to apply the concepts of matrix theory in Electrical Engineering problems
- To Impart the knowledge of Fuzzy set and Fuzzy logic.
- To impart deep knowledge and concepts to solve complicated problems using linear programming.
- To emphasizes the Transportation and Assignment Problem.
- To develop the capability of solving problems using non - linear programming Techniques

|               |                      |           |
|---------------|----------------------|-----------|
| <b>UNIT I</b> | <b>MATRIX THEORY</b> | <b>12</b> |
|---------------|----------------------|-----------|

The Cholesky decomposition - Generalized Eigenvectors - Canonical basis - QR factorization - Singular value decomposition - Pseudo inverses - Least square approximation.

|                |                    |           |
|----------------|--------------------|-----------|
| <b>UNIT II</b> | <b>FUZZY LOGIC</b> | <b>12</b> |
|----------------|--------------------|-----------|

Classical logic – Multivalued logics – Fuzzy propositions – Fuzzy quantifiers.

|                 |                                   |           |
|-----------------|-----------------------------------|-----------|
| <b>UNIT III</b> | <b>LINEAR PROGRAMMING PROBLEM</b> | <b>12</b> |
|-----------------|-----------------------------------|-----------|

Formulation - Graphical solution - Simplex method - Big M method - Two phase Method.

|                |                                                    |           |
|----------------|----------------------------------------------------|-----------|
| <b>UNIT IV</b> | <b>TRANSPORTATION MODELS AND ASSIGNMENT MODELS</b> | <b>12</b> |
|----------------|----------------------------------------------------|-----------|

Transportation Models (Minimising and Maximising Problems) –Balanced and unbalanced problems –Initial Basic feasible solution by N-W Corner Rule, Least cost and Vogel's approximation methods. Check for optimality. Solution by MODI / Stepping Stone method. Assignment Models(Minimising and Maximising Problems)- Balanced and Unbalanced Problems, Solution by Hungarian.

|               |                                          |           |
|---------------|------------------------------------------|-----------|
| <b>UNIT V</b> | <b>NON – LINEAR PROGRAMMING PROBLEMS</b> | <b>12</b> |
|---------------|------------------------------------------|-----------|

Lagrange multipliers – Equality constraints – Inequality constraints – Kuhn – Tucker Conditions –Quadratic programming.

**ACTIVITIES:** Perform Cholesky decomposition, Design fuzzy membership functions for student performance , Formulate and solve linear programming using opensource software, Review of GATE questions.

**TOTAL: 60 PERIODS**

### COURSE OUTCOMES:

**CO1:** Able to apply the concepts of matrix theory in Electrical Engineering problems.

**CO2:** Apply the concept of fuzzy logic in real-life problems.

**CO3:** Able to understood the basic concepts and also to solve complicated problems using linear programming.

**CO4:** Interpret and relate the principles of Transportation and Assignment models.

**CO5:** Analyse non - linear programming techniques.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

### TEXTBOOKS:

1. Kreyszig, E., "Advanced Engineering Mathematics", , Wiley India, 10th Edition 2015.
2. Hamdy A. Taha, Operations Research, Pearson Education, 11th Edition, 2022.

### REFERENCES:

1. Jain, R.K. and Iyengar, S.R.K., "Advanced Engineering Mathematics", Narosa Publications.



2. Rao, S.S., "Engineering Optimization: Theory and Practice", Wiley. 5th Edition.
3. Strang, G., "Linear Algebra and Its Applications", 4th Edition, Cengage Learning, 4th Edition.
4. G. Srinivasan, Operations Research: Principles and Applications, PHI Learning, 2nd Edition, 2011.

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | -    | -    |
| CO2 | 2   | 1   | 3   | -    | -    |
| CO3 | 2   | 1   | 3   | -    | -    |
| CO4 | 3   | 1   | 3   | -    | -    |
| CO5 | 2   | 1   | 3   | -    | -    |
| AVG | 2.2 | 1   | 3   | -    | -    |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|         |                                      |   |   |   |   |
|---------|--------------------------------------|---|---|---|---|
| PS26101 | COMPUTER AIDED POWER SYSTEM ANALYSIS | L | T | P | C |
| SDG:7,9 |                                      | 3 | 0 | 0 | 3 |

#### COURSE OBJECTIVES:

- To equip students with efficient computational solution techniques, including sparse matrix methods, matrix factorization, and computer-aided tools for analyzing and solving large-scale power system problems.
- To impart in-depth knowledge on different power flow solution methods for large power system networks.
- To perform various optimal power flow methods involving operating and security constraints.
- To perform short circuit fault analysis for various fault conditions on three phase basis.
- To understand and apply transient stability analysis techniques for evaluating and improving power system stability.

|                                                                                                                                                                                                                                                                                                                                                                                           |                            |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                             | <b>SOLUTION TECHNIQUE</b>  | <b>9</b> |
| Sparse Matrix-Based Load Flow Solution ,Optimal Matrix Ordering Techniques, LU Factorization for Power System Analysis ,Gauss Elimination for Large Power Networks, Fast Solution of Power Flow Equations, Repeat Solution Using L-U Factors, State Estimation Using Sparse Matrix Methods, Parallel Computing for Large-Scale Power System Solutions ,Computer-Aided Solution Techniques |                            |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                            | <b>POWER FLOW ANALYSIS</b> | <b>9</b> |
| Power flow equation in real and polar forms - Review of Newton Raphson method for solution; Adjustment of P-V buses - Review of Fast Decoupled Power Flow method - Sensitivity factors for P-V bus adjustment.                                                                                                                                                                            |                            |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                           | <b>OPTIMAL POWER FLOW</b>  | <b>9</b> |
| Problem statement - Solution of Optimal Power Flow (OPF) - The gradient method - Newton's method- Linear Sensitivity Analysis - LP methods - With real power variables only - LP method with AC power flow variables and detailed cost functions - Security constrained Optimal Power Flow - Interior point algorithm - Bus Incremental costs.                                            |                            |          |



|                |                               |          |
|----------------|-------------------------------|----------|
| <b>UNIT IV</b> | <b>SHORT CIRCUIT ANALYSIS</b> | <b>9</b> |
|----------------|-------------------------------|----------|

Formation of bus impedance matrix with mutual coupling (single phase basis and three phase basis) -Computer method for fault analysis using ZBUS and sequence components - Derivation of equations for bus voltages -fault current and line currents - both in sequence and phase - symmetrical and unsymmetrical faults.

|               |                                     |          |
|---------------|-------------------------------------|----------|
| <b>UNIT V</b> | <b>TRANSIENT STABILITY ANALYSIS</b> | <b>9</b> |
|---------------|-------------------------------------|----------|

SMIB Transient Stability Analysis , Multi-Machine Stability Simulation, Critical Clearing Time (CCT) Assessment ,Fault Impact on System Stability, Power System Stabilizer (PSS) Design ,AVR and Excitation System Analysis, PMU-Based Real-Time Stability Monitoring ,AI-Based Transient Stability Prediction.

**ACTIVITIES:** Computer-Aided Solution Techniques Using MATLAB/ETAP/DigSILENT/PSS®E , Optimal Power Flow problem considering generation cost and system operating constraints using MATLAB/Python, Review of GATE questions.

**TOTAL: 45 PERIODS**

#### **COURSE OUTCOMES:**

**CO1:** Apply sparse matrix techniques, matrix factorization methods, and computer-aided computational tools to efficiently solve large-scale power system analysis and state estimation problems.

**CO2:** Analyze power flow in power systems using Newton-Raphson and Fast Decoupled Load Flow methods.

**CO3:** Formulate and solve optimal power flow problems using classical and modern optimization techniques.

**CO4:** Perform short-circuit studies and evaluate symmetrical and unsymmetrical fault conditions in power systems.

**CO5:** Analyze transient stability and apply suitable control and monitoring techniques to improve the dynamic performance of power systems

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

#### **TEXTBOOKS:**

1.Kothari, D.P. and Nagrath, I.J., "Modern Power System Analysis", 5th Edition, McGraw Hill Education, 2022.

#### **REFERENCES:**

1. Pai, M.A., "Computer Techniques in Power System Analysis", 2nd Edition, Tata McGraw Hill.

2. Wood, A.J., Wollenberg, B.F. and Sheble, G.B., "Power Generation, Operation and Control", Wiley.

3. Grainger, J.J. and Stevenson, W.D., "Power System Analysis", McGraw Hill.

4. Anderson, P.M. and Fouad, A.A., "Power System Control and Stability", IEEE Press.

5. Hadi Saadat, "Power System Analysis", McGraw Hill.

#### **CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 1   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 1   | 3   | 3    | 2    |
| CO5 | 3   | 2   | 3   | 2    | 3    |
| AVG | 3   | 1.4 | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

ME-PSE

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**ACTIVITIES:** Tutorial on ALFC for single and two area systems AVR with conventional controllers, State estimation of AC network with PMU, UC and ED problems, Contingency Analysis for simple power networks, Review of GATE questions.

**45 PERIODS**

**COURSE OUTCOMES:**

**CO1:** Analyze real power-frequency control mechanisms, load frequency control models, and economic load sharing in single- and multi-area power systems.

**CO2:** Evaluate reactive power compensation and voltage regulation techniques using AVR, FACTS devices, transformer tap changers, and distribution voltage control methods.

**CO3:** Formulate and solve unit commitment, economic dispatch, and hydro-thermal scheduling problems using optimization techniques.

**CO4:** Assess power system security using contingency analysis, sensitivity factors, SCADA, EMS, and corrective control strategies.

**CO5:** Apply state estimation algorithms, observability analysis, bad data detection, and PMU-based monitoring techniques for reliable power system operation.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. Wood, A. J., & Wollenberg, B. F. (2016). Power generation, operation, and control. John Wiley and Sons.

**REFERENCES:**

1. Kundur, P. (2008). Power system stability and control (5th reprint). Tata McGraw Hill.
2. Elgerd, O. I. (2002). Electric energy system theory: An introduction. Tata McGraw Hill.
3. Kothari, D. P., & Nagrath, I. J. (2003). Modern power system analysis (4th ed.). Tata McGraw Hill Publishing Company Limited.
4. Grigsby, L. L. (2001). The electric power engineering handbook. CRC Press & IEEE Press.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 3   | 3   | 3    | 3    |
| CO4 | 3   | 3   | 3   | 3    | 2    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2.6 | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

  
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                              |   |   |   |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|---|---|---|---|
| PS26103                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | RESEARCH METHODOLOGY AND IPR | L | T | P | C |
| SDG:4,9,17                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                              | 2 | 0 | 0 | 2 |
| <b>COURSE OBJECTIVES:</b> <ul style="list-style-type: none"><li>• Understand the fundamentals of research methodology and research design.</li><li>• Learn various data collection, sampling, and statistical analysis techniques for engineering research.</li><li>• Develop skills for preparing technical reports and presenting research findings effectively.</li><li>• Gain knowledge of Intellectual Property Rights (IPR), patents, copyrights, trademarks, and their significance.</li><li>• Understand patent filing procedures and the legal aspects of intellectual property relevant to engineering research.</li></ul> |                              |   |   |   |   |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | RESEARCH DESIGN              |   |   |   | 6 |
| Overview of research process and design, Use of Secondary and exploratory data to answer the research question, Qualitative research, Observation studies, Experiments and Surveys.                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                              |   |   |   |   |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | DATA COLLECTION AND SOURCES  |   |   |   | 6 |
| Measurements, Measurement Scales, Questionnaires and Instruments, Sampling and methods. Data - Preparing, Exploring, examining and displaying.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                              |   |   |   |   |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | DATA ANALYSIS AND REPORTING  |   |   |   | 6 |
| Overview of Multivariate analysis, Hypotheses testing and Measures of Association, Presenting Insights and findings using written reports and oral presentation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                              |   |   |   |   |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | INTELLECTUAL PROPERTY RIGHTS |   |   |   | 6 |
| Intellectual Property – The concept of IPR, Evolution and development of concept of IPR, IPR development process, Trade secrets, utility Models, IPR & Bio diversity, Role of WIPO and WTO in IPR establishments, Right of Property, Common rules of IPR practices, Types and Features of IPR Agreement, Trademark, Functions of UNESCO in IPR maintenance.                                                                                                                                                                                                                                                                          |                              |   |   |   |   |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | PATENTS                      |   |   |   | 6 |
| Patents – objectives and benefits of patent, Concept, features of patent, Inventive step, Specification, Types of patent application, process E-filing, Examination of patent, Grant of patent, Revocation, Equitable Assignments, Licences, Licensing of related patents, patent agents, Registration of patent agents.                                                                                                                                                                                                                                                                                                             |                              |   |   |   |   |
| <b>ACTIVITIES:</b> Preparation of a research proposal related to Power Systems, Technical paper review and presentation from IEEE journals, Seminar on Intellectual Property Rights in Electrical Engineering, Statistical analysis of engineering data using spreadsheet/MATLAB/SPSS.                                                                                                                                                                                                                                                                                                                                               |                              |   |   |   |   |
| 30 PERIODS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                              |   |   |   |   |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                              |   |   |   |   |
| <b>CO1:</b> Explain the concepts of research methodology, research design, and qualitative and quantitative research methods.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                              |   |   |   |   |



**CO2:** Apply appropriate data collection, sampling, measurement, and data analysis techniques for engineering research.

**CO3:** Analyze research data, perform hypothesis testing, and communicate research findings through technical reports and presentations.

**CO4:** Illustrate the concepts of Intellectual Property Rights, patents, trademarks, copyrights, and international IPR organizations.

**CO5:** Demonstrate knowledge of patent drafting, filing procedures, examination, licensing, and commercialization of innovations.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. Kothari, C. R., & Garg, G., Research Methodology: Methods and Techniques, 4th Edition, New Age International Publishers, 2019.

2. Cornish, W., Llewelyn, D., & Aplin, T., Intellectual Property: Patents, Copyrights, Trade Marks and Allied Rights, 10th Edition, Sweet & Maxwell, 2024.

**REFERENCES:**

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 11e (2012).

2. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets", Entrepreneur Press, 2007.

3. David Hunt, Long Nguyen, Matthew Rodgers, "Patent searching: tools & techniques", Wiley, 2007.

4. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, "Professional Programme Intellectual Property Rights, Law and practice", September 2013.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 1   | 2    | 1    |
| CO2 | 3   | 2   | 2   | 3    | 2    |
| CO3 | 3   | 3   | 2   | 3    | 2    |
| CO4 | 2   | 1   | 2   | 2    | 2    |
| CO5 | 2   | 2   | 2   | 2    | 3    |
| AVG | 2.6 | 1.8 | 1.8 | 2.4  | 2    |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

  
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                              |  |   |   |   |                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|--|---|---|---|-------------------|
| PS26104                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | ANALYSIS OF POWER CONVERTERS |  | L | T | P | C                 |
| SDG:7,12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                              |  | 3 | 0 | 2 | 4                 |
| <b>COURSE OBJECTIVES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                              |  |   |   |   |                   |
| <ul style="list-style-type: none"><li>To provide the mathematical fundamentals necessary for deep understanding of power converter operating modes.</li><li>To introduce the electrical circuit concepts behind the different working modes of power converters so as to enable deep understanding of their operation.</li><li>To impart required skills to formulate and design inverters for generic load and for machine loads.</li><li>To equip with required skills to derive the criteria for the design of power converters starting from basic fundamentals.</li><li>To inculcate knowledge to perform analysis and comprehend the various operating modes of different configurations of power converters.</li></ul> |                              |  |   |   |   |                   |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | SINGLE PHASE AC-DC CONVERTER |  |   |   |   | <b>9</b>          |
| Half controlled and fully controlled converters with R-L, R-L-E loads and freewheeling diodes – continuous and discontinuous modes of operation- inverter operation and its limit –Sequence control of converters – performance parameters –effect of source impedance and overlap-reactive power and power balance in converter circuit.                                                                                                                                                                                                                                                                                                                                                                                     |                              |  |   |   |   |                   |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | THREE PHASE AC-DC CONVERTER  |  |   |   |   | <b>9</b>          |
| Half controlled and fully controlled converters with R, R-L, R-L-E loads and freewheeling diodes –inverter operation and its limit – performance parameters – effect of source impedance and overlap - 12 pulse converter – Applications - Excitation system, DC drive system.                                                                                                                                                                                                                                                                                                                                                                                                                                                |                              |  |   |   |   |                   |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | SINGLE PHASE INVERTERS       |  |   |   |   | <b>9</b>          |
| Introduction to self-commutated switches : MOSFET and IGBT - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – Design of UPS – VSR operation                                                                                                                                                                                                                                                                                                                                                                                                                             |                              |  |   |   |   |                   |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | THREE PHASE INVERTERS        |  |   |   |   | <b>9</b>          |
| 180 degree and 120 degree conduction mode inverters with star and delta connected loads – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques-Impact of power system Capacitance– Current source inverters.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                              |  |   |   |   |                   |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | MODERN INVERTERS             |  |   |   |   | <b>9</b>          |
| Multilevel concept – cascaded type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters – PWM techniques for MLI –Single phase &Three phase Impedance source inverters – Filters.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                              |  |   |   |   |                   |
| <b>ACTIVITIES:</b> Analyze the operation of three-phase controlled converters and evaluate the effect of source inductance using MATLAB/Simulink , Implement SPWM and SVPWM techniques for three-phase inverters and evaluate their performance in AC drive applications. Model multilevel and impedance source inverters and compare their harmonic distortion, efficiency, and power quality characteristics.                                                                                                                                                                                                                                                                                                               |                              |  |   |   |   |                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                              |  |   |   |   | <b>45 PERIODS</b> |
| <b>LIST OF EXPERIMENTS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                              |  |   |   |   | <b>30 PERIODS</b> |
| <ul style="list-style-type: none"><li>1.Simulation and Experimental Study of DC–DC Buck–Boost Converter.</li><li>2. Analysis of Single-Phase Fully Controlled Rectifier.</li><li>3. Investigation of DC–DC Buck Converter.</li><li>4. Analysis of DC–DC Boost Converter.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                            |                              |  |   |   |   |                   |



5. Performance Evaluation of Three-Phase PWM Inverter.
6. Analysis of Single-Phase Voltage Source Inverter (VSI) Using PWM.

**TOTAL: 75 PERIODS**

**COURSE OUTCOMES:**

**CO1:** Analyze the operating characteristics and performance of single-phase and three-phase AC-DC converters under various loading conditions.

**CO2:** Evaluate the effect of source impedance, overlap, and control strategies on converter operation and performance.

**CO3:** Design and analyze single-phase inverter circuits employing PWM techniques for voltage control and harmonic reduction.

**CO4:** Analyze the operation and applications of three-phase inverters and voltage source converters in industrial drive systems.

**CO5:** Evaluate modern multilevel and impedance source inverter topologies for power quality and renewable energy applications.

**WEIGHTAGE:** Continuous Assessment: 50%, End Semester Examinations: 50%

**TEXTBOOKS:**

1. Mohan, N., Undeland, T.M. and Robbins, W.P., "Power Electronics: Converters, Applications and Design", 3rd Edition, Wiley India, 2017.

**REFERENCES:**

1. Rashid, M.H., "Power Electronics: Circuits, Devices and Applications", 4th Edition, Pearson Education.
2. Bimbhra, P.S., "Power Electronics", Khanna Publishers.
3. Ned Mohan, "Advanced Power Electronics Converters and Applications", Wiley.
4. Daniel W. Hart, "Power Electronics", McGraw Hill Education.
5. Bose, B.K., "Modern Power Electronics and AC Drives", Pearson Education.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 3   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 1   | 3   | 3    | 2    |
| CO5 | 3   | 2   | 3   | 2    | 3    |
| AVG | 3   | 1.8 | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

  
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|         |                                    |   |   |   |   |
|---------|------------------------------------|---|---|---|---|
| PS26111 | POWER SYSTEM SIMULATION LABORATORY | L | T | P | C |
| SDG:4,9 |                                    | 0 | 0 | 4 | 2 |

#### COURSE OBJECTIVES:

- Illustrate the power system issues under normal and abnormal conditions.
- Analyze the performance of power system under normal and abnormal conditions using simulation software.
- Evaluate the existing system and system under smart environment.

#### LIST OF EXPERIMENTS:

60 PERIODS

1. Power flow analysis by Newton-Raphson/ Fast decoupled method
2. Transient stability analysis of single machine-infinite bus system using classical machine model
3. Economic load dispatch using lambda-iteration method
4. Unit commitment: Priority-list scheme and dynamic programming
5. Contingency analysis: Generator shift factors and line outage distribution factors
6. Load flow analysis of two-bus system with STATCOM
7. Available Transfer Capability(ATC) calculation using an existing load flow program in deregulated environment.
8. Harmonic Analysis of Power system with nonlinear load
9. Study of protective relaying schemes of Power Apparatus
10. Study of Relay Coordination
11. Demand Side Management in Smart Power Grid environment
12. Determination of Sequence Impedances of Power Network

**WEIGHTAGE:** Continuous Assessment: 60%, End Semester Examinations: 40%

#### COURSE OUTCOMES:

- CO1: Acquire expertise in usage of simulation software as applied to power system  
CO2: Apply tools to simulate the mathematical model of power network for power system Analysis  
CO3: Analyze the power system through various numerical methods under normal and Abnormal conditions

#### LABORATORY REQUIREMENTS:

1. Desktop Computers(Intel i5/i7 Processor, 16 GB RAM, 512 GB SSD)
2. MATLAB & Simulink((9 User Licenses)
3. Power Quality Analyzer-1 Nos
4. Digital Storage Oscilloscope-2 Nos
5. Digital Multimeter-3 Nos
6. Clamp Meter-2 Nos
7. Power System Simulation Trainer Kit-1 set
8. Protective Relay Trainer Kit-1 set

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 3    |
| CO2 | 3   | 1   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 2    |
| AVG | 2.6 | 1.3 | 3   | 2.6  | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High



# **SEMESTER-II**







CO2: Analyze energy costs, utility rate structures, load management techniques, and economic feasibility of energy conservation measures.

CO3: Apply demand-side management strategies and energy conservation techniques to improve the efficiency of electrical power systems.

CO4: Perform comprehensive energy audits, financial analysis, and techno-economic evaluation of energy conservation projects.

CO5: Evaluate and recommend energy-efficient technologies for motors, power factor improvement, industrial drives, furnaces, boilers, and lighting systems.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. Barney L. Capehart, Wayne C. Turner, William J. Kennedy, "Guide to Energy Management", CRC press, Taylor & Francis group, Eighth Edition, 2016.

2. Eastop T.D and Croft D.R, "Energy Efficiency for Engineers and Technologists", Logman Scientific & Technical, 1990.

**REFERENCES:**

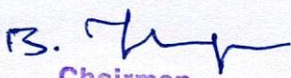
1. Amit K. Tyagi, "Handbook on Energy Audits and Management", TERI, 2003.

2. Barney L. Capehart, Wayne C. Turner, William J. Kennedy, "Guide to Energy Management", CRC press, Taylor & Francis group, Eighth Edition, 2016.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 1    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 3   | 3   | 3    | 2    |
| CO5 | 3   | 2   | 3   | 3    | 3    |
| AVG | 3   | 2   | 3   | 3    | 2.2  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

  
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|         |                                |   |   |   |   |
|---------|--------------------------------|---|---|---|---|
| PS26301 | ENERGY MANAGEMENT AND AUDITING | L | T | P | C |
| SDG:7,9 |                                | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- Understand the fundamentals of energy resources, energy policies, energy conservation regulations, and the principles of energy management and auditing.
- Analyze energy costs, economic evaluation methods, and load management techniques for improving energy efficiency.
- Apply demand-side management strategies, energy conservation measures, and tariff options for efficient utilization of electrical energy.
- Develop the ability to conduct energy audits, perform financial analysis, and evaluate energy conservation projects using standard audit methodologies.
- Evaluate energy-efficient technologies and conservation techniques for industrial electrical systems and lighting applications.

### UNIT I ENERGY SCENARIO

9

Basics of Energy and its various forms - Conventional and non-conventional sources - Energy policy - Energy conservation act 2001, Amendments (India) in 2010 - Need for energy management- Designing and starting an energy management program - Energy managers and energy auditors - Roles and responsibilities of energy managers - Energy labelling and energy standards.

### UNIT II ENERGY COST AND LOAD MANAGEMENT

9

Important concepts in an economic analysis - Economic models-Time value of money-Utility rate structures- Cost of electricity-Loss evaluation- Load management: Demand control techniques-Utility monitoring and control system-HVAC and energy management-Economic justification.

### UNIT III ENERGY MANAGEMENT

9

Demand side management (DSM)– DSM planning – DSM techniques – Load management as a DSM strategy – Energy conservation – Tariff options for DSM.

### UNIT IV ENERGY AUDITING

9

Definition – Energy audit methodology: audit preparation, execution and reporting – Financial analysis – Sensitivity analysis – Project financing options - Instruments for energy audit – Energy audit for generation, distribution and utilization systems – Economic analysis.

### UNIT V ENERGY EFFICIENT TECHNOLOGIES

9

Energy saving opportunities in electric motors - Power factor improvement benefit and techniques Shunt capacitor, Synchronous Condenser and Phase Advancer - Energy conservation in industrial drives, electric furnaces, ovens and boilers - Lighting techniques: Natural, CFL, LED lighting sources and fittings.

**ACTIVITIES:** Study and presentation on India's Energy Conservation Act and amendments., Numerical problems on tariff calculations and economic analysis, DSM planning and load curve analysis exercise, Case study on industrial energy auditing and study of energy-efficient lighting systems.

**TOTAL:45 PERIODS**

### COURSE OUTCOMES:

CO1: Explain energy resources, energy policies, Energy Conservation Act, energy management principles, and the roles of energy managers and auditors.







# **SEMESTER-III**







**COURSE OUTCOMES:**

**CO1:** Analyze power quality, voltage regulation, and state estimation using simulation tools for power system studies.

**CO2:** Apply evolutionary algorithms and artificial intelligence techniques to solve unit commitment, economic dispatch, and load forecasting problems.

**CO3:** Evaluate the performance of power system control schemes, including Automatic Voltage Regulator (AVR), Power System Stabilizer (PSS), and Automatic Generation Control (AGC).

**CO4:** Simulate standalone and grid-connected renewable energy systems and assess their integration into modern power grids.

**CO5:** Analyze complex power system operation and planning problems using advanced computational techniques and simulation software.

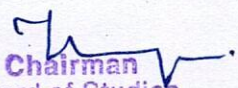
**LABORATORY REQUIREMENTS:**

1. Desktop Computers (Intel i5/i7 Processor, 16 GB RAM, 512 GB SSD)
2. MATLAB & Simulink ((9 User Licenses)
3. Power Quality Analyzer-1 Nos
4. Digital Storage Oscilloscope-2 Nos
5. Digital Multimeter-3 Nos
6. Solar PV simulation/training kit – 1 Set
7. Wind Energy Conversion System trainer – 1 Set
8. Smart grid and renewable energy integration kit – 1 Set

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 2    |
| CO4 | 3   | 2   | 3   | 2    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2.2 | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

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### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 1   | 3   | 3    | 2    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 2    | 3    |
| AVG | 3   | 1.8 | 3   | 2.8  | 2.4  |

Correlation Levels: 1 – Low, 2 – Medium, 3 – High

|         |                                |   |   |   |   |
|---------|--------------------------------|---|---|---|---|
| PS26211 | MODERN POWER SYSTEM LABORATORY | L | T | P | C |
| SDG:4,7 |                                | 0 | 0 | 4 | 2 |

#### COURSE OBJECTIVES:

- Develop simulation models for advanced power system operation, control, and planning using modern software tools.
- Analyze power quality, economic operation, and stability of power systems under various operating conditions.
- Apply artificial intelligence, evolutionary algorithms, and soft computing techniques to solve power system problems.
- Simulate renewable energy integration and evaluate its impact on power system performance and reliability.
- Enhance research and problem-solving skills through simulation-based studies of modern power systems.

#### LIST OF EXPERIMENTS:

**60 PERIODS**

1. AC-DC power quality analysis
2. Application of neural networks to load forecasting and contingency analysis
3. Solution of Unit commitment Problem through Evolutionary algorithm
4. Solution of Economic Dispatch using Evolutionary algorithm
5. Automatic Voltage Regulator with Power System Stabilizer
6. Simulation of Grid-Connected Solar Photovoltaic (PV) System with Grid Interface
7. Simulation of Standalone Solar Photovoltaic (PV) System without Grid Interface
8. Intelligent control techniques for Automatic Generation Control
9. Soft Computing Techniques for Power System Problems
10. State Estimation of Power System
11. Analysis of Power grid in presence of Renewable Energy Source

**WEIGHTAGE:** Continuous Assessment: 60%, End Semester Examinations: 40%



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                 |                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|--------------------------|
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>PC APPLICATIONS FOR DESIGNING PROTECTIVE RELAYING SCHEME</b> | <b>9</b>                 |
| Types of faults – Assumptions - Development of algorithm for SC studies - PC based integrated software for SC studies - Transformation to component quantities - SC studies of multiphase systems Ultra-high-speed protective relays for high voltage long transmission line.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                 |                          |
| <b>ACTIVITIES:</b> Technical seminar: Analyse the principles behind the digital protection of synchronous generators and the algorithms used. Case Study: Analyse the steps involved in transforming electrical quantities to component quantities during SC studies for protective relaying, Review of GATE questions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                 |                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                 | <b>45 PERIODS</b>        |
| <b>LIST OF EXPERIMENTS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                 | <b>30 PERIODS</b>        |
| <ol style="list-style-type: none"> <li>1. Study of electromechanical &amp; numerical type IDMT over current relay.</li> <li>2. Study of directional over current relay.</li> <li>3. Study of earth fault relay.</li> <li>4. Study of numerical type differential relay.</li> <li>5. Study the application of numerical type over current relay for distribution feeder protection and synchro phasor assisted current differential relay for transmission/distribution line protection.</li> <li>6. Study of transmission line fault detection, classification and location estimation using distance relays by simulating different faults on the WSCC 9-bus test power system through PSCAD/EMTDC software or MATLAB/Simulink.</li> <li>7. Study of Power Swing and its impact on distance relaying-based transmission line protection scheme through PSCAD/EMTDC software or MATLAB/Simulink</li> </ol> |                                                                 |                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                 | <b>TOTAL: 75 PERIODS</b> |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                 |                          |
| <b>CO1:</b> Apply numerical protection techniques for overcurrent, transformer differential, and distance protection..                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                 |                          |
| <b>CO2:</b> Analyze and implement digital protection schemes for EHV/UHV transmission lines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                 |                          |
| <b>CO3:</b> Design suitable digital protection schemes for generators and transformers under various fault conditions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                 |                          |
| <b>CO4:</b> Evaluate relay settings and coordination techniques for secure and selective system protection.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                 |                          |
| <b>CO5:</b> Develop PC-based algorithms for short-circuit studies and protective relaying applications.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                 |                          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 50%, End Semester Examinations: 50%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                 |                          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                 |                          |
| <ol style="list-style-type: none"> <li>1. Y. G. Paithankar and S. R. Bhide, Fundamentals of Power System Protection, PHI Learning Private Limited, Second Edition.</li> <li>2. B. Ravindranath and M. Chander, Power System Protection and Switchgear, , New Age International Publishers, Second Edition.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                 |                          |
| <b>REFERENCES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                 |                          |
| <ol style="list-style-type: none"> <li>1.T.S. Madhava Rao, Power system Protection static relay, Tata McGrawHill Publishing Company limited, 2nd Edition, 2004.</li> <li>2. Badri Ram and D.N. Vishwakarma, Power system Protection and Switchgear, Tata McGraw Hill Publication Company limited, 2nd Edition, 2013.</li> <li>3. Bhavesh Bhalja, R. P. Maheshwari, N. G. Chothani, Protection and Switchgear, Oxford University Press, 2nd Edition, New Delhi, India, 2018.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                 |                          |



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 3    | 1    |
| CO2 | 3   | 1   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 2    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 2   | 3   | 2    | 3    |
| AVG | 2.8 | 1.6 | 3   | 2.8  | 2    |

Correlation Levels: 1 – Low, 2 – Medium, 3 – High

|         |                                  |   |   |   |   |
|---------|----------------------------------|---|---|---|---|
| PS26203 | ADVANCED POWER SYSTEM PROTECTION | L | T | P | C |
| SDG:7,9 |                                  | 3 | 0 | 2 | 4 |

### COURSE OBJECTIVES:

- To provide knowledge of numerical relay principles and digital protection techniques for power system components.
- To develop an understanding of digital and traveling-wave-based protection schemes for transmission lines.
- To impart knowledge of digital protection schemes for synchronous generators and power transformers.
- To develop the ability to coordinate distance and overcurrent relays for reliable power system protection.
- To provide knowledge of computer-based short-circuit analysis and protective relay design for modern power systems.

|                                                                                                                                                                                                                                                                                                                                                |                                                                      |          |
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| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                  | <b>NUMERICAL PROTECTION</b>                                          | <b>9</b> |
| Introduction - Block diagram of numerical relay - Sampling theorem - Correlation with a reference wave - Least Error Squared (LES) technique - Digital filtering and numerical over - Current Protection - Numerical transformer differential protection- Numerical distance protection of transmission line.                                  |                                                                      |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                 | <b>DIGITAL PROTECTION OF TRANSMISSION LINE</b>                       | <b>9</b> |
| Introduction - Protection scheme of transmission line – Distance relays - Traveling wave relays - Digital protection scheme based upon fundamental signal - Hardware design - Software design - Digital protection of EHV/UHV transmission line based upon traveling wave phenomenon - new relaying scheme using amplitude comparison          |                                                                      |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                | <b>DIGITAL PROTECTION OF SYNCHRONOUS GENERATOR &amp; TRANSFORMER</b> | <b>9</b> |
| Introduction - Faults in synchronous generator - Protection schemes for Synchronous Generator - Digital protection of Synchronous Generator - Faults in a Transformer - Schemes used for Transformer Protection - Digital Protection of Transformer.                                                                                           |                                                                      |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                 | <b>DISTANCE AND OVERCURRENT RELAY SETTING AND CO- ORDINATION</b>     | <b>9</b> |
| Directional instantaneous IDMT over current relay - Directional multi-Zone distance relay - Distance relay setting - Co-ordination of distance relays - Co-ordination of over current relays - Computer graphics display - Man-machine interface subsystem - Integrated operation of national power system - Application of computer graphics. |                                                                      |          |



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| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>SYNCHRONOUS MACHINE MODELLING</b>   | <b>9</b> |
| Classical model and its limitations- Park's transformation, d-q axis equations- Modelling of synchronous machines with and without damper windings- Turbine-governor and load modelling (static & dynamic).                                                                                                                                                                                                                                                          |                                        |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>EXCITATION SYSTEMS</b>              | <b>9</b> |
| Excitation system requirements and IEEE models- Effect of excitation on power system stability- Static & dynamic load models.                                                                                                                                                                                                                                                                                                                                        |                                        |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>SMALL SIGNAL STABILITY ANALYSIS</b> | <b>9</b> |
| Small-signal stability of SMIB and multimachine systems-Damping and synchronizing torque concepts- Eigenvalue analysis and participation factors-Effect of Field circuit dynamics-Effect of AVR dynamics- Power System Stabilizers (PSS) design and application.                                                                                                                                                                                                     |                                        |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>TRANSIENT STABILITY</b>             | <b>9</b> |
| Transient stability studies — equal area criterion- Numerical integration methods: step-by-step, modified Euler, Runge-Kutta- Critical clearing time and angle- Stability enhancement methods: fast valving, braking resistors, high-speed excitation- Case studies with renewables and inverter-based systems.                                                                                                                                                      |                                        |          |
| <b>ACTIVITIES:</b> MATLAB/Python simulation of swing equation for a single machine connected to infinite bus (SMIB). Simulate a synchronous machine model in MATLAB. Eigenvalue and participation factor analysis of SMIB system. Transient stability simulation of a multi-machine system under fault conditions, Review of GATE questions.                                                                                                                         |                                        |          |
| <b>TOTAL: 45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                        |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                        |          |
| <b>CO1:</b> Ability to Explain the need and fundamentals of power system dynamics and stability.                                                                                                                                                                                                                                                                                                                                                                     |                                        |          |
| <b>CO2:</b> Ability to Develop models of synchronous machines, exciters, and loads for system studies                                                                                                                                                                                                                                                                                                                                                                |                                        |          |
| <b>CO3:</b> Ability to Perform small-signal stability analysis using eigenvalue methods.                                                                                                                                                                                                                                                                                                                                                                             |                                        |          |
| <b>CO4:</b> Analyze the small-signal stability of power systems using eigenvalue analysis and design appropriate Power System Stabilizers.                                                                                                                                                                                                                                                                                                                           |                                        |          |
| <b>CO5:</b> Evaluate transient stability and determine critical clearing time using numerical methods and appropriate stability enhancement techniques.                                                                                                                                                                                                                                                                                                              |                                        |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                         |                                        |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        |          |
| 1. P. Kundur, Power System Stability and Control, McGraw Hill, 1994.<br>2. K.R.Padiyar, Power System Dynamics: Stability and Control, BS Publications, 2002.                                                                                                                                                                                                                                                                                                         |                                        |          |
| <b>REFERENCES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                        |          |
| 1. P.M. Anderson & A.A. Fouad, Power System Control and Stability, IEEE Press.<br>2. Machowski, Bialek, Bumby, Power System Dynamics: Stability and Control, Wiley, 2020.<br>3. Vijay Vittal, James D. McCalley, Paul, P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa, 3 <sup>rd</sup> edition, 2019.<br>4. P. W. Sauer and M. A. Pai, "Power System Dynamics and Stability", Stipes Publishing Co, 2007. |                                        |          |



**TEXTBOOKS:**

1. Allan Greenwood, "Electrical Transients in Power Systems", Wiley-Interscience, 2nd Edition, 1991.
2. Pritindra Chowdhuri, "Electromagnetic Transients in Power Systems", Research Studies Press, 2nd Edition, 2004.
3. Juan A. Martinez-Velasco, "Power System Transients: Parameter Determination", CRC Press, 2010.

**REFERENCES:**

1. Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York, 2012.
2. Andrew R. Hileman, "Insulation Coordination for Power Systems", CRC press, Taylor & Francis Group, New York, 1999.
3. Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York, 1980.
4. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", (Second edition) Newage International (P) Ltd., New Delhi, 2006.
5. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 1   | 3   | 3    | 2    |
| CO3 | 3   | 1   | 3   | 3    | 2    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 2   | 3   | 3    | 2    |
| AVG | 3   | 1.4 | 3   | 3    | 2.2  |

Correlation Levels: 1 – Low, 2 – Medium, 3 – High

|         |                       |   |   |   |   |
|---------|-----------------------|---|---|---|---|
| PS26202 | POWER SYSTEM DYNAMICS | L | T | P | C |
| SDG:7,9 |                       | 3 | 0 | 0 | 3 |

**COURSE OBJECTIVES:**

- To introduce the dynamic behaviour of power systems under small and large disturbances.
- To model synchronous machines, exciters, and loads for dynamic studies.
- To analyse transient and small-signal stability in interconnected systems.
- To provide knowledge of small-signal stability analysis and the role of excitation systems and power system stabilizers in improving system stability.
- To develop the ability to analyze transient stability and apply suitable methods for enhancing power system stability under disturbances.

|                                                                                                                                                                                                                                                                                 |                                              |          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                   | <b>INTRODUCTION TO POWER SYSTEM DYNAMICS</b> | <b>9</b> |
| Need for dynamic analysis in power systems- Stability concepts: steady-state, transient, small-signal, voltage, frequency-Mathematical preliminaries: nonlinear system behaviour, equilibrium points, stability definitions- Review of numerical methods for stability studies. |                                              |          |



|         |                         |   |   |   |   |
|---------|-------------------------|---|---|---|---|
| PS26201 | POWER SYSTEM TRANSIENTS | L | T | P | C |
| SDG:7,9 |                         | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To gain knowledge in sources of transients like lightning, switching and temporary over voltages.
- To model power system components and estimate the over voltages in power system
- To analyze travelling wave phenomena against different over voltages
- To impart knowledge on insulation coordination principles for the reliable protection of power system equipment against overvoltages.
- To develop the ability to model and analyze electromagnetic transients in power systems and simplified methods.

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| <b>UNIT I</b> | <b>LIGHTNING OVERVOLTAGES</b> | <b>9</b> |
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Classification of over voltages- Mechanism and parameters of lightning flash, protective shadow, striking distance, electro geometric model for lightning strike, Grounding for protection against lightning – Steady state and dynamic tower-footing resistance, substation grounding Grid, Direct lightning strokes to overhead lines, without and with shield Wires

|                |                                             |          |
|----------------|---------------------------------------------|----------|
| <b>UNIT II</b> | <b>SWITCHING AND TEMPORARY OVERVOLTAGES</b> | <b>9</b> |
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Switching transients – concept – phenomenon – system performance under switching surges- Ferranti Effect, Temporary overvoltages – load rejection – line faults –ferro resonance, VFTO

|                 |                                              |          |
|-----------------|----------------------------------------------|----------|
| <b>UNIT III</b> | <b>TRAVELLING WAVES ON TRANSMISSION LINE</b> | <b>9</b> |
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Circuits and distributed constants, wave equation, reflection and refraction – behaviour of travelling waves at the line terminations – Lattice Diagrams – attenuation and distortion –multiconductor system and multi velocity waves

|                |                                 |          |
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| <b>UNIT IV</b> | <b>INSULATION CO-ORDINATION</b> | <b>9</b> |
|----------------|---------------------------------|----------|

insulation co-ordination –volt –time characteristics , Insulation strength and their selection-Evaluation of insulation strength standard BILs-Characteristics of protective devices, applications, location of arresters – insulation co-ordination in AIS and GIS

|               |                                               |          |
|---------------|-----------------------------------------------|----------|
| <b>UNIT V</b> | <b>COMPUTATION OF POWER SYSTEM TRANSIENTS</b> | <b>9</b> |
|---------------|-----------------------------------------------|----------|

Computation of transients using electromagnetic transient program-Modelling of power system components-Simple case studies - Application of simplified method: single line station, two line station, gas insulated substations, comparison with IEEE and IEC guides

**ACTIVITIES:** Analyze a real-world published IEEE case study involving VFTO in a GIS substation or a ferro resonance catastrophic failure in a VT. Develop a MATLAB script or python program to draw a Bewley Lattice Diagram and plot the voltage at a specific junction. Simulate line-switching transients or fault-induced overvoltages and cross-examine the simulation profile with IEEE Std 1313 guidelines.

**TOTAL:45 PERIODS**

### COURSE OUTCOMES:

- CO1: Ability to analyse various sources of transients.  
CO2: Ability to compute possible overvoltages in power systems.  
CO3: Ability to predict overvoltages in power system using travelling wave theory.  
CO4: Explain the principles of insulation coordination and insulation strength evaluation.  
CO5: Analyze electromagnetic transients using simplified methods and practical case studies.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                         |          |
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| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>SERIES COMPENSATION OF POWER DISTRIBUTION SYSTEM</b> | <b>9</b> |
| Rectifier supported DVR – DC Capacitor supported DVR – DVR Structure – Voltage Restoration –Series Active Filter – Unified Power Quality Conditioner.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                         |          |
| <b>ACTIVITIES:</b> Identify major harmonic-producing loads in industrial and commercial systems, Compare DVR, DSTATCOM, and UPQC for different distribution network problems, Review of GATE questions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                         |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                         |          |
| <b>COURSE OUTCOMES:</b><br>CO1: Explain various power quality disturbances, their causes, effects, and applicable power quality standards for electrical power systems.<br>CO2: Analyze power quality problems in single-phase and three-phase systems with linear, nonlinear, balanced, and unbalanced loads.<br>CO3: Apply conventional compensation techniques for load balancing, voltage regulation, harmonic mitigation, and reactive power compensation in distribution systems.<br>CO4: Evaluate the performance of DSTATCOM using suitable control algorithms for effective power quality improvement under balanced and unbalanced operating conditions.<br>CO5: Evaluate the performance of DVR,SAF, UPQC, and other custom power devices for mitigating power quality problems in distribution systems. |                                                         |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                         |          |
| <b>TEXTBOOKS:</b><br>1. Arindam Ghosh and Gerard Ledwich, <i>Power Quality Enhancement Using Custom Power Devices</i> , Springer, 2012.<br>2. Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, <i>Power Quality: Problems and Mitigation Techniques</i> , Wiley, 2015.<br>3. C. Sankaran, <i>Power Quality</i> , CRC Press, 2017.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                         |          |
| <b>REFERENCES:</b><br>1. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty, <i>Electrical Power Systems Quality</i> , McGraw-Hill.<br>2. Jos Arrillaga, Neville R. Watson and S. Chen, <i>Power System Quality Assessment</i> , Wiley.<br>3. Alexander Kusko and Marc T. Thompson, <i>Power Quality in Electrical Systems</i> , McGraw-Hill.<br>4. Math H.J. Bollen, <i>Understanding Power Quality Problems: Voltage Sags and Interruptions</i> , IEEE Press.                                                                                                                                                                                                                                                                                                                                  |                                                         |          |

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 3   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2.2 | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High



**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2   | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|            |               |   |   |   |   |
|------------|---------------|---|---|---|---|
| PS26008    | POWER QUALITY | L | T | P | C |
| SDG:9,7,12 |               | 3 | 0 | 0 | 3 |

**COURSE OBJECTIVES:**

- To Understand power quality phenomena, causes of power quality disturbances, and relevant international power quality standards.
- To Analyze power quality issues in single-phase and three-phase linear and nonlinear electrical systems under balanced and unbalanced operating conditions.
- To Evaluate conventional load compensation techniques for voltage regulation, harmonic reduction, load balancing, and reactive power compensation.
- To Understand the operating principles, control strategies, and applications of DSTATCOM for power quality enhancement in distribution systems.
- To Analyze dynamic voltage restoration and unified power quality conditioning techniques for mitigating voltage disturbances and improving power quality.

|                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                 |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                             | INTRODUCTION                                    | <b>9</b> |
| Introduction – Characterization of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Non-linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards. |                                                 |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                            | ANALYSIS OF SINGLE PHASE AND THREE PHASE SYSTEM | <b>9</b> |
| Single phase linear and non-linear loads – single phase sinusoidal, non-sinusoidal source – supplying linear and nonlinear loads – three phase balanced system – three phase unbalanced system – three phase unbalanced and distorted source supplying non-linear loads – concept of power factor – three phase- three wire – three phase - four wire system.                                                                             |                                                 |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                           | CONVENTIONAL LOAD COMPENSATION METHODS          | <b>9</b> |
| Principle of load compensation and voltage regulation – classical load balancing problem : open loop balancing – closed loop balancing, current balancing – harmonic reduction and voltage sag reduction– analysis of unbalance – instantaneous of real and reactive powers – Extraction of fundamental sequence component from measured.                                                                                                 |                                                 |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                            | LOAD COMPENSATION USING DSTATCOM                | <b>9</b> |
| Compensating single – phase loads – Ideal three phase shunt compensator structure – generating reference currents using instantaneous PQ theory – Instantaneous symmetrical components theory – Generating reference currents when the source is unbalanced – Realization and control of DSTATCOM – DSTATCOM in Voltage control mode                                                                                                      |                                                 |          |



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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|----------|
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>ELECTRICAL ENERGY STORAGE</b>             | <b>9</b> |
| Fundamental concept of batteries – Measuring of battery performance, charging and dis charging of a battery, storage density, energy density, and safety issues - Types of batteries: – Lead Acid, Nickel- Cadmium, Zinc-Manganese dioxide - Mathematical Modelling for Lead Acid Batteries – Flow Batteries.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>FUEL CELL</b>                             | <b>9</b> |
| Fuel Cell – History of Fuel cell, Principles of Electrochemical storage – Types: Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, Alkaline fuel cell -Detailed analysis – Advantages and disadvantages –Fuel Cell Thermodynamics.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>ALTERNATE ENERGY STORAGE TECHNOLOGIES</b> | <b>9</b> |
| Flywheel, Super capacitors, Principles& Methods – Applications, Compressed air Energy storage, Concept of Hybrid Storage – Applications, Pumped Hydro Storage – Applications.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |          |
| <b>ACTIVITIES:</b> Compare various storage technologies based on efficiency, energy density, response time, cost, and applications, Develop an equivalent circuit model for a Lead Acid battery and study its behaviour, Calculate efficiency and energy conversion performance of PEM fuel cells, Compare battery and supercapacitor response for transient load conditions, Review of GATE questions.                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |          |
| <b>COURSE OUTCOMES:</b><br><br>CO1: Explain the necessity, classification, operating principles, and applications of energy storage technologies in electrical power systems.<br><br>CO2: Analyze the design, modeling, and performance of thermal energy storage systems for improved energy efficiency.<br><br>CO3: Evaluate battery technologies, charging and discharging characteristics, mathematical models, and safety considerations for electrical energy storage applications.<br><br>CO4: Analyze different fuel cell technologies, their electrochemical principles, thermodynamic performance, advantages, limitations, and power system applications.<br><br>CO5: Assess the suitability of advanced energy storage technologies and hybrid storage systems for power system applications. |                                              |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |          |
| <b>TEXTBOOKS:</b><br>1. Robert A. Huggins, <i>Energy Storage</i> , Springer, 2nd Edition, 2016.<br>2. Ibrahim Dincer and Marc A. Rosen, <i>Thermal Energy Storage: Systems and Applications</i> , Wiley, 3rd Edition, 2020.<br>3. Danny Harvey, <i>Energy and the New Reality – Energy Storage and Grid Integration</i> , Earthscan Publications.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                              |          |
| <b>REFERENCES:</b><br>1.H. Chen, T.N. Cong, W. Yang, C. Tan, Y. Li and Y. Ding, "Progress in Electrical Energy Storage System", <i>Progress in Natural Science</i> .<br>2.James Larminie and Andrew Dicks, 'Fuel cell systems Explained', Wiley publications, 2003.<br>3.Jiujun Zhang (Editor), Lei Zhang (Editor), Hansan Liu (Editor), Andy Sun (Editor), Ru-Shi Liu (Editor), "Electrochemical technologies for energy storage and conversion", Two Volume Set, Wiley publications, 2012                                                                                                                                                                                                                                                                                                               |                                              |          |



2. Siegfried Heier, *Grid Integration of Wind Energy Conversion Systems*, Wiley, 3rd Edition, 2014.
3. Chetan Singh Solanki, *Solar Photovoltaics: Fundamentals, Technologies and Applications*, PHI Learning, 3rd Edition, 2015.

#### REFERENCES:

- 1.G.N. Tiwari and Swapnil Dubey, *Fundamentals of Photovoltaic Modules and Their Applications*, RSC Publishing.
- 2.S.N. Bhadra, D. Kastha and S. Banerjee, *Wind Electrical Systems*, Oxford University Press.
3. Roger A. Messenger and Jerry Ventre, *Photovoltaic Systems Engineering*, CRC Press.
- 4.Thomas Ackermann, *Wind Power in Power Systems*, Wiley Publications.

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 2    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2   | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|             |                             |   |   |   |   |
|-------------|-----------------------------|---|---|---|---|
| PS26007     | ENERGY STORAGE TECHNOLOGIES | L | T | P | C |
| SDG:7,12,13 |                             | 3 | 0 | 0 | 3 |

#### COURSE OBJECTIVES:

- To Understand the need, classification, principles, and applications of various energy storage technologies in modern power systems.
- To Analyze thermal energy storage systems, their modeling techniques, and applications for efficient energy utilization.
- To Evaluate the characteristics, operation, modeling, and performance of different battery technologies used for electrical energy storage.
- To Understand the operating principles, thermodynamics, performance characteristics, and applications of various fuel cell technologies.
- To Analyze advanced energy storage technologies such as flywheels, supercapacitors, compressed air energy storage, hybrid storage, and pumped hydro storage for power system applications.

|               |              |          |
|---------------|--------------|----------|
| <b>UNIT I</b> | INTRODUCTION | <b>9</b> |
|---------------|--------------|----------|

Necessity of energy storage – types of energy storage –energy storage technologies – Applications.

|                |                        |          |
|----------------|------------------------|----------|
| <b>UNIT II</b> | THERMAL STORAGE SYSTEM | <b>9</b> |
|----------------|------------------------|----------|

Thermal storage – Types – Modeling of thermal storage units – Simple water and rock bed storage system – Pressurized water storage system – Modelling of phase change storage system – Simple units, Packed bed storage units - Modelling using porous medium approach.



|                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                   |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                              | <b>WIND ENERGY CONVERSION</b>                     | <b>9</b> |
| Wind resources – Nature and occurrence of wind – Power in the wind – Wind characteristics – Principles of wind energy conversions – Components of wind energy conversion system (WECS) – Classification of WECS – Advantages and disadvantages of WECS.                                                                                                                                                                    |                                                   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                             | <b>WIND ELECTRIC GENERATORS</b>                   | <b>9</b> |
| Characteristics of Induction generators – Permanent magnet generators – Single phase operation of induction generators – Doubly fed generators – Grid connected and standalone systems – Controllers for wind driven self-excited systems and capacitor excited isolated systems – Synchronized operation with grid supply – Real and reactive power control.                                                              |                                                   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                            | <b>PHOTO VOLTAIC MODELS</b>                       | <b>9</b> |
| Solar cells and panels – Structure of PV cells – Semiconductor materials for PV cells – I-V characteristics of PV systems – PV models and equivalent circuits – Effects of irradiance and temperature on PV characteristics.                                                                                                                                                                                               |                                                   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                             | <b>PHOTO VOLTAIC ENERGY CONVERSION SYSTEM</b>     | <b>9</b> |
| Basic photo voltaic system for power generation – Advantages and disadvantages of photo voltaic solar energy conversion – Application of solar photo voltaic system – Components of PV systems – Design of PV systems – Power conditioning and storage arrangement – Maximum power point tracking (MPPT) – Introduction to string inverters.                                                                               |                                                   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                              | <b>RECENT ADVANCEMENTS IN WIND AND PV SYSTEMS</b> | <b>9</b> |
| Wind farms and grid connections – Grid related problems on absorption of wind – Grid interfacing arrangement – Operation, control and technical issues of wind generated electrical energy – Interconnected operation – Hybrid systems. Recent Advances in PV Applications: Building Integrated PV systems, Grid Connected PV systems, Hybrid systems, Solar cars, Solar energy storage system and their economic aspects. |                                                   |          |
| <b>ACTIVITIES:</b> Develop a MATLAB model of a Doubly-Fed Induction Generator, Determine battery storage requirements for a standalone PV installation, Perform life-cycle cost analysis of wind, solar, and hybrid systems.                                                                                                                                                                                               |                                                   |          |
| <b>TOTAL: 45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                    |                                                   |          |
| CO1: Explain wind energy resources, wind characteristics, and the design and operation of wind energy conversion systems.                                                                                                                                                                                                                                                                                                  |                                                   |          |
| CO2: Analyze the performance of induction, permanent magnet, and doubly fed generators in standalone and grid-connected wind energy systems, including real and reactive power control.                                                                                                                                                                                                                                    |                                                   |          |
| CO3: Evaluate photovoltaic cell characteristics, equivalent circuit models, and the effects of irradiance and temperature on PV system performance.                                                                                                                                                                                                                                                                        |                                                   |          |
| CO4: Design photovoltaic energy systems by selecting suitable components, power conditioning units, storage systems, and MPPT techniques for efficient energy conversion.                                                                                                                                                                                                                                                  |                                                   |          |
| CO5: Assess modern wind and photovoltaic technologies, hybrid renewable energy systems, and grid integration issues for sustainable power generation.                                                                                                                                                                                                                                                                      |                                                   |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                               |                                                   |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                          |                                                   |          |
| 1. Mukund R. Patel, <i>Wind and Solar Power Systems</i> , CRC Press, 2nd Edition, 2006.                                                                                                                                                                                                                                                                                                                                    |                                                   |          |



CO2: Analyze voltage regulation techniques, reactive power compensation, harmonic control, and protection coordination for reliable distribution system operation.

CO3: Evaluate feeder configurations, reliability indices, economic design, and load balancing techniques for efficient distribution system planning.

CO4: Apply modern distribution automation technologies, communication systems, smart metering, GIS, MIS, and substation automation for enhanced system monitoring and control.

CO5: Design and evaluate distribution system expansion plans using load forecasting, optimal substation location, radial feeder design, and planning methodologies.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

#### TEXTBOOKS:

1. Turan Gonen, *Electric Power Distribution Engineering*, CRC Press, 3rd Edition, 2014.
2. A.S. Pabla, *Electric Power Distribution*, McGraw Hill Education, 6th Edition, 2017.
3. Willis H.L., *Power Distribution Planning Reference Book*, CRC Press, 2nd Edition, 2004.

#### REFERENCES:

1. C.L. Wadhwa, "Electrical Power Systems", New Age International Publishers, Sixth Edition, 2014.
2. V. Kamaraju, "Electrical Power Distribution Systems", Tata McGraw Hill Books Company, Sixth Edition, 2009.
3. Anthony J. Pansini, "Electrical Distribution Engineering", CRC Press, 2005.
4. James A Momoh, "Electric Power Distribution Automation Protection and Control" CRC Press, 2007.

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 3   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2.2 | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |                               |   |   |   |   |
|----------|-------------------------------|---|---|---|---|
| PS26006  | WIND AND SOLAR ENERGY SYSTEMS | L | T | P | C |
| SDG:7,13 |                               | 3 | 0 | 0 | 3 |

#### COURSE OBJECTIVES:

- To Understand wind energy resources, wind characteristics, and the operating principles and components of wind energy conversion systems.
- To Analyze different wind electric generators, grid-connected and standalone wind energy systems, and their control strategies.
- To Understand the operating principles, characteristics, modeling, and performance analysis of photovoltaic (PV) cells and modules.
- To Evaluate the design, power conditioning, energy storage, and MPPT techniques used in photovoltaic energy conversion systems.
- To Analyze recent developments in wind and solar energy technologies, hybrid renewable systems, and grid integration challenges.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                      |   |   |   |          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|---|---|---|----------|
| PS26005                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ELECTRICAL POWER DISTRIBUTION SYSTEM | L | T | P | C        |
| SDG:7,9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                      | 3 | 0 | 0 | 3        |
| <b>COURSE OBJECTIVES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                      |   |   |   |          |
| <ul style="list-style-type: none"><li>Understand the configuration, design principles, voltage levels, and operational characteristics of electrical power distribution systems.</li><li>Analyze voltage control methods, reactive power compensation, harmonic mitigation, and protection schemes used in distribution systems.</li><li>Evaluate the reliability, economic design, feeder configurations, and load balancing aspects of electrical distribution networks.</li><li>Understand the concepts and applications of distribution automation, communication systems, smart metering, and substation automation.</li><li>Analyze distribution system planning, load forecasting, substation design, and expansion strategies for reliable and economical power delivery.</li></ul> |                                      |   |   |   |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>DISTRIBUTION SYSTEMS</b>          |   |   |   | <b>9</b> |
| Distribution systems: Types of distribution systems - Section and size of feeders – Primary and secondary distribution – Distribution substations – Effect of working voltage on the size of feeders and distributors – Effect of system voltage on economy – Voltage drop and efficiency of transmission -Qualitative treatment of rural distribution and industrial distribution.                                                                                                                                                                                                                                                                                                                                                                                                         |                                      |   |   |   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>CONTROL AND PROTECTION</b>        |   |   |   | <b>9</b> |
| Voltage control: Application of shunt capacitance for loss reduction – Harmonics in the system – Static VAR systems – Voltage profile enhancement schemes.<br>System protection: Fuses and section analyzers - Over current protection - Under voltage and under frequency protection – Coordination of protective device.                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                      |   |   |   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>RELIABILITY ANALYSIS</b>          |   |   |   | <b>9</b> |
| Primary and secondary system design considerations - Primary circuit configurations - Primary feeder loading - Secondary networks design- Economic design -Unbalance loads and voltage considerations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |   |   |   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>DISTRIBUTION AUTOMATION</b>       |   |   |   | <b>9</b> |
| Definitions – Automation switching control – Management information systems (MIS) – Remote terminal units – Communication methods for data transfer – Consumer information service (CIS) –Graphical information systems (GIS) - Automatic meter reading (AMR) – Remote control load management. Substation automation – Requirements – Control aspects in substations – Feeder automation – Consumer side automation.                                                                                                                                                                                                                                                                                                                                                                       |                                      |   |   |   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>EXPANSION PLANNING</b>            |   |   |   | <b>9</b> |
| Distribution system planning: Short term planning - Long term planning - dynamic planning – Sub transmission and substation design. Sub-transmission networks configurations - Substation bus schemes - Distribution substations ratings - Service areas calculations. Distribution system expansion:Planning – Load characteristics – Load forecasting – Design concepts – Optimal location of substation– Design of radial lines – Solution technique.                                                                                                                                                                                                                                                                                                                                    |                                      |   |   |   |          |
| <b>ACTIVITIES:</b> Model a radial and ring distribution system using MATLAB/, Compare different network configurations based on reliability and cost, Prepare a 10-year distribution expansion plan for a developing service area, Review of GATE questions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                      |   |   |   |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                      |   |   |   |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                      |   |   |   |          |
| CO1: Explain the structure, operation, and design considerations of electrical power distribution systems and evaluate the effect of voltage levels on system performance and economy.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |   |   |   |          |



**COURSE OUTCOMES:**

CO1: Explain renewable energy technologies, grid integration requirements, grid codes, and power electronic interfaces used in renewable energy systems.

CO2: Design and evaluate standalone and grid-connected photovoltaic systems considering load requirements, converter selection, battery sizing, and system performance.

CO3: Analyze the performance of wind energy conversion systems, different wind generators, and their grid integration under varying operating conditions.

CO4: Apply suitable MPPT techniques to maximize energy extraction from solar photovoltaic and wind energy systems.

CO5: Evaluate hybrid renewable energy systems with energy storage and recommend suitable configurations for efficient and reliable grid operation.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. B.H. Khan, *Non-Conventional Energy Resources*, McGraw Hill Education – Renewable energy fundamentals, grid integration and power converters.
2. Mukund R. Patel, *Wind and Solar Power Systems*, CRC Press – Solar PV systems, characteristics and design.
3. Trishan Eram and Patrick L. Chapman, MPPT techniques for photovoltaic and wind energy systems; relevant journal papers and textbook references.
4. Felix A. Farret and M. Godoy Simoes, *Integration of Alternative Sources of Energy*, Wiley-IEEE Press – Hybrid systems and storage technologies.

**REFERENCES:**

- 1 Siegfried Heier, *Grid Integration of Wind Energy Conversion Systems*, Wiley.
2. Fredé Blaabjerg and Dan M. Ionel, *Renewable Energy Devices and Systems with Simulations in MATLAB and ANSYS*, CRC Press.
3. Gilbert M. Masters, *Renewable and Efficient Electric Power Systems*, Wiley India.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2   | 3   | 3    | 2.8  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                            |   |   |   |          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---|---|---|----------|
| PS26004                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | RENEWABLE ENERGY AND GRID INTEGRATION      | L | T | P | C        |
| SDG:7,13,17                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                            | 3 | 0 | 0 | 3        |
| <b>COURSE OBJECTIVES:</b> <ul style="list-style-type: none"><li>Understand renewable energy resources, environmental impacts, grid integration requirements, grid codes, and power electronic converters used in renewable energy systems.</li><li>Analyze the operating principles, characteristics, design, and grid integration of photovoltaic energy conversion systems.</li><li>Understand wind energy conversion principles, wind turbine technologies, electrical generators, and grid-connected wind energy systems.</li><li>Evaluate maximum power point tracking (MPPT) techniques and their application in improving the performance of solar PV and wind energy systems.</li><li>Analyze hybrid renewable energy systems, energy storage technologies, and their role in reliable grid management and power system operation.</li></ul> |                                            |   |   |   |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | INTRODUCTION                               |   |   |   | <b>9</b> |
| Introduction to renewable energy systems, environmental aspects of electric energy conversion, impacts of renewable energy penetration to grid. Grid Codes in India and other countries . Basic power electronic converters for renewable energy integration to grid-Qualitative analysis -Boost and buck-boost converters, three phase AC voltage controllers- AC-DC-AC converters, PWM Inverters, Grid Interactive Inverters-matrix converters.                                                                                                                                                                                                                                                                                                                                                                                                    |                                            |   |   |   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | PHOTO VOLTAIC ENERGY CONVERSION SYSTEMS    |   |   |   | <b>9</b> |
| Introduction, Photo Voltaic (PV) effect, Solar Cell, Types, Equivalent circuit of PV cell, PV cell characteristics (I/V and P/V) for variation of insolation, temperature and shading effect,Stand-alone PV system, Grid connected PV system, Design of PV system-load calculation, array sizing,selection of converter/inverter, battery sizing.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            |   |   |   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | WIND ENERGY CONVERSION SYSTEMS             |   |   |   | <b>9</b> |
| Introduction, Power contained in wind, Efficiency limit in wind, types of wind turbines, Wind control strategies, Power curve and Operating area, Types of wind generators system based on Electrical machines- Induction Generator and Permanent Magnet Synchronous generator(PMSG), Grid Connected-Single and Double output system, Self-excited operation of Induction Generator and Variable Speed PMSG.                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                            |   |   |   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | MPPT TECHNIQUES IN SOLAR AND WIND SYSTEMS  |   |   |   | <b>9</b> |
| Case studies of PV-Maximum Power Point Tracking (MPPT) and Wind Energy system.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |   |   |   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | HYBRID STORAGE SYSTEMS AND GRID MANAGEMENT |   |   |   | <b>9</b> |
| Energy Storage systems, Need for Hybrid Systems, Features of Hybrid Systems, Range and types of Hybrid systems (Wind-Diesel, PV-Diesel and Wind-PV)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                            |   |   |   |          |
| <b>ACTIVITIES:</b> Study Indian Grid Code requirements for renewable energy integration and prepare a comparative report with international grid codes, Implement and compare Perturb & Observe (P&O) and Incremental Conductance MPPT algorithms using MATLAB/Simulink..                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                            |   |   |   |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                            |   |   |   |          |

  
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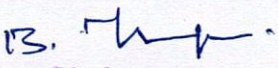


|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                     |          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------|
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>CASE STUDIES</b> | <b>9</b> |
| Industrial IoT, Home Automation, smart cities, Smart Grid, connected vehicles, electric vehicle charging, Environment, Agriculture, Productivity Applications, IOT Defense.                                                                                                                                                                                                                                                                                                                                                                                                        |                     |          |
| <b>ACTIVITIES:</b> Seminar-IoT Trends in Future Smart Grids, Comparative Study-Communication Technologies for Advanced Metering Infrastructure (AMI), Hands-on Practice-Sensor Interfacing and Cloud Data Visualization using Arduino/Raspberry Pi.                                                                                                                                                                                                                                                                                                                                |                     |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                     |          |
| <b>COURSE OUTCOMES:</b><br>CO1: Explain the fundamentals, enabling technologies, and applications of IoT systems.<br>CO2: Analyze IoT architecture, networking models, cloud integration, and communication technologies.<br>CO3: Evaluate IoT communication protocols and wireless technologies for smart system applications.<br>CO4: Develop IoT-based solutions using embedded processors, Raspberry Pi, Arduino, and Python programming.<br>CO5: Apply IoT concepts to Smart Grid, Industrial Automation, Smart Cities, Electric Vehicles, and other real-world applications. |                     |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                     |          |
| <b>TEXTBOOKS:</b><br>1. Arshdeep Bahga and Vijay Madisetti, Internet of Things – A Hands-on Approach, Universities Press, 2015<br>2. Olivier Hersent, David Boswarthick and Omar Elloumi, The Internet of Things – Key Applications and Protocols, Wiley, 2012.                                                                                                                                                                                                                                                                                                                    |                     |          |
| <b>REFERENCES:</b><br>1. Raj Kamal, Internet of Things – Architecture and Design Principles, McGraw Hill Education, 2017.<br>2. Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stefan Avesand, Stamatis Karnouskos and David Boyle, From Machine-to-Machine to the Internet of Things, Academic Press, 2014.<br>3. David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Rob Barton and Jerome Henry, IoT Fundamentals, Cisco Press, 2017.                                                                                                                                        |                     |          |

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 2   | 2    | 3    |
| CO2 | 3   | 1   | 2   | 2    | 3    |
| CO3 | 3   | 2   | 2   | 2    | 3    |
| CO4 | 3   | 2   | 2   | 2    | 3    |
| CO5 | 3   | 2   | 3   | 3    | 3    |
| AVG | 2.8 | 1.6 | 2.2 | 2.2  | 3    |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

  
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Vellore - 632 059



**REFERENCES:**

1. Ajith Abraham and Swagatham Das., "Computational Intelligence in Power Engineering", 2010 Springer Verlag.
2. Yong Hua Song, Johns Allen, Aggarwal Raj, 'Computational Intelligence Application to Power System', Springer Netherlands., 1997.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 3   | 3    | 3    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 2   | 3   | 3    | 3    |
| AVG | 3   | 2   | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|               |                       |   |   |   |   |
|---------------|-----------------------|---|---|---|---|
| PS26003       | IoT FOR SMART SYSTEMS | L | T | P | C |
| SDG:11,7,9,13 |                       | 3 | 0 | 0 | 3 |

**COURSE OBJECTIVES:**

- To study about Internet of Things technologies and its role in real time applications.
- To introduce the infrastructure required for IoT
- To familiarize the accessories and communication techniques for IoT.
- To provide insight about the embedded processor and sensors required for IoT
- To familiarize the different platforms and Attributes for IoT

|                                                                                                                                                                                                                                                                          |                                                       |          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                            | INTRODUCTION TO INTERNET OF THINGS                    | <b>9</b> |
| Overview, Hardware and software requirements for IOT, Sensor and actuators, Technology drivers, Business drivers, Typical IoT applications, Trends and implications.                                                                                                     |                                                       |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                           | IOT ARCHITECTURE                                      | <b>9</b> |
| IoT reference model and architecture -Node Structure - Sensing, Processing, Communication, Powering, Networking - Topologies, Layer/Stack architecture, IoT standards, Cloud computing for IoT, Bluetooth, Bluetooth Low Energy beacons.                                 |                                                       |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                          | PROTOCOLS AND WIRELESS TECHNOLOGIES FOR IOT PROTOCOLS | <b>9</b> |
| NFC, SCADA and RFID, Zigbee MIPI, M-PHY, UniPro, SPMI, SPI, M-PCIe GSM, CDMA, LTE, GPRS, small cell, Wireless technologies for IoT: WiFi (IEEE 802.11), Bluetooth/Bluetooth Smart, ZigBee/ZigBee Smart, UWB (IEEE 802.15.4), 6LoWPAN, Proprietary systems-Recent trends. |                                                       |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                           | IOT PROCESSORS                                        | <b>9</b> |
| Services/Attributes: Big-Data Analytics for IOT, Dependability, Interoperability, Security, Maintainability, Embedded processors for IOT :Introduction to Python programming -Building IOT with RASPBERRY PI and Arduino.                                                |                                                       |          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                        |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>INTRODUCTION</b>                                                                    | <b>9</b> |
| Application of genetic algorithm to power system load forecasting, particle swarm optimization for reactive power optimization, Optimization Techniques for emission dispatch of power plant, Differential Evolution Algorithm, Optimization Techniques for pole placement and state feedback algorithms, –Problem formulation and forms of optimal Control– Selection of performance measures. Necessary conditions for optimal control – State inequality constraints – Minimum time problem. |                                                                                        |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>LINEAR QUADRATIC TRACKING PROBLEMS AND NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL</b> | <b>9</b> |
| Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation. Numerical solution of 2-point boundary value problem by steepest descent and Fletcher Powell method - solution of Riccati equation by negative exponential and iterative Methods.                                               |                                                                                        |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>MODEL DECOMPOSITION AND CONVOLUTIONAL NEURAL NETWORK</b>                            | <b>9</b> |
| CNN Classification, CNN Algorithm, model decomposition techniques, application of model decomposition and CNN based techniques for various power system fault diagnosis problems, model predictive controllers for power system for power system stabilizers                                                                                                                                                                                                                                    |                                                                                        |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>FILTERING AND ESTIMATION</b>                                                        | <b>9</b> |
| Filtering – Linear system and estimation – System noise smoothing and prediction – Gauss Markov discrete time model – Estimation criteria – Minimum variance estimation, Least square estimation –Recursive estimation                                                                                                                                                                                                                                                                          |                                                                                        |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>KALMAN FILTER</b>                                                                   | <b>9</b> |
| Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement –Extended Kalman filter. Application of Kalman filter for power system protection applications                                                                                                                                                                                                 |                                                                                        |          |
| <b>ACTIVITIES:</b> Implement Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) for Economic Load Dispatch and Reactive Power Optimization using MATLAB, Develop a CNN-based fault classification model for transmission line fault diagnosis using power system datasets., Design and simulate Kalman Filter and Extended Kalman Filter for generator state estimation and protection applications, Review of GATE questions.                                                        |                                                                                        |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                        |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                        |          |
| CO1: Apply computational intelligence techniques such as Genetic Algorithms and Differential Evolution to solve power system optimization problems.                                                                                                                                                                                                                                                                                                                                             |                                                                                        |          |
| CO2: Analyze optimal control and dynamic programming methods for power system operation and control applications.                                                                                                                                                                                                                                                                                                                                                                               |                                                                                        |          |
| CO3: Develop CNN-based and model decomposition approaches for fault diagnosis and power system stability enhancement.                                                                                                                                                                                                                                                                                                                                                                           |                                                                                        |          |
| CO4: Apply filtering and estimation techniques for dynamic state estimation and monitoring of power systems.                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                        |          |
| CO5: Evaluate Kalman filter and Extended Kalman filter algorithms for power system protection and control applications.                                                                                                                                                                                                                                                                                                                                                                         |                                                                                        |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                        |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                        |          |
| 1. Kwang Y. Lee and Mohamed A. El-Sharkawi, "Modern Heuristic Optimization Techniques: Theory and Applications to Power Systems", Wiley-IEEE Press.                                                                                                                                                                                                                                                                                                                                             |                                                                                        |          |
| 2. D. P. Kothari and J. S. Dhillon, "Power System Optimization", PHI Learning, Second Edition.                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                        |          |



|                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------|
| CO3: Evaluate alternative state estimation formulations and compare their computational performance.                        |
| CO4: Assess network observability and identify bad data using statistical and topological methods.                          |
| CO5: Analyze power system security issues and apply static and dynamic security assessment techniques for secure operation. |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                |
| <b>TEXTBOOKS:</b>                                                                                                           |
| 1.Ali Abur and Antonio Gomez Exposito, "Power System State Estimation", Marcel Dekker Publications.                         |
| 2.John J. Grainger and William D. Stevenson Jr., "Power System Analysis", McGraw-Hill Education.                            |
| <b>REFERENCES:</b>                                                                                                          |
| 1. J J Grainger and W D Stevenson, " Power System Analysis", McGraw-Hill, Inc., 1994.                                       |
| 2. A Monticelli, "State Estimation in Electric Power Systems", Kluwer Academic Publishers,1999.                             |
| 3. Mukhtar Ahmad, "Power System State Estimation", Lap Lambert Acad Publishers,2013.                                        |
| 4. Felix L. Chernousko, " State Estimation for Dynamic Systems", CRC Press, 1993                                            |
| 5. Naim Logic, "Power System State Estimation" , LAP Lambert Acad. Publ., 2010.                                             |
| 6. Power System Security Assessment and Enhancement: A Bibliographical Survey.                                              |

### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 2    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 2   | 3   | 3    | 2    |
| AVG | 3   | 1.8 | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|         |                                                        |   |   |   |   |
|---------|--------------------------------------------------------|---|---|---|---|
| PS26002 | COMPUTATIONAL INTELLIGENCE TECHNIQUES TO POWER SYSTEMS | L | T | P | C |
| SDG:7,9 |                                                        | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To introduce computational intelligence and optimization techniques applicable to power system operation and control.
- To understand optimal control formulations and numerical techniques for solving power system optimization problems.
- To study machine learning approaches such as Convolutional Neural Networks (CNN) and model decomposition techniques for power system applications.
- To impart knowledge on filtering, estimation, and recursive estimation methods in dynamic power systems.
- To analyze Kalman filtering techniques and their applications in power system monitoring, protection, and control.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                               |   |   |   |          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|---|---|---|----------|
| PS26001                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | POWER SYSTEM STATE ESTIMATION AND SECURITY ASSESSMENT         | L | T | P | C        |
| SDG:7,9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                               | 3 | 0 | 0 | 3        |
| <b>COURSE OBJECTIVES:</b> <ul style="list-style-type: none"><li>• To introduce the state estimation on DC network.</li><li>• To impart in-depth knowledge on power system state estimation.</li><li>• To study alternative formulations of WLS state estimation.</li><li>• To get insight of network observability and bad data identification.</li><li>• To gain knowledge on Power System Security Assessment.</li></ul>                                                                                                                                                                           |                                                               |   |   |   |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | INTRODUCTION TO STATE ESTIMATION                              |   |   |   | <b>9</b> |
| Need for state estimation – Measurements – Noise - Measurement functions – Measurement Jacobian– Weights - Gain matrix - State estimation as applied to DC networks - Comparison of Power flow and State Estimation problems - Energy Management System.                                                                                                                                                                                                                                                                                                                                             |                                                               |   |   |   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | WEIGHTED LEAST SQUARE ESTIMATION                              |   |   |   | <b>9</b> |
| Modeling of transmission lines - Shunt capacitors and reactors - Tap changing and phase shifting transformers - loads and generators - Building network models - Maximum likelihood estimation - Measurement model and assumptions - WLS State Estimation Algorithm - Measurement functions -Measurement Jacobian matrix - Gain matrix - Cholesky decomposition and performing forward and backward substitutions - Decoupled formulation of WLS State estimation - DC State estimation model- Role of Phasor Measurement Units (PMU) in state estimation.                                           |                                                               |   |   |   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ALTERNATIVE FORMULATION OF WLS STATE ESTIMATION               |   |   |   | <b>9</b> |
| Weakness of normal equation formulation, Orthogonal factorization, Hybrid method, Method of Peters and Wilkinsons, Equality constraints WLS State estimation, Augmented matrix approach, Blocked formulation and comparison of techniques.                                                                                                                                                                                                                                                                                                                                                           |                                                               |   |   |   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | NETWORK OBSERVABILITY AND BAD DATA DETECTION 9 IDENTIFICATION |   |   |   | <b>9</b> |
| Network and graphs, Network matrices, loop equations, Methods Observability analysis, Numerical Method based on Nodal Variable formulation and branch variable formulation, Topological Observability analysis, Determination of critical measurements – Role of PMU in network observability. Properties of measurement residuals - Classification of measurements - Bad data detection and identification using Chi-squares distribution and normalized residuals - Bad data identification -Largest normalized residual test and Hypothesis testing identification. bad data detection using PMU. |                                                               |   |   |   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | POWER SYSTEM SECURITY ASSESSMENT                              |   |   |   | <b>9</b> |
| Introduction to Security Assessment -Static Security Assessment-Summary of Different Types of Static SecurityIndices-Methods for Assessing Power System Security-Methods for Assessing Power System Security-Dynamic Security Assessment-Future Trends to Assessing Dynamic Security-Issues Related to Integration of Renewable Energies-Security Enhancement-Issues and Methods to Solve SCOPF Problem-Deal with the Challenges for Enhancing Dynamic Security.                                                                                                                                     |                                                               |   |   |   |          |
| <b>ACTIVITIES:</b> Implement WLS state estimation algorithm using MATLAB, Comparative study of normal equation, orthogonal factorization, and hybrid methods for state estimation. Case study on static and dynamic security assessment of IEEE test systems with renewable integration, Review of GATE questions.                                                                                                                                                                                                                                                                                   |                                                               |   |   |   |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                               |   |   |   |          |
| <b>COURSE OUTCOMES:</b><br>CO1: Analyze power system state estimation problems and formulate estimation models for DC and AC networks.<br>CO2: Apply WLS state estimation algorithms and PMU-based estimation techniques for power system monitoring.                                                                                                                                                                                                                                                                                                                                                |                                                               |   |   |   |          |







**PROGRAMME  
ELECTIVE  
COURSES (PE)**



|         |                          |   |   |   |   |
|---------|--------------------------|---|---|---|---|
| PS26009 | POWER SYSTEM RELIABILITY | L | T | P | C |
| SDG:7,9 |                          | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To Understand the fundamental concepts of power system reliability, probability theory, security assessment, contingency analysis, and reliability evaluation techniques.
- To Analyze generation system reliability using probability-based methods, capacity outage models, and adequacy indices.
- To Evaluate generation system reliability using frequency and duration methods and determine system risk indices under practical operating conditions.
- To Analyze the reliability of composite generation and transmission systems using network models, conditional probability, and load point reliability indices.
- To Evaluate distribution system reliability using interruption indices and assess the impact of protection schemes and load transfer on system performance.

|               |                     |          |
|---------------|---------------------|----------|
| <b>UNIT I</b> | <b>INTRODUCTION</b> | <b>9</b> |
|---------------|---------------------|----------|

Definition of Reliability and Failure - Bathtub Curve - Concepts of Probability- Evaluation Techniques: Markov Process, Recursive Technique - Security levels of system – Reliability cost – Adequacy indices – Functions of system security – Contingency analysis – Linear sensitivity factors- Hierarchical Levels in Power System Reliability Assessment.

|                |                                                       |          |
|----------------|-------------------------------------------------------|----------|
| <b>UNIT II</b> | <b>GENERATING CAPACITY: BASIC PROBABILITY METHODS</b> | <b>9</b> |
|----------------|-------------------------------------------------------|----------|

Generation system models – Capacity outage probability tables – Loss of load indices – Equivalent forced outage rate – Capacity expansion analysis – Scheduled outages – Evaluation methods on period basis– Loss of energy indices.

|                 |                                                           |          |
|-----------------|-----------------------------------------------------------|----------|
| <b>UNIT III</b> | <b>GENERATING CAPACITY: FREQUENCY AND DURATION METHOD</b> | <b>9</b> |
|-----------------|-----------------------------------------------------------|----------|

Introduction – Generation model with no derated states– System risk indices with individual and cumulative load model– Practical system studies.

|                |                                                     |          |
|----------------|-----------------------------------------------------|----------|
| <b>UNIT IV</b> | <b>COMPOSITE GENERATION AND TRANSMISSION SYSTEM</b> | <b>9</b> |
|----------------|-----------------------------------------------------|----------|

Introduction – Radial configurations – Conditional probability approach – Network configurations – State selection – System and load point indices – Application to practical system – Data requirements for composite system reliability evaluation.

|               |                            |          |
|---------------|----------------------------|----------|
| <b>UNIT V</b> | <b>DISTRIBUTION SYSTEM</b> | <b>9</b> |
|---------------|----------------------------|----------|

Introduction – Evaluation techniques – Interruption indices: Customer oriented, Load and Energy oriented – Application to radial systems – Effects of lateral distributor protection, disconnects, protection failures and transferring loads – Probability distribution of reliability indices.

**ACTIVITIES:** Collect and analyze failure and repair rate data of power system components and develop reliability curves, Calculate SAIFI, SAIDI, CAIDI, ASAI, and ENS indices for a radial distribution feeder, Review of GATE questions.

**TOTAL:45 PERIODS**

### COURSE OUTCOMES:

CO1: Explain reliability concepts, security assessment, contingency analysis, probability models, and reliability evaluation techniques used in power systems.

CO2: Analyze generation adequacy using capacity outage probability tables, loss of load indices, forced outage rates, and capacity expansion planning methods.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO3: Evaluate generation system reliability using frequency and duration techniques to determine system risk and reliability indices.                                                                                                                                                                                                                                                                                                                              |
| CO4: Assess the reliability of composite generation and transmission systems using conditional probability approaches, network configurations, and load point reliability indices.                                                                                                                                                                                                                                                                                 |
| CO5: Evaluate distribution system reliability using customer, load, and energy-oriented interruption indices while analyzing the effects of protection coordination and load transfer strategies.                                                                                                                                                                                                                                                                  |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>TEXTBOOKS:</b><br>1. Roy Billinton and Ronald N. Allan, <i>Reliability Evaluation of Power Systems</i> , Springer, 2nd Edition.                                                                                                                                                                                                                                                                                                                                 |
| <b>REFERENCES:</b><br>1. Endrenyi J., <i>Reliability Modeling in Electric Power Systems</i> , Wiley.<br>2. Mohamed A. El-Sharkawi, <i>Electric Energy: An Introduction</i> , CRC Press.<br>3. Richard Brown, <i>Electric Power Distribution Reliability</i> , CRC Press.<br>4. M.V. Deshpande, <i>Elements of Electrical Power Station Design</i> , PHI.<br>5. IEEE Gold Book, <i>Reliability Analysis and Design of Industrial and Commercial Power Systems</i> . |

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 3   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2.2 | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|         |                     |  |  |   |   |   |   |
|---------|---------------------|--|--|---|---|---|---|
| PS26010 | EHV AC TRANSMISSION |  |  | L | T | P | C |
| SDG:7,9 |                     |  |  | 3 | 0 | 0 | 3 |

#### COURSE OBJECTIVES:

- To Understand EHV AC and HVDC transmission systems, transmission line configurations, power transfer capability, line losses, and economic considerations.
- To Analyze the electrical parameters of EHV transmission lines, including resistance, inductance, capacitance, sequence parameters, and ground return effects.
- To Evaluate conductor voltage gradients, corona phenomena, radio interference, and electric field distribution in EHV transmission lines.
- To Analyze electrostatic and electromagnetic field effects and apply design principles for safe and reliable EHV transmission systems.
- To Understand the design, operation, protection, maintenance, and environmental aspects of HVDC transmission systems.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>INTRODUCTION</b>                                | <b>9</b> |
| Standard transmission voltages-AC and DC – different line configurations– average values of line parameters – power handling capacity and line loss – costs of transmission lines and equipment – mechanical considerations in line performance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>CALCULATION OF LINE PARAMETERS</b>              | <b>9</b> |
| Calculation of resistance, inductance and capacitance for multi-conductor lines –calculation of sequence inductances and capacitances – line parameters for different modes of propagation – effect of ground return                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                    |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>VOLTAGE GRADIENTS OF CONDUCTORS</b>             | <b>9</b> |
| Charge-potential relations for multi-conductor lines – surface voltage gradient on conductors – gradient factors and their use – distribution of voltage gradient on sub conductors of bundle - voltage gradients on conductors in the presence of ground wires on towers-I <sup>2</sup> R loss and corona loss-RIV                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                    |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>ELECTROSTATIC FIELD AND DESIGN OF EHV LINES</b> | <b>9</b> |
| Effect of EHV line on heavy vehicles - calculation of electrostatic field of AC lines- effect of high field on humans, animals, and plants - measurement of electrostatic fields -electrostatic Induction in un energised circuit of a D/C line - induced voltages in insulated ground wires - electromagnetic interference, Design of EHV lines                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                    |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>HVDC LINES</b>                                  | <b>9</b> |
| Introduction- Reliability and failure issues-Design-tower, ROW, clearances, insulators, electrical and mechanical protection-Maintenance-Control and protection-D.C Electric field and Magnetic field -Regulations and guide lines-underground line design.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                    |          |
| <b>ACTIVITIES:</b> Calculate resistance, inductance, capacitance, and sequence parameters of bundled conductors, simulate electric field distribution under EHV lines using MATLAB, Review of GATE questions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                    |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    |          |
| <b>COURSE OUTCOMES:</b><br>CO1: Explain the concepts, configurations, performance, and economic aspects of EHV AC and HVDC transmission systems.<br>CO2: Calculate transmission line parameters, sequence components, and propagation characteristics for multi-conductor EHV transmission lines.<br>CO3: Analyze voltage gradients, corona losses, radio interference voltage (RIV), and electric field distribution in EHV transmission systems.<br>CO4: Evaluate electrostatic and electromagnetic field effects on living beings and nearby objects, and design EHV transmission lines considering technical and environmental requirements.<br>CO5: Assess the design, control, protection, reliability, maintenance, and operational requirements of modern HVDC transmission systems. |                                                    |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                    |          |
| <b>TEXTBOOKS:</b> <ol style="list-style-type: none"> <li>1. Rakosh Das Begamudre, <i>Extra High Voltage AC Transmission Engineering</i>, New Age International Publishers.</li> <li>2. K.R. Padiyar, <i>HVDC Power Transmission Systems</i>, New Age International Publishers.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                    |          |
| <b>REFERENCES:</b> <ol style="list-style-type: none"> <li>1. E.W. Kimbark, <i>Direct Current Transmission</i>, Wiley Interscience.</li> <li>2. J. Arrillaga, <i>High Voltage Direct Current Transmission</i>, IET Publications.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |          |



3.S. Rao, *EHV AC and HVDC Transmission Engineering and Practice*, Khanna Publishers.

4.M.S. Naidu and V. Kamaraju, *High Voltage Engineering*, McGraw Hill Education.

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 3   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 3   | 2.2 | 3   | 3    | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |                                                                 |   |   |   |   |
|----------|-----------------------------------------------------------------|---|---|---|---|
| PS26011  | ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY IN SYSTEM DESIGN | L | T | P | C |
| SDG:9,11 |                                                                 | 3 | 0 | 0 | 3 |

#### COURSE OBJECTIVES:

- To provide fundamental knowledge of Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) in electrical and electronic systems.
- To analyze grounding systems, cabling techniques, shielding methods, and coupling mechanisms for minimizing electromagnetic interference in electrical and electronic installations.
- To design suitable EMI filters, shielding techniques, and EMC protection methods for improving the electromagnetic compatibility of power electronic and electrical systems.
- To evaluate electromagnetic emissions generated by electrical components, switching devices, nonlinear circuits, and power electronic equipment, and recommend appropriate mitigation techniques.
- To apply electrostatic discharge (ESD) protection methods, EMC standards, EMI measurement procedures, and testing techniques to ensure regulatory compliance and reliable system performance.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INTRODUCTION                       | 9 |
| Definitions of EMI/EMC –Sources of EMI- Inter systems and Intra system- Conducted and radiated interference- Characteristics – Designing for electromagnetic compatibility (EMC)- EMC regulation typical noise path- EMI predictions and modeling, Methods of eliminating interferences and noise mitigation                                                                                                                                                                                 |                                    |   |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | GROUNDING AND CABLING              | 9 |
| Cabling- types of cables, mechanism of EMI emission / coupling in cables –capacitive coupling, inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding –safety grounds – signal grounds- single point and multipoint ground systems –hybrid grounds functional ground layout –grounding of cable shields- -guard shields- isolation, neutralizing transformers, shield grounding at high frequencies, digital grounding- Earth measurement Methods |                                    |   |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | BALANCING, FILTERING AND SHIELDING | 9 |
| Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- EMI filters characteristics of LPF, HPF, BPF, BEF and power line filter design –Choice of capacitors, inductors, transformers and resistors, EMC design components –shielding – near and far fields shielding effectiveness- absorption and                                                                                                                                                       |                                    |   |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                  |          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|----------|
| reflection loss- magnetic materials as a shield, shield discontinuities, slots and holes, seams and joints, conductive gaskets-windows and coatings – grounding of shields                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                  |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>EMI IN ELEMENTS AND CIRCUITS</b>                              | <b>9</b> |
| Electromagnetic emissions, noise from relays and switches, non-linearities in circuits, passive inter modulation, transients in power supply lines, EMI from power electronic equipment, EMI as combination of radiation and conduction                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                  |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES</b> | <b>9</b> |
| Static Generation- human body model- static discharges- ESD versus EMC, ESD protection in equipment-standards – FCC requirements – EMI measurements – Open area test site measurements and precautions- Radiated and conducted interference measurements, Control requirements and testing methods                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                  |          |
| <b>ACTIVITIES:</b> Classify EMI sources in substations, power electronic converters, and communication systems, Compare different cable shielding techniques, Study radiated and conducted emission testing procedures as per IEC/CISPR standards, Review of GATE questions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                  |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                  |          |
| <b>COURSE OUTCOMES:</b><br><br>CO1: Explain the sources, mechanisms, prediction methods, and mitigation techniques of electromagnetic interference and electromagnetic compatibility in electrical systems.<br><br>CO2: Analyze grounding, cabling, shielding, and isolation techniques to minimize EMI in power and electronic systems.<br><br>CO3: Design appropriate filtering, balancing, shielding, and EMC protection methods for high-frequency and power electronic applications.<br><br>CO4: Evaluate electromagnetic emissions and interference generated by electrical components, switching devices, and power electronic circuits.<br><br>CO5: Apply ESD protection methods, EMC standards, and testing techniques to ensure compliance and reliability of electrical and electronic equipment. |                                                                  |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                  |          |
| <b>TEXTBOOKS:</b><br>1. Clayton R. Paul, <i>Introduction to Electromagnetic Compatibility</i> , Wiley India, 2nd Edition.<br>2. Henry W. Ott, <i>Electromagnetic Compatibility Engineering</i> , Wiley Publications.<br>3. V.P. Kodali, <i>Engineering Electromagnetic Compatibility</i> , IEEE Press.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                  |          |
| <b>REFERENCES:</b><br>1. Bernhard Keiser, <i>Principles of Electromagnetic Compatibility</i> , Artech House.<br>2. William D. Kimmel and Daryl D. Gerke, <i>Practical Electromagnetic Compatibility</i> , CRC Press.<br>3. Donald R.J. White and Michel Mardiguian, <i>EMC Design Guides for Electronic Systems</i> , Interference Control Technologies.<br>4. Michel Mardiguian, <i>Electromagnetic Compatibility: Methods, Analysis and Applications</i> , Wiley.                                                                                                                                                                                                                                                                                                                                          |                                                                  |          |

  
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**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 1    |
| CO2 | 3   | 1   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 3   | 3   | 2    | 2    |
| AVG | 2.8 | 1.8 | 3   | 2.6  | 2    |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |                                             |   |   |   |   |
|----------|---------------------------------------------|---|---|---|---|
| PS26012  | INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN | L | T | P | C |
| SDG:9,12 |                                             | 3 | 0 | 0 | 3 |

**COURSE OBJECTIVES:**

- To understand the principles of motor starting analysis, voltage drop calculations, acceleration time estimation, and the application of computer-aided techniques for industrial motor starting studies.
- To analyze power factor correction techniques, capacitor switching phenomena, voltage magnification, switching surges, and system performance using computer-based studies.
- To design harmonic mitigation strategies by analyzing harmonic sources, system response, harmonic filters, and computer-aided harmonic evaluation in industrial power systems.
- To evaluate voltage flicker caused by industrial loads and apply suitable analysis methods and mitigation techniques to improve power quality.
- To apply ground grid design principles, performance evaluation methods, and computer-aided analysis for developing safe and reliable industrial grounding systems.

|                                                                                                                                                                                                                          |                                 |          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                            | MOTOR STARTING STUDIES          | <b>9</b> |
| Introduction-Evaluation Criteria-Starting Methods-System Data-Voltage Drop Calculations-Calculation of Acceleration time-Motor Starting with Limited-Capacity Generators-Computer-Aided Analysis-Conclusions.            |                                 |          |
| <b>UNIT II</b>                                                                                                                                                                                                           | POWER FACTOR CORRECTION STUDIES | <b>9</b> |
| Introduction-System Description and Modeling-Acceptance Criteria-Frequency Scan Analysis-Voltage Magnification Analysis-Sustained Overvoltage's-Switching Surge Analysis-Back-to-Back Switching-Summary and Conclusions. |                                 |          |
| <b>UNIT III</b>                                                                                                                                                                                                          | HARMONIC ANALYSIS               | <b>9</b> |
| Harmonic Sources-System Response to Harmonics-System Model for Computer-Aided Analysis- Acceptance Criteria-Harmonic Filters-Harmonic Evaluation-Case Study-Summary and Conclusions.                                     |                                 |          |
| <b>UNIT IV</b>                                                                                                                                                                                                           | FLICKER ANALYSIS                | <b>9</b> |
| Sources of Flicker-Flicker Analysis-Flicker Criteria-Data for Flicker analysis- Case Study-Arc Furnace Load-Minimizing the Flicker Effects-Summary                                                                       |                                 |          |
| <b>UNIT V</b>                                                                                                                                                                                                            | GROUND GRID ANALYSIS            | <b>9</b> |
| Introduction-Acceptance Criteria-Ground Grid Calculations-Computer-Aided Analysis - Improving the Performance of the Grounding Grids-Conclusions.                                                                        |                                 |          |



**ACTIVITIES:** Analyze voltage fluctuations caused by arc furnace or large motor loads and propose flicker reduction measures, Measure harmonic spectrum of nonlinear loads and design passive harmonic filters using simulation tools, Review of GATE questions.

**TOTAL:45 PERIODS**

**COURSE OUTCOMES:**

CO1: Analyze motor starting methods, voltage drop, acceleration time, and generator capacity requirements for industrial power systems using computer-aided techniques.

CO2: Evaluate power factor correction methods, switching transients, voltage magnification, and capacitor bank performance in industrial power networks.

CO3: Design harmonic mitigation solutions using harmonic analysis, filter design, and computer-aided system evaluation.

CO4: Assess voltage flicker in industrial power systems and recommend suitable mitigation techniques to improve power quality.

CO5: Apply grounding grid design procedures, acceptance criteria, and computer-aided analysis to ensure safe industrial power system operation.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. J. C. Das, *Power System Analysis: Short-Circuit Load Flow and Harmonics*, 3rd Edition, CRC Press, Taylor & Francis Group, 2018.
2. J. C. Das, *Power System Analysis for Industrial and Commercial Power Systems*, IEEE Press & Wiley, 2022.

**REFERENCES:**

1. H. Wayne Beaty and Donald G. Fink (Eds.), *Standard Handbook for Electrical Engineers*, 17th Edition, McGraw-Hill Education, 2018.
2. Surya Santoso, H. Wayne Beaty and Roger C. Dugan, *Electrical Power Systems Quality*, 4th Edition, McGraw-Hill Education, 2020.
3. Math H. J. Bollen, *Understanding Power Quality Problems: Voltage Sags and Interruptions*, IEEE Press Series on Power Engineering, Wiley-IEEE Press.
4. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty, *Electrical Power Systems Quality*, 4th Edition, McGraw-Hill Education, 2020.
5. P. Kundur, *Power System Stability and Control*, McGraw-Hill Education, Reprint Edition

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 2   | 2   | 3   | 3    | 3    |
| AVG | 2.8 | 1.8 | 3   | 3    | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                         |   |   |   |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|---|---|---|----------|
| PS26013                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | ADVANCED POWER SYSTEM DYNAMICS                                          | L | T | P | C        |
| SDG:7,13                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                         | 3 | 0 | 0 | 3        |
| <b>COURSE OBJECTIVES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                         |   |   |   |          |
| <ul style="list-style-type: none"><li>• To understand the mechanisms of subsynchronous resonance, turbine-generator interactions, and analytical methods for evaluating SSR in series-compensated power systems.</li><li>• To analyze the influence of transmission networks, generators, controllers, and load characteristics on power system voltage stability.</li><li>• To evaluate small-signal stability using multi-machine dynamic models and design suitable stabilizers for improving system damping and oscillation control.</li><li>• To apply numerical integration algorithms and unified dynamic simulation techniques for transient, mid-term, and long-term stability studies.</li><li>• To design suitable preventive and corrective control measures for mitigating short-term and long-term voltage instability in modern power systems.</li></ul> |                                                                         |   |   |   |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | SUBSYNCHRONOUS RESONANCE (SSR ) AND OSCILLATIONS                        |   |   |   | <b>9</b> |
| Subsynchronous Resonance (SSR) – Types of SSR - Characteristics of series –Compensated transmission systems –Modelling of turbine-generator-transmission network- Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Methods of analyzing SSR – Numerical examples illustrating instability of sub synchronous oscillations –time-domain simulation of sub synchronous resonance – EMTP with detailed synchronous machine model- Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters.                                                                                                       |                                                                         |   |   |   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS |   |   |   | <b>9</b> |
| Review of transmission aspects – Generation Aspects: Review of synchronous machine theory – Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.                                                                                                                                                                                                                                                                                                                                                                   |                                                                         |   |   |   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | SMALL SIGNAL STABILITY ANALYSIS AND ENHANCEMENT                         |   |   |   | <b>9</b> |
| Multi machine small signal stability analysis - Effects of Excitation System - Power System Stabilizer: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix with classical model and variable voltage behind transient reactant model of synchronous machines, illustration of stability analysis using a numerical example. Principle behind small-signal stability improvement methods: delta-omega and delta P-omega stabilizers.                                                                                   |                                                                         |   |   |   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | UNIFIED ALGORITHM FOR DYNAMIC ANALYSIS OF POWERSYSTEMS                  |   |   |   | <b>9</b> |
| Need for unified algorithm- numerical integration algorithmic steps-truncation error- variable step size – handling the discontinuities-- numerical stability- application of the algorithm for transient. Mid-term and long-term stability simulations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                         |   |   |   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | INSTABILITY MECHANISM AND COUNTER MEASURES                              |   |   |   | <b>9</b> |
| Types of Counter measures – Classification of Instability Mechanisms – Examples of Short term Voltage Instability- Counter measures to Short – term Instability – Case studies of Long Term voltage Instability – Corrective Actions against Long-term Instability.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                         |   |   |   |          |



**ACTIVITIES:** Study of synchronous generator capability curves, Development of state-space models for multi-machine systems, Analysis of real-world voltage instability events.

**TOTAL:45 PERIODS**

**COURSE OUTCOMES:**

CO1: Analyze SSR phenomena, turbine-generator interactions, and oscillatory behavior in series-compensated transmission systems using suitable analytical and simulation methods.

CO2: Evaluate the effects of transmission networks, generation systems, and load dynamics on voltage stability under various operating conditions.

CO3: Design small-signal stability enhancement techniques using excitation systems, power system stabilizers, and multi-machine dynamic models.

CO4: Apply unified numerical algorithms for transient, mid-term, and long-term dynamic stability analysis of power systems.

CO5: Assess instability mechanisms and recommend appropriate countermeasures to improve voltage stability and dynamic performance of interconnected power systems.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. R.Ramanujam," Power System Dynamics Analysis and Simulation, PHI Learning Private Limited, New Delhi,2009 .
2. T.V. Cutsem and C.Vournas, "Voltage Stability of Electric Power Systems", Kluwer publishers,1998.
3. P. Kundur, Power System Stability and Control, McGraw-Hill,1993.

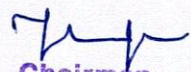
**REFERENCES:**

1. H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS- 91, pp, 1643-1650, July/August1972.
2. Roderick J.Frowd and J. C. Giri, "Transient stability and Long term dynamics unified", IEEE Trans., Vol 101, No. 10, October1982.
3. M.Stubbe, A.Bihain,J.Deuse, J.C.Baader, "A New Unified software program for the study of the dynamic behaviour of electrical power system," IEEE Transaction, Power Systems, Vol.4.No.1,Feb:1989,Pg.129 to 138.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 3   | 1   | 3   | 3    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 2   | 3   | 2    | 2    |
| AVG | 3   | 1.8 | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|---|---|---|----------|
| PS26014                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | COMPUTER RELAYING AND WIDE AREA MEASUREMENT<br>SYSTEMS | L | T | P | C        |
| SDG:9,7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                        | 3 | 0 | 0 | 3        |
| <b>COURSE OBJECTIVES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                        |   |   |   |          |
| <ul style="list-style-type: none"><li>• To understand the architecture of computer relays, digital signal acquisition, Fourier analysis, and the fundamental concepts of phasor representation used in digital protection systems.</li><li>• To analyze digital filtering techniques, Fourier transforms, wavelets, Kalman filtering, and artificial intelligence methods for signal processing in computer relaying applications.</li><li>• To apply phasor estimation algorithms, frequency estimation techniques, and recursive updating methods for accurate power system measurement and protection.</li><li>• To evaluate the architecture, synchronization, performance, and transient response characteristics of PMUs and Wide Area Measurement Systems.</li><li>• To design state estimation and adaptive protection schemes using synchronized phasor measurements for reliable monitoring and protection of interconnected power systems.</li></ul> |                                                        |   |   |   |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | INTRODUCTION                                           |   |   |   | <b>9</b> |
| Historical background - Expected benefits - Computer relay architecture - Analog to digital converters - Anti-aliasing filters - Substation computer hierarchy - Fourier series Exponential fourier series - Sine and cosine fourier series – Phasor.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                        |   |   |   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | FILTERS IN COMPUTER RELAYING                           |   |   |   | <b>9</b> |
| Walsh functions - Fourier transforms - Discrete fourier transform - Random processes - Filtering of random processes - Kalman filtering - Digital filters - Windows and windowing - Linear phase Approximation - Filter synthesis – Wavelets - Elements of artificial intelligence.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                        |   |   |   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | COMPUTATION OF PHASORS                                 |   |   |   | <b>9</b> |
| Introduction - Phasor representation of sinusoids - Fourier series and Fourier transform and DFT Phasor representation - Phasor Estimation of Nominal Frequency Signals - Formulas for updating phasors – Non-recursive updates - Recursive updates - Frequency Estimation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                        |   |   |   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | PHASOR MEASUREMENT UNITS                               |   |   |   | <b>9</b> |
| A generic PMU - The global positioning system - Hierarchy for phasor measurement systems - Functional requirements of PMUs and PDCs - Transient Response of: Phasor Measurement Units, of instrument transformers, filters. Transient response during electromagnetic transients and power swings.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                        |   |   |   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | PHASOR MEASUREMENT APPLICATIONS                        |   |   |   | <b>9</b> |
| State Estimation - History, Operator’s load flow - Weighted least square: least square, Linear weighted least squares, Nonlinear weighted least squares - Static state estimation - State estimation with Phasors measurements - Linear state estimation – Protection system with phasor inputs: Differential and distance protection of transmission lines - Adaptive protection - Adaptive out-of-step protection.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                        |   |   |   |          |
| <b>ACTIVITIES:</b> Design and implementation of digital filters using MATLAB, Computation of phasors using DFT algorithms.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                        |   |   |   |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                        |   |   |   |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                        |   |   |   |          |
| CO1: Explain the architecture of computer relays, digital signal acquisition methods, Fourier analysis, and phasor representation used in modern protection systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                        |   |   |   |          |



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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO2: Analyze digital signal processing techniques including digital filters, Kalman filters, wavelets, and artificial intelligence methods for computer relaying applications.                                                                                                |
| CO3: Apply phasor and frequency estimation algorithms for accurate synchronized measurements in digital protection systems.                                                                                                                                                   |
| CO4: Evaluate the performance of PMUs, GPS synchronization, and Wide Area Measurement Systems under steady-state and transient operating conditions.                                                                                                                          |
| CO5: Design phasor-based state estimation and adaptive protection schemes for improving the reliability and security of modern power systems.                                                                                                                                 |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                  |
| <b>TEXTBOOKS:</b><br>1. A.G. Phadke, J.S. Thorp, "Computer Relaying for Power Systems", John Wiley and Sons Ltd., Research Studies Press Limited, 2nd Edition, 2009.<br>2. A.G. Phadke, J.S. Thorp, "Synchronized Phasor Measurements and Their Applications", Springer, 2008 |
| <b>REFERENCES:</b><br>1. Antonello Monti, Carlo Muscas, Ferdinanda Ponci, "Phasor Measurement Units and Wide Area Monitoring Systems" Academic Press, 09-Jun-2016.<br>2. Stanley H. Horowitz, Arun G. Phadke, "Power System Relaying", John Wiley & Sons, 25-Oct 2013.        |

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|         |                                               |   |   |   |   |
|---------|-----------------------------------------------|---|---|---|---|
| PS26015 | APPLICATION OF DSP TO POWER SYSTEM PROTECTION | L | T | P | C |
| SDG:9,7 |                                               | 3 | 0 | 0 | 3 |

#### COURSE OBJECTIVES:

- To understand the fundamental digital signal processing techniques, including sampling, Fourier transforms, wavelet transforms, and numerical algorithms used in power system protection.
- To analyze the architecture, operating principles, and performance characteristics of digital and numerical relays used for protecting generators, transformers, feeders, and busbars.
- To apply numerical and DSP-based protection algorithms for accurate fault detection, signal processing, and protection of power system components.
- To evaluate advanced digital protection techniques based on Fourier, wavelet, and differential algorithms for transformer, transmission line, and cable protection.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|----------|
| <ul style="list-style-type: none"> <li>To design intelligent digital protective relays using adaptive decision-making, fuzzy logic, and artificial intelligence techniques for modern power system protection.</li> </ul>                                                                                                                                                                                                                                   |                                             |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>DIGITAL SIGNAL PROCESSING TECHNIQUES</b> | <b>9</b> |
| Sampling-Principle of scaling-aliasing-Decimation, Interpolation. Fourier and discrete Fourier transforms - Fast Fourier Transforms.-Wavelet transform -Numerical Algorithms.                                                                                                                                                                                                                                                                               |                                             |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>DIGITAL PROTECTION</b>                   | <b>9</b> |
| Digital Protection -performance and operational characteristics of digital protection. Basic components of digital relays -Signal conditioning systems -Conversion subsystem -digital relay subsystem Numerical relay for generator, transformer, feeder, busbar protection                                                                                                                                                                                 |                                             |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>ALGORITHMIC TECHNIQUES</b>               | <b>9</b> |
| Finite difference techniques- Interpolation-Numerical differentiation-curve fitting and smoothing. Sinusoidal wave based algorithms -First and second derivative method -two and three sample technique .Walsh function analysis- least squares based methods-differential equation based techniques -Travelling wave protective schemes.FIR based algorithms-Least square curve fitting algorithm.                                                         |                                             |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>DIGITAL PROTECTION TECHNIQUES</b>        | <b>9</b> |
| Transformer protection- -Fourier based algorithm-basic hardware of microprocessor based transformer protection .Digital line differential scheme. Measurement algorithms for digital protection power-voltage -current - Impedance -phase shift.-short window Wavelet based fault identification techniques-sliding window-FWHT-signal analysis and synthesis-AC/DC cable fault location-intrinsic and extrinsic fault-harmonic filtering in fault analysis |                                             |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>DIGITAL PROTECTIVE RELAYS</b>            | <b>9</b> |
| Decision making in protective relays- Deterministic Decision Making - Statistical Hypotheses Testing Decision Making with Multiple Criteria - Adaptive Decision Schemes .Elements of Fuzzy Logic in Protective Relays - Fuzzy Sets and Fuzzy Numbers -Boolean Versus Fuzzy Logic -Fuzzy Reasoning - Fuzzy Logic Applications for Protection and Control.                                                                                                    |                                             |          |
| <b>ACTIVITIES:</b> MATLAB implementation of DFT, FFT algorithms, finite difference and interpolation algorithms, Development of decision-making algorithms for digital relays.                                                                                                                                                                                                                                                                              |                                             |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |          |
| CO1: Explain DSP concepts including sampling, Fourier transform, FFT, wavelet transform, and numerical algorithms used in digital power system protection.                                                                                                                                                                                                                                                                                                  |                                             |          |
| CO2: Analyze the architecture, performance, and operational characteristics of digital and numerical relays for protecting major power system equipment.                                                                                                                                                                                                                                                                                                    |                                             |          |
| CO3: Apply DSP-based algorithms such as least squares, differential equation, Walsh transform, FIR filters, and travelling wave methods for fault detection and protection.                                                                                                                                                                                                                                                                                 |                                             |          |
| CO4: Evaluate advanced digital protection algorithms for transformers, transmission lines, and cables using Fourier and wavelet-based techniques.                                                                                                                                                                                                                                                                                                           |                                             |          |
| CO5: Design intelligent digital protective relay schemes using adaptive decision-making, fuzzy logic, and AI techniques for reliable power system protection.                                                                                                                                                                                                                                                                                               |                                             |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                |                                             |          |



**TEXTBOOKS:**

1. J.L. Blackburn, Protective Relaying: Principles and Applications, Marcel Dekker, New York, 1987.
2. A.G. Phadke and J.S. Thorp, Computer Relaying for Power Systems, John Wiley & Sons, New York, 1988.

**REFERENCES:**

1. J.G. Proakis and D.G. Manolakis, 'Digital Signal Processing Principles, Algorithms
2. Y.G. Paithankar and S.R Bhide, "Fundamentals of Power System Protection", PHI Learning; 2nd edition edition (July 30, 2013)

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|         |                         |  |  |  |   |   |   |   |
|---------|-------------------------|--|--|--|---|---|---|---|
| PS26016 | HIGH VOLTAGE TECHNOLOGY |  |  |  | L | T | P | C |
| SDG:7,9 |                         |  |  |  | 3 | 0 | 0 | 3 |

**COURSE OBJECTIVES:**

- To understand the principles and techniques for generating high DC voltages using rectifiers, voltage multiplier circuits, electrostatic generators, and laboratory high-voltage systems.
- To analyze high AC voltage generation methods using testing transformers, cascaded transformers, and resonant circuits for high-voltage testing applications.
- To apply impulse voltage and current generation techniques, including Marx generators, switching impulse generators, and VFTO generation, in accordance with IS and IEC standards.
- To evaluate high-voltage and high-current measurement techniques using modern measuring instruments and digital recording systems for laboratory and industrial applications.
- To design appropriate safety measures and electrostatic protection techniques for high-voltage laboratories and electrical installations in compliance with international standards.

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| <b>UNIT I</b> | GENERATION OF DIRECT VOLTAGES | <b>9</b> |
|---------------|-------------------------------|----------|

Requirements of HV generation in Laboratory, voltage stress, testing voltages, generation of direct voltages – AC to DC conversion – single phase rectifier circuits – cascade circuits – Voltage multiplier circuits – Cockcroft-Walton circuit – voltage regulation – ripple-factor – Electrostatic generators.

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| <b>UNIT II</b> | GENERATION OF ALTERNATING VOLTAGE | <b>9</b> |
|----------------|-----------------------------------|----------|

Testing transformer – single unit testing transformer, cascaded transformer – equivalent circuit of cascaded transformer – resonant circuits – resonant transformer – voltage regulation.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                    |          |
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| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>GENERATION OF IMPULSE VOLTAGES AND CURRENTS</b> | <b>9</b> |
| Impulse voltage, general shape and definition of lightning impulses, generator circuit – Marx generator –analysis of various impulse voltage generator circuits, controlled switching – multistage impulse generator circuits – Switching impulse generator circuits – Generation of impulse currents, generation of non- standard impulse voltages and very fast transient voltage (VFTO)- Relevant IS and IEC Standards                                                              |                                                    |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>MEASUREMENT OF HIGH VOLTAGES</b>                | <b>9</b> |
| Measurement of high AC, DC Impulse voltages - Peak voltage measurements by sphere gaps – Electrostatic voltmeter – generating voltmeters and field sensors – Chubb-Forbes method – voltage 82 dividers, types, dynamic response and impulse voltage measurements- Relevant IS and IEC Standards, measurement of high DC, AC and impulse currents – shunts, measurement using magnetic potentiometers and magnetic coupling - Fast digital transient recorders for impulse measurements |                                                    |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>SAFETY AND ELECTROSTATIC HAZARDS</b>            | <b>9</b> |
| Introduction – Nature of static electricity – Triboelectric series – Basic laws of Electrostatic electricity– materials and static electricity – Electrostatic discharges (ESD) – Static electricity problems – Hazards of Electrostatic electricity in industry – Hazards from electrical equipment and installations – Static eliminators and charge neutralizers – Lightning protection- safety measures and standards                                                              |                                                    |          |
| <b>ACTIVITIES:</b> Study and modeling of testing transformers, Design and simulation of Marx impulse generators, Review of Gate questions.                                                                                                                                                                                                                                                                                                                                             |                                                    |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                    |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                    |          |
| CO1: Explain the principles of high DC voltage generation using rectifier circuits, voltage multipliers, Cockcroft–Walton circuits, and electrostatic generators.                                                                                                                                                                                                                                                                                                                      |                                                    |          |
| CO2: Analyze high AC voltage generation techniques using testing transformers, cascaded transformers, and resonant circuits for high-voltage testing.                                                                                                                                                                                                                                                                                                                                  |                                                    |          |
| CO3: Apply impulse voltage and current generation techniques, including Marx generators and switching impulse generators, in accordance with IS and IEC standards.                                                                                                                                                                                                                                                                                                                     |                                                    |          |
| CO4: Evaluate high-voltage and high-current measurement methods using sphere gaps, voltage dividers, electrostatic voltmeters, digital transient recorders, and related instruments.                                                                                                                                                                                                                                                                                                   |                                                    |          |
| CO5: Design safety procedures and electrostatic hazard mitigation techniques for high-voltage equipment and installations based on industrial safety standards.                                                                                                                                                                                                                                                                                                                        |                                                    |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                           |                                                    |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    |          |
| 1. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsevier India Pvt. Ltd, Second edition, 2008                                                                                                                                                                                                                                                                                                                                                      |                                                    |          |
| 2. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata McGraw-hill Publishing Company Ltd., Fifth edition., New Delhi, 2017.                                                                                                                                                                                                                                                                                                                                                    |                                                    |          |
| <b>REFERENCES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                    |          |
| 1. R.Mazen Abdel-Salam, Hussein Anis, Ahdab El-Morshedy, RoshdyRadwan, “High Voltage Engineering Theory and Practice” Second Edition, Revised and Expanded, Marcel Dekker, Inc., New York, 2000.                                                                                                                                                                                                                                                                                       |                                                    |          |
| 2. Adolf J. Schwab, “High Voltage Measurement Techniques”, M.I.T Press, 1972.                                                                                                                                                                                                                                                                                                                                                                                                          |                                                    |          |
| 3. Indian Electricity Rules; IS-5216; Electrical Safety Handbook by John Cadick                                                                                                                                                                                                                                                                                                                                                                                                        |                                                    |          |



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 3   | 3   | 3    | 2    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.2  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |            |   |   |   |   |
|----------|------------|---|---|---|---|
| PS26017  | SMART GRID | L | T | P | C |
| SDG:7,11 |            | 3 | 0 | 0 | 3 |

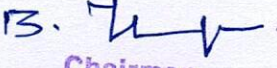
### COURSE OBJECTIVES:

- To understand the evolution, architecture, functions, benefits, policies, and applications of Smart Grid technologies in modern power systems.
- To analyze smart grid technologies including substation automation, transmission and distribution automation, FACTS, HVDC, and electric vehicle integration for efficient grid operation.
- To apply advanced metering infrastructure, smart metering, PMUs, and demand-side management techniques for intelligent monitoring and energy management.
- To evaluate power quality issues, renewable energy integration challenges, and power quality improvement techniques in Smart Grid environments.
- To design secure Smart Grid communication architectures using modern networking technologies, cloud computing, and cybersecurity principles.

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| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>INTRODUCTION TO SMART GRID</b>                        | <b>9</b> |
| Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, Comparison of Micro grid and Smart grid, Present development & International policies in Smart Grid, Smart Grid Initiative for Power Distribution Utility in India – Case Study.                                                                                                                               |                                                          |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>SMART GRID TECHNOLOGIES</b>                           | <b>9</b> |
| Technology Drivers, Smart Integration of energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control, Distribution systems: DMS, Volt/Var control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV) – Grid to Vehicle and Vehicle to Grid charging concepts. |                                                          |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>SMART METERS AND ADVANCED METERING INFRASTRUCTURE</b> | <b>9</b> |
| Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit(PMU) & their application for                                                                                                                                                                                                                                                                                        |                                                          |          |



|                                                                                                                                                                                                                                                           |                                                               |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|----------|
| monitoring & protection. Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.                                                                                                       |                                                               |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                            | <b>POWER QUALITY MANAGEMENT IN SMART GRID</b>                 | <b>9</b> |
| Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.                                                   |                                                               |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                             | <b>HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS</b> | <b>9</b> |
| Architecture and Standards -Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), PLC, Zigbee, GSM, IP based Protocols, Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid. |                                                               |          |
| <b>ACTIVITIES:</b> Case study analysis of Smart Grid implementation in India, Modeling of Smart Substation and Feeder Automation systems, Study of Smart Meter architecture and communication protocols.                                                  |                                                               |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                   |                                                               |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                   |                                                               |          |
| CO1: Explain the concepts, architecture, benefits, and policy initiatives of Smart Grids and compare them with conventional power grids.                                                                                                                  |                                                               |          |
| CO2: Analyze Smart Grid technologies including automation, FACTS, HVDC, EMS, DMS, and electric vehicle integration for improving power system performance.                                                                                                |                                                               |          |
| CO3: Apply smart metering, AMI, PMUs, and demand-side management techniques for intelligent monitoring and energy management in Smart Grids.                                                                                                              |                                                               |          |
| CO4: Evaluate power quality issues associated with Smart Grids and renewable energy integration, and recommend suitable mitigation techniques.                                                                                                            |                                                               |          |
| CO5: Design Smart Grid communication networks and cybersecurity frameworks using modern communication protocols and cloud computing technologies.                                                                                                         |                                                               |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                              |                                                               |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                         |                                                               |          |
| 1. Stuart Borlase 'Smart Grid: Infrastructure, Technology and Solutions', CRC Press 2012.                                                                                                                                                                 |                                                               |          |
| 2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, 'Smart Grid: Technology and Applications', Wiley, 2012.                                                                                                             |                                                               |          |
| <b>REFERENCES:</b>                                                                                                                                                                                                                                        |                                                               |          |
| 1. Mini S. Thomas, John D McDonald, 'Power System SCADA and Smart Grids', CRC Press, 2015                                                                                                                                                                 |                                                               |          |
| 2. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, 'Communication Networks for Smart Grids', Springer, 2014                                                                                                                                         |                                                               |          |
| 3. SMART GRID Fundamentals of Design and Analysis, James Momoh, IEEE press, A John Wiley & Sons, Inc., Publication.                                                                                                                                       |                                                               |          |

  
**Chairman**  
 Board of Studies  
 M.E. Power Systems Engineering  
 Kingston Engineering College  
 Vellore - 632 059



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |                                       |   |   |   |   |
|----------|---------------------------------------|---|---|---|---|
| PS26018  | DISTRIBUTED GENERATION AND MICRO GRID | L | T | P | C |
| SDG:7,13 |                                       | 3 | 0 | 0 | 3 |

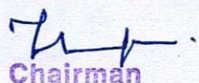
### COURSE OBJECTIVES:

- To understand the concepts, benefits, and technical, environmental, and economic impacts of distributed generation on transmission and distribution systems.
- To analyze the operating principles and integration of distributed energy resources, including renewable energy sources, energy storage systems, and power electronic interfaces.
- To apply planning methodologies and protection schemes for distributed generation systems to ensure reliable and secure power system operation.
- To evaluate the architecture, control strategies, operational modes, and modeling of microgrids for grid-connected and islanded operation.
- To assess the technical, economic, environmental, and operational impacts of microgrids and formulate strategies for their efficient implementation in modern power systems.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|----------|
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                      | INTRODUCTION TO DISTRIBUTED GENERATION | <b>9</b> |
| DG definition - Reasons for distributed generation-Benefits of integration - Distributed generation and the distribution system - Technical, Environmental and Economic impacts of distributed generation on the distribution system - Impact of distributed generation on the transmission system-Impact of distributed generation on central generation                                                                                          |                                        |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     | DISTRIBUTED ENERGY RESOURCES           | <b>9</b> |
| Combined heat and power (CHP) systems-Wind energy conversion systems (WECS)- Solar photovoltaic (PV) systems-Small-scale hydroelectric power generation-Other renewable energy sources-Storage devices-Inverter interfaces                                                                                                                                                                                                                         |                                        |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                    | DG PLANNING AND PROTECTION             | <b>9</b> |
| Generation capacity adequacy in conventional thermal generation systems-Impact of distributed generation-Impact of distributed generation on network design-Protection of distributed generation Protection of the generation equipment from internal Faults-Protection of the faulted distribution network from fault currents supplied by the distributed generator-Impact of distributed generation on existing distribution system protection. |                                        |          |



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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|----------|
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>CONCEPT OF MICROGRID</b> | <b>9</b> |
| Microgrid Definition-A typical Microgrid configuration- Functions of Micro source controller and central controller- Energy Management Module (EMM) and Protection Co-ordination Module (PCM)- Modes of Operation- Grid connected and islanded modes- Modelling of Microgrid- Microturbine Model- PV Solar Cell Model- Wind Turbine Model-Role of Microgrid in power market competition.                                                                                                                                                                                                       |                             |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>IMPACTS OF MICROGRID</b> | <b>9</b> |
| Technical and economical advantages of Microgrid-Challenges and disadvantages of Microgrid development- Management and operational issues of a Microgrid- Impact on heat utilization-Impact on process optimization-Impact on market-Impact on environment-Impact on distribution system-Impact on communication standards and protocols. Microgrid economics-Main issues of Microgrid economics-Microgrids and traditional power system economics-Emerging economic issues in Microgrids-Economic issues between Microgrids and bulk power systems-Potential benefits of Microgrid economics. |                             |          |
| <b>ACTIVITIES:</b> Case study on Distributed Generation integration in modern power systems, Analysis of DG penetration effects on network reliability, Modelling and simulation of grid-connected Microgrids, Economic feasibility analysis of Microgrid projects.                                                                                                                                                                                                                                                                                                                            |                             |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                             |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                             |          |
| CO1: Explain the concepts, benefits, and impacts of distributed generation on transmission, distribution, and conventional power systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                             |          |
| CO2: Analyze the characteristics and integration of distributed energy resources, renewable energy systems, storage technologies, and inverter interfaces.                                                                                                                                                                                                                                                                                                                                                                                                                                     |                             |          |
| CO3: Apply planning techniques and protection schemes for distributed generation systems to improve reliability and safety of distribution networks.                                                                                                                                                                                                                                                                                                                                                                                                                                           |                             |          |
| CO4: Evaluate the configuration, control, modeling, and operation of microgrids under grid-connected and islanded operating conditions.                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                             |          |
| CO5: Assess the technical, economic, environmental, and communication aspects of microgrids and recommend suitable strategies for sustainable deployment.                                                                                                                                                                                                                                                                                                                                                                                                                                      |                             |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                             |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                             |          |
| 1. Nick Jenkins, Janaka Ekanayake , Goran Strbac , “Distributed Generation”, Institution of Engineering and Technology, London, UK,2010.                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                             |          |
| 2. S. Chowdhury, S.P. Chowdhury and P. Crossley, “Microgrids and Active Distribution Networks”, The Institution of Engineering and Technology, London, United Kingdom, 2009.                                                                                                                                                                                                                                                                                                                                                                                                                   |                             |          |
| <b>REFERENCES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                             |          |
| 1. Math H. Bollen , Fainan Hassan, “Integration of Distributed Generation in the Power System”, John Wiley & Sons, New Jersey, 2011.                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                             |          |
| 2. Magdi S. Mahmoud, Fouad M. AL-Sunni, “Control and Optimization of Distributed Generation Systems”, Springer International Publishing, Switzerland, 2015.                                                                                                                                                                                                                                                                                                                                                                                                                                    |                             |          |
| 3. Nadarajah Mithulananthan, Duong Quoc Hung, Kwang Y. Lee, “Intelligent Network Integration of Distributed Renewable Generation”, Springer International Publishing, Switzerland, 2017.                                                                                                                                                                                                                                                                                                                                                                                                       |                             |          |

13.   
Chairman



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 2    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.6  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|         |                                         |   |   |   |   |
|---------|-----------------------------------------|---|---|---|---|
| PS26019 | PYTHON PROGRAMMING FOR MACHINE LEARNING | L | T | P | C |
| SDG:4,9 |                                         | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To understand the fundamentals of machine learning, Python programming, data structures, and control statements required for developing machine learning applications.
- To apply Python functions, modules, object-oriented programming concepts, and scientific computing libraries for engineering and machine learning applications.
- To analyze regression techniques, standard datasets, and SciPy-based machine learning models for solving engineering problems.
- To evaluate classification, clustering, and data visualization techniques using Scikit-learn and Matplotlib for intelligent data analysis.
- To design neural network models and embedded machine learning applications using TensorFlow, Keras, and TinyML for real-time engineering systems.

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| <b>UNIT I</b> | INTRODUCTION TO MACHINE LEARNING AND PYTHON | <b>9</b> |
|---------------|---------------------------------------------|----------|

Introduction to Machine Learning: Significance, Advantage and Applications – Categories of Machine Learning – Basic Steps in Machine Learning: Raw Data Collection, Pre-processing, Training a Model, Evaluation of Model, Performance Improvement Introduction to Python and its significance – Difference between C, C++ and Python Languages; Compiler and Interpreters – Python3 Installation & Running – Basics of Python Programming Syntax: Variable Types, Basic Operators, Reading Input from User – Arrays/List, Dictionary and Set – Conditional Statements – Control Flow and loop control statements

|                |                               |          |
|----------------|-------------------------------|----------|
| <b>UNIT II</b> | PYTHON FUNCTIONS AND PACKAGES | <b>9</b> |
|----------------|-------------------------------|----------|

File Handling: Reading and Writing Data – Errors and Exceptions Handling – Functions & Modules – Package Handling in Python – Pip Installation & Exploring Functions in python package – Installing the Numpy Library and exploring various operations on Arrays: Indexing, Slicing, Multi-Dimensional Arrays, Joining Numpy Arrays, Array intersection and Difference, Saving and Loading Numpy Arrays – Introduction to SciPy Package & its functions - Introduction to Object Oriented Programming with Python

|                 |                                                 |          |
|-----------------|-------------------------------------------------|----------|
| <b>UNIT III</b> | IMPLEMENTATION OF MACHINE LEARNING USING PYTHON | <b>9</b> |
|-----------------|-------------------------------------------------|----------|

Description of Standard Datasets: Coco, ImageNet, MNIST (Handwritten Digits) Dataset, Boston Housing Dataset – Introducing the concepts of Regression – Linear, Polynomial & Logistic Regression with analytical understanding - Introduction to SciPy Package & its functions – Python Application of Linear Regression and



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                      |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|----------|
| Polynomial Regression using SciPy – Interpolation, Overfitting and Underfitting concepts & examples using SciPy.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                      |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>CLASSIFICATION AND CLUSTERING CONCEPTS OF ML</b>                  | <b>9</b> |
| Introduction to ML Concepts of Clustering and Classification – Types of Classification Algorithms – Support Vector Machines (SVM) - Decision Tree - Random Forest – Introduction to ML using scikit learn – Using scikit-learn, Loading a sample dataset, Learning & prediction, interpolation & fitting, Multiclass fitting - Implementation of SVM using Blood Cancer Dataset, Decision Tree using data from csv. Types of Clustering Algorithms & Techniques – K-means Algorithm, Mean Shift Algorithm & Hierarchical Clustering Algorithm – Introduction to Python Visualization using Matplotlib: Plotting 2 dimensional, 3-dimensional graphs; formatting axis values; plotting multiple rows of data in same graph – Implementation of K-means Algorithm and Mean Shift Algorithm using Python |                                                                      |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>INTRODUCTION TO NEURAL NETWORKS AND EMBEDDED MACHINE LEARNING</b> | <b>9</b> |
| Introduction to Neural Networks & Significance – Neural Network Architecture – Single Layer Perceptron & Multi-Layer Perceptron (MLP) – Commonly Used Activation Functions - Forward Propagation, Back Propagation, and Epochs – Gradient Descent – Introduction to Tensorflow and Keras ML Python packages – Implementation of MLP Neural Network on Iris Dataset – Introduction to Convolution Neural Networks – Implementation of Digit Classification using MNIST Dataset ML for Embedded Systems: Comparison with conventional ML – Challenges & Methods for Overcoming – TinyML and Tensorflow Lite for Microcontrollers – on-Board AI – ML Edge Devices: Arduino Nano BLE Sense, Google Edge TPU and Intel Movidius                                                                            |                                                                      |          |
| <b>ACTIVITIES:</b> File handling and exception handling programming exercises, Dataset exploration using MNIST, Boston Housing, and ImageNet datasets, Implementation of SVM, Decision Tree, and Random Forest algorithms, Development of MLP models using TensorFlow and Keras.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                      |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                      |          |
| <b>COURSE OUTCOME:</b><br>CO1: Explain the fundamentals of machine learning, Python programming, data structures, and programming constructs required for engineering applications.<br>CO2: Apply Python programming concepts, scientific libraries (NumPy and SciPy), file handling, and object-oriented programming for engineering computations.<br>CO3: Analyze regression models and implement machine learning algorithms using Python for engineering datasets.<br>CO4: Evaluate classification, clustering, and visualization techniques using Scikit-learn and Matplotlib for predictive data analytics.<br>CO5: Design neural network models and embedded machine learning solutions using TensorFlow, Keras, and TinyML for intelligent engineering applications.                          |                                                                      |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                      |          |
| <b>TEXTBOOKS:</b><br>1. Mark Lutz, "Learning Python, Powerful OOPs, O'Reilly, 2011<br>2. Zelle, John "M. Python Programming: An Introduction to Computer Science.", Franklin Beedle & Associates, 2003.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                      |          |
| <b>REFERENCES:</b><br>1. Andreas C. Müller, Sarah Guido, "Introduction to Machine Learning with Python", O'Reilly, 2016<br>2. Sebastian Raschka, Vahid Mirjalili, "Python Machine Learning - Third Edition", Packt, December 2019.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                      |          |



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 2   | 1    | 2    |
| CO2 | 3   | 2   | 2   | 2    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 2.6 | 2.2  | 2.8  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |                           |   |   |   |   |
|----------|---------------------------|---|---|---|---|
| PS26020  | RESTRUCTURED POWER SYSTEM | L | T | P | C |
| SDG:7,12 |                           | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To understand the concepts, objectives, economic principles, and market structures involved in the restructuring of electric power systems.
- To analyze transmission congestion management techniques, available transfer capability (ATC), and market-based approaches for efficient utilization of transmission networks.
- To apply locational marginal pricing (LMP) methods and financial transmission rights (FTRs) for congestion pricing and risk management in deregulated electricity markets.
- To evaluate ancillary service markets and transmission pricing mechanisms for ensuring secure, reliable, and economical operation of deregulated power systems.
- To assess the evolution of electricity markets, international market models, and power sector reforms in India for sustainable power market development.

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| <b>UNIT I</b> | <b>INTRODUCTION</b> | <b>9</b> |
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Reasons for restructuring - Understanding the restructuring process - objectives of deregulation of various power systems across the world - Consumer behavior - Supplier behavior - Market equilibrium - Short-run and Long-run costs - Various costs of production. The Philosophy of Market Models: Market models based on contractual arrangements - Market architecture

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| <b>UNIT II</b> | <b>TRANSMISSION CONGESTION MANAGEMENT</b> | <b>9</b> |
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Importance of congestion management in deregulated environment - Classification of congestion management methods - Calculation of ATC - Non-market methods - Market based methods – Nodal pricing - Inter-zonal Intra-zonal congestion management - Price area congestion management - Capacity alleviation method.

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|-----------------|---------------------------------------------------------------------|----------|
| <b>UNIT III</b> | <b>LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS</b> | <b>9</b> |
|-----------------|---------------------------------------------------------------------|----------|

Fundamentals of locational marginal pricing - Lossless DCOPF model for LMP calculation – Loss compensated DCOPF model for LMP calculation - ACOPF model for LMP calculation - Risk Hedging Functionality Of financial Transmission Rights - FTR issuance process - Treatment of revenue shortfall - Secondary trading of FTRs - Flow Gate rights - FTR and market power



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| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK</b> | <b>9</b> |
| Types of ancillary services -Load-generation balancing related services - Voltage control and reactive power support services - Black start capability service - Mandatory provision of ancillary services -Markets for ancillary services - Co-optimization of energy and reserve services – International comparison. Pricing of transmission network: wheeling - principles of transmission pricing -transmission pricing methods - Marginal transmission pricing paradigm - Composite pricing paradigm -loss allocation methods.                                                                                                                                                                                                                                  |                                                                         |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>MARKET EVOLUTION</b>                                                 | <b>9</b> |
| US markets: PJM market - The Nordic power market - Reforms in Indian power sector: Framework of Indian power sector - Reform initiatives - availability based tariff (ABT) - The Electricity Act 2012 -Open Access issues - Power exchange                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                         |          |
| <b>ACTIVITIES:</b> Case study on restructuring of electricity markets in India, UK, and USA, Comparative study of ancillary service markets in PJM, ERCOT, and India, Seminar on Indian Power Exchanges (IEX/PXIL) and recent market reforms                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                         |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                         |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                         |          |
| CO1: Explain the concepts, objectives, market models, and economic principles of restructured electricity markets.<br>CO2: Analyze transmission congestion management techniques, ATC evaluation, and market-based congestion management methods in deregulated power systems.<br>CO3: Apply locational marginal pricing methods and financial transmission rights for congestion pricing and transmission risk management.<br>CO4: Evaluate ancillary service markets, transmission pricing methods, wheeling charges, and loss allocation techniques for competitive electricity markets.<br>CO5: Assess the evolution of global electricity markets and Indian power sector reforms for improving the efficiency and competitiveness of deregulated power systems. |                                                                         |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                         |          |
| <b>TEXTBOOKS:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                         |          |
| 1.Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, "Operation of Restructured Power Systems", Springer Science & Business Media, Second Edition.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                         |          |
| 2.Steven Stoft, "Power System Economics: Designing Markets for Electricity", Wiley-IEEE Press, First Edition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                         |          |
| 3.Mohammad Shahidehpour, Muwaffaq Alomoush, "Restructured Electrical Power Systems: Operation, Trading and Volatility", CRC Press.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                         |          |
| <b>REFERENCES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                         |          |
| 1. Loi Lei Lai, "Power System Restructuring and Deregulation: Trading, Performance and Information Technology", John Wiley & Sons.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                         |          |
| 2. Leonard L. Grigsby, "Electric Power Generation, Transmission and Distribution", CRC Press.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                         |          |
| 3. Daniel S. Kirschen and Goran Strbac, "Fundamentals of Power System Economics", Wiley.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                         |          |
| 4. Mohammad Shahidehpour and Marwan Alomoush, "Restructured Electrical Power Systems", CRC Press.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                         |          |



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 2    |
| CO5 | 3   | 3   | 3   | 3    | 2    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

|          |                                        |   |   |   |   |
|----------|----------------------------------------|---|---|---|---|
| PS26021  | ELECTRIC VEHICLES AND POWER MANAGEMENT | L | T | P | C |
| SDG:7,13 |                                        | 3 | 0 | 0 | 3 |

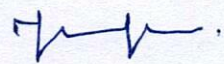
### COURSE OBJECTIVES:

- To understand the evolution, classification, architecture, vehicle dynamics, and driving cycle characteristics of electric vehicles.
- To analyze electric propulsion systems, motor drive technologies, control strategies, and regenerative braking for efficient electric vehicle operation.
- To apply battery technologies, battery management systems, and hybrid energy storage solutions for enhancing electric vehicle performance and reliability.
- To evaluate power electronic converters, charging technologies, bidirectional energy flow, thermal management, and EMI mitigation techniques used in electric vehicles.
- To design intelligent energy management strategies for electric vehicles integrated with smart grids, renewable energy sources, and advanced AI-based optimization techniques.

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| <b>UNIT I</b>                                                                                                                                                                                                                                 | INTRODUCTION TO ELECTRIC VEHICLES             | <b>9</b> |
| EV evolution and classification (BEV, HEV, PHEV, FCEV) - EV configurations and architecture -Vehicle dynamics: tractive effort, energy consumption, gradability - Driving cycles: EPA, NEDC, WLTP, and custom profiles                        |                                               |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                | ELECTRIC PROPULSION AND DRIVE SYSTEMS         | <b>9</b> |
| Types of electric motors used in EVs: PMSM, BLDC, IM, SRM - Motor characteristics and drive selection - Motor control strategies: Field-Oriented Control (FOC), Direct Torque Control (DTC) - Regenerative braking – Torque Vs. Speed Control |                                               |          |
| <b>UNIT III</b>                                                                                                                                                                                                                               | ENERGY STORAGE SYSTEMS AND BATTERY MANAGEMENT | <b>9</b> |
| Battery types: Li-ion, NiMH, Lead-acid – comparison and characteristics - Battery modeling and performance parameters - Battery Management Systems (BMS): SoC, SoH, cell balancing - Supercapacitors and hybrid storage systems               |                                               |          |



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| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>POWER ELECTRONICS AND ENERGY CONVERSION</b>       | <b>9</b> |
| DC-DC converters, inverters, and onboard chargers - Bidirectional power flow and energy recuperation - Charging infrastructure: AC vs DC, wireless charging, V2G systems - Safety, thermal management, and EMI issues                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>POWER MANAGEMENT STRATEGIES AND FUTURE TRENDS</b> | <b>9</b> |
| Power flow optimization and energy scheduling in EVs - Smart energy management using AI and predictive algorithms - Integration with smart grids and renewable sources - Trends in EV policy, standardization, and sustainable mobility                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      |          |
| <b>ACTIVITIES:</b> Quiz on BEV, HEV, PHEV, FCEV features, Group Discussion/Debate: Types of electric motors used in EVs, Group Discussion/Debate: Compare AC charging vs DC fast charging, Technical seminar: Compare Li-ion, NiMH, and Lead-acid batteries based on key parameters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      |          |
| <b>COURSE OUTCOMES:</b><br>CO1: Explain the evolution, architecture, vehicle dynamics, and driving cycles of different types of electric vehicles.<br>CO2: Analyze electric propulsion systems, motor characteristics, control strategies, and regenerative braking techniques for electric vehicles.<br>CO3: Apply battery technologies, battery management systems, and hybrid energy storage techniques to improve electric vehicle performance and reliability.<br>CO4: Evaluate power electronic converters, charging infrastructure, bidirectional power flow, thermal management, and EMI issues in electric vehicle systems.<br>CO5: Design intelligent power management strategies integrating AI, smart grids, renewable energy resources, and vehicle-to-grid (V2G) technologies for sustainable electric mobility |                                                      |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |          |
| <b>TEXTBOOKS:</b><br>1.Iqbal Husain, <i>Electric and Hybrid Vehicles: Design Fundamentals</i> , 3rd Edition, CRC Press, Taylor & Francis, 2021.<br>2.Sheldon S. Williamson (Ed.), <i>Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles</i> , Springer, 2013.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                      |          |
| <b>REFERENCES:</b><br>1. Ali Emadi, Mehrdad Ehsani, John M. Miller, "Advanced Electric Drive Vehicles", , Publisher:CRC Press, Published Year:2014<br>2. C.C. Chan, K.T. Chau, "Modern Electric Vehicle Technology", Publisher: Oxford University Press, Published Year: 2001<br>3. Philip Weicker, "Battery Management Systems for Large Lithium-Ion Battery Packs", Publisher: SAE International, Published Year:2013<br>4. Shuai Jiang, "Power Electronics for Electric Vehicles and Energy Storage Systems", Publisher: Springer, Published Year:2022                                                                                                                                                                                                                                                                     |                                                      |          |

B. 



## CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 2   | 3   | 2    | 2    |
| CO2 | 3   | 1   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 2   | 3   | 3    | 3    |
| AVG | 2.8 | 1.8 | 3   | 2.8  | 2.8  |

Correlation Levels: 1 – Low, 2 – Medium, 3 – High

|            |       |   |   |   |   |
|------------|-------|---|---|---|---|
| PS26022    | FACTS | L | T | P | C |
| SDG:7,9,13 |       | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To understand the fundamentals of FACTS technology, power flow control, voltage regulation, and the role of FACTS controllers in enhancing power system stability.
- To analyze the operating principles, control strategies, and performance characteristics of SVC and STATCOM for reactive power compensation and voltage control.
- To apply series FACTS controllers for power flow control, oscillation damping, and subsynchronous resonance mitigation in transmission systems.
- To evaluate the operation, control, and coordination of UPFC and IPFC for simultaneous control of voltage, impedance, and power flow in transmission networks.
- To design mathematical models and simulation-based solutions for FACTS devices to improve the performance, stability, and reliability of modern transmission systems.

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| <b>UNIT I</b>                                                                                                                                                                                                                                                                   | INTRODUCTION TO FACTS AND POWER FLOW CONTROL  | 9 |
| Overview of power system stability and control needs- Basic types of FACTS controllers: series, shunt, and combined- Benefits and challenges in implementing FACTS devices- Power flow control and voltage regulation using FACTS                                               |                                               |   |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                  | STATIC VAR COMPENSATOR AND STATCOM            | 9 |
| SVC: Configuration, operating principles, and characteristics- STATCOM: V-I characteristics, control strategies, dynamic performance- Comparison between SVC and STATCOM- Reactive power compensation and voltage support.                                                      |                                               |   |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                 | SERIES COMPENSATION USING TCSC AND SSSC       | 9 |
| Thyristor Controlled Series Capacitor (TCSC): operation and control- Sub-Synchronous Resonance (SSR) and mitigation using TCSC- Static Synchronous Series Compensator (SSSC): features and advantages- Power flow control and damping of oscillations using series controllers. |                                               |   |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                  | UNIFIED POWER FLOW CONTROLLER (UPFC) AND IPFC | 9 |
| Basic operation and control of UPFC- Power flow control using UPFC: modeling and simulation- Interline Power Flow Controller (IPFC): structure and advantages- Control interactions and coordination with other devices.                                                        |                                               |   |



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| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>MODELING, SIMULATION, AND APPLICATION OF FACTS</b> | <b>9</b> |
| Mathematical modeling and steady-state analysis of FACTS- Dynamic modeling and simulation using MATLAB/Simulink, PSCAD- Integration of FACTS in transmission networks- Case studies and future trends in FACTS deployment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                       |          |
| <b>ACTIVITIES:</b><br>Modeling of SVC and STATCOM in MATLAB, Comparative analysis of series vs shunt compensation using case study data, Case study analysis of grid stability improvement using FACTS in Indian or global power networks.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                       |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                       |          |
| <b>COURSE OUTCOMES:</b><br>CO1: Explain the concepts, classifications, operating principles, and applications of FACTS controllers for power flow control and voltage regulation.<br>CO2: Analyze the performance, control strategies, and reactive power compensation capabilities of SVC and STATCOM in power systems.<br>CO3: Apply TCSC and SSSC for transmission line compensation, power flow control, oscillation damping, and subsynchronous resonance mitigation.<br>CO4: Evaluate the operation and coordination of UPFC and IPFC for enhancing transmission system flexibility and stability.<br>CO5: Design and simulate FACTS controllers using software tools such as MATLAB/Simulink and PSCAD for improving transmission system performance. |                                                       |          |
| <b>WEIGHTAGE:</b> Continuous Assessment: 40%, End Semester Examinations: 60%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                       |          |
| <b>TEXTBOOKS:</b><br>1. N.G. Hingorani and L. Gyugyi, 'Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems,' , IEEE Press, Wiley, First Edition.<br>2. Prabha Kundur, 'Power System Stability and Control' , , McGraw-Hill Education.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                       |          |
| <b>REFERENCES:</b><br>1.R. Mohan Mathur and Rajiv K. Varma, 'Thyristor-Based FACTS Controllers for Electrical Transmission Systems', Wiley-IEEE Press, 2002. - Practical insight into thyristor-controlled devices.<br>2. K. R. Padiyar, 'FACTS Controllers in Power Transmission and Distribution', New Age International, 2nd Edition, 2017. - Indian perspective with emphasis on control and system integration.<br>3. Song, Yong-Hua, and Allan T. Johns, 'Flexible AC Transmission Systems (FACTS)', IET Power and Energy Series, 1999. - Covers research-based insights and advanced control schemes.<br>4. IEEE/PES Special Publications and Technical Papers on FACTS applications and developments.                                                |                                                       |          |

#### CO's-PO's & PSO's MAPPING

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 2    |
| CO2 | 3   | 2   | 3   | 3    | 3    |
| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.8  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

B. [Signature]

**Chairman**

Board of Studies

M.E. Power Systems Engineering  
Kingston Engineering College  
Vellore - 632 059



|          |                                              |   |   |   |   |
|----------|----------------------------------------------|---|---|---|---|
| PS26023  | APPLICATION OF AI TECHNIQUES TO POWER SYSTEM | L | T | P | C |
| SDG:9,12 |                                              | 3 | 0 | 0 | 3 |

### COURSE OBJECTIVES:

- To provide knowledge of Artificial Intelligence concepts, learning paradigms, and the challenges of modern power systems that motivate AI-based solutions.
- To familiarize students with Artificial Neural Networks, deep learning architectures, learning algorithms, and their applications in forecasting, protection, and power system control.
- To develop the ability to design fuzzy logic-based intelligent systems for handling uncertainty and improving power system control and decision making.
- To enable students to formulate and solve optimization problems in power systems using Genetic Algorithms and evolutionary programming techniques.
- To expose students to advanced AI techniques including reinforcement learning, PSO, differential evolution, IoT integration, and cybersecurity applications in smart grids.

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| <b>UNIT I</b> | <b>INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND POWER SYSTEMS</b> | <b>9</b> |
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Definition of artificial intelligence and its subfields, Expert Systems and Knowledge-Based Systems, Supervised, unsupervised, and reinforcement learning paradigms. Traditional power system architecture and components (generation, transmission, distribution). Challenges and complexities in modern power systems: Grid stability, reliability, efficiency, and integrating renewables.

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| <b>UNIT II</b> | <b>ARTIFICIAL NEURAL NETWORKS</b> | <b>9</b> |
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Biological neuron function and its emulation in artificial neurons, Basic terminology and characteristics of ANNs. Single-layer and multi-layer feed-forward networks, Back propagation learning algorithm, Radial Basis Function Network, Hopfield Network, Recurrent Neural Networks (RNNs) and their variants (LSTMs, GRUs), Convolutional Neural Networks (CNNs). Gradient Descent and its variants (Momentum, Adam), Vanishing/exploding gradient problem, over fitting, L2 regularization, dropout, Transfer learning. Applications in Power System: Load forecasting (short-term, long-term), Fault detection and diagnosis, Stability analysis and control, Renewable energy forecasting (solar, wind), Power system protection.

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| <b>UNIT III</b> | <b>FUZZY LOGIC AND FUZZY SYSTEMS</b> | <b>9</b> |
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Introduction to classical set theory and its limitations in dealing with imprecision, Fuzzy sets: Membership functions and fuzzy set operations. Mamdani and Sugeno fuzzy inference models, Fuzzy rule-based systems and defuzzification methods. Applications in power systems: Reactive power and voltage control, Load frequency control, Fault diagnosis.

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|----------------|--------------------------------------------------------|----------|
| <b>UNIT IV</b> | <b>GENETIC ALGORITHMS AND EVOLUTIONARY PROGRAMMING</b> | <b>9</b> |
|----------------|--------------------------------------------------------|----------|

Natural selection, population, fitness function, reproduction operators, Genetic operators: Crossover (single, two-point, multi-point, uniform, matrix), inversion, deletion, mutation. Applications in power systems: Optimal power flow, Economic load dispatch, Generation and transmission expansion planning, Optimal placement of FACTS devices and capacitor banks, Hydro-thermal plant coordination.

|               |                                           |          |
|---------------|-------------------------------------------|----------|
| <b>UNIT V</b> | <b>MACHINE LEARNING AND AI TECHNIQUES</b> | <b>9</b> |
|---------------|-------------------------------------------|----------|

Deep reinforcement learning for stochastic control and optimal decision making, Convolutional Neural Networks for image analysis (e.g., fault detection in visual data). Particle Swarm Optimization (PSO), Differential evolution. Data acquisition: Sensors, smart meters, SCADA systems, Data cleaning, normalization, feature selection, dimensionality reduction. Smart grid management with AI and IoT, Cyber security and data privacy in AI-enabled smart grids.

13. 

**Chairman**  
**Board of Studies**



**ACTIVITIES:** Development of fuzzy logic controllers for voltage regulation, ANN-based load forecasting using MATLAB, Seminar, Quiz, Model making, Project development, Poster presentation of Research, Education, and Training for the AI.

**TOTAL:45 PERIODS**

**COURSE OUTCOMES:**

- CO1: Explain the principles of Artificial Intelligence, machine learning paradigms, and the role of AI in addressing challenges of modern power systems.
- CO2: Apply Artificial Neural Networks and deep learning models for forecasting, fault diagnosis, stability assessment, renewable energy prediction, and protection of power systems.
- CO3: Develop fuzzy logic-based intelligent controllers for power system applications including voltage regulation, reactive power control, load frequency control, and fault diagnosis.
- CO4: Analyze and optimize power system planning and operation problems using Genetic Algorithms and evolutionary programming techniques.
- CO5: Evaluate advanced AI and machine learning techniques integrated with IoT, optimization algorithms, and cybersecurity for smart grid management and intelligent power system operation.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. Kevin Warwick, Arthur Ekwue, Rag Aggarwal, "Artificial Intelligence Techniques in Power Systems", Institution of Engineering and Technology, 1997.
2. Frede Blaabjerg, Weihao Hu, Gouzhou Zhang, Zhenyuan Zhang, Sayed Abulanwar, "AI for Power Electronics and Renewable Energy Systems (Energy Engineering)", Institution of Engineering and Technology, 2024.
3. Juan Miguel Lujano Rojas, Rodolfo Dufo Lopez, Jose Antonio Dominguez Navarro, "Genetic Optimization Techniques for Sizing and Management of Modern Power Systems", Elsevier, 2022.

**REFERENCES:**

1. Fangxing Li, Yan Du, "Deep Learning for Power System Applications: Case Studies Linking Artificial Intelligence and Power Systems (Power Electronics and Power Systems), Springer International Publishing AG; 1st ed. 2024.
2. P. Sanjeevikumar, Sivaraman Palanisamy, Sharmeeela Chenniappan, "Artificial Intelligence-based Smart Power Systems", Wiley-IEEE Press; 1st edition, 2022.
3. Nagendra Singh (Editor), Sitendra Tamrakar (Editor), Arvind Mewada (Editor), Sanjeev Kumar Gupta, "Artificial Intelligence Techniques in Power Systems Operations and Analysis (Advances in Computational Collective Intelligence)", Auerbach Publications, 2023.

**CO's-PO's & PSO's MAPPING**

| COs | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 3   | 2    | 1    |
| CO2 | 3   | 2   | 3   | 3    | 2    |
| CO3 | 3   | 2   | 3   | 3    | 2    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.2  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                       |   |   |   |          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|---|---|---|----------|
| PS26024                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | CYBERSECURITY OF SMART GRIDS                          | L | T | P | C        |
| SDG: 9,16                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                       | 3 | 0 | 0 | 3        |
| <b>COURSE OBJECTIVES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                       |   |   |   |          |
| <ul style="list-style-type: none"><li>To introduce the architecture of smart grids, communication technologies, cyber-physical systems, and fundamental cybersecurity concepts including threats, vulnerabilities, and attack surfaces.</li><li>To familiarize students with international cybersecurity standards, regulatory compliance, data governance, cybersecurity policies, and risk management frameworks for smart grid infrastructure.</li><li>To develop knowledge of data preprocessing, machine learning techniques, and data analytics methods for cyber threat detection, anomaly identification, and secure monitoring of smart grid operations.</li><li>To enable students to analyze cyberattacks on smart grids and implement intrusion detection, secure state estimation, attack mitigation, and defense mechanisms for resilient power system operation.</li><li>To expose students to emerging cybersecurity technologies including blockchain, federated learning, edge AI, digital twins, quantum-safe cryptography, and resilient security solutions for future smart grids.</li></ul> |                                                       |   |   |   |          |
| <b>UNIT I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | FOUNDATIONS OF SMART GRIDS AND CYBERSECURITY          |   |   |   | <b>9</b> |
| Introduction to Smart Grids: Architecture, Components, and Functions-Communication Technologies and Protocols (SCADA, PMU, AMI, IoT)-Cybersecurity Challenges in Smart Grids-Key Concepts in Cybersecurity: Confidentiality, Integrity, Availability (CIA)-Security Threat Landscape: Vulnerabilities, Threat Vectors, and Attack Surfaces-Smart Grid Cyber-Physical Architecture.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                       |   |   |   |          |
| <b>UNIT II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | CYBERSECURITY STANDARDS AND FRAMEWORKS                |   |   |   | <b>9</b> |
| Overview of Smart Grid Cybersecurity Standards: ISO/IEC 27001, IEC 62351, NIST IR 7628, NERC-CIP - Legal and Regulatory Compliance (GDPR, Indian IT Act, etc.) - Data Privacy and Governance in Smart Grid Infrastructure - Risk Management and Cybersecurity Policies for Utilities - Role of CERTs, Cybersecurity Frameworks (NIST-CSF).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                       |   |   |   |          |
| <b>UNIT III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | DATA ANALYTICS FOR CYBER THREAT DETECTION             |   |   |   | <b>9</b> |
| Importance of Data in Smart Grid Security Monitoring - Data Preprocessing and Cleaning Techniques - Machine Learning for Threat Detection: Classification (SVM, Random Forest), Clustering (K-Means, DBSCAN) - PMU and AMI Data Analytics - Topology and Fault Detection - Anomaly Detection and Root Cause Analysis.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                       |   |   |   |          |
| <b>UNIT IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ATTACK DETECTION AND MITIGATION IN SMART GRIDS        |   |   |   | <b>9</b> |
| Types of Attacks: False Data Injection (FDI), Denial of Service (DoS), Load Forecasting Attacks, Replay Attacks - Bayesian and Deterministic State Estimation under Attack - Intrusion Detection Systems (IDS) for Smart Grid - Attack Resilience Mechanisms - Secure State Estimation and Event Localization - Defense-in-Depth Strategy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                       |   |   |   |          |
| <b>UNIT V</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | EMERGING TRENDS AND RESILIENCE IN SMART GRID SECURITY |   |   |   | <b>9</b> |
| Blockchain for Smart Grid Transactions and Authentication - Federated Learning and Edge AI for Cybersecurity - Quantum-Safe Cryptography in Smart Grids - Digital Twins and Cyber Resilience Modeling - Cybersecurity in Distributed Energy Resources (DERs) and Microgrids - Future Challenges and Research Directions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                       |   |   |   |          |
| <b>ACTIVITIES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                       |   |   |   |          |
| Case study analysis – Analyze recent cyberattacks on smart grids, Build an ML-based anomaly detection model using MATLAB, Group Seminar or Poster Presentation – On emerging technologies like Blockchain/Quantum Cryptography in smart grids.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                       |   |   |   |          |
| <b>TOTAL:45 PERIODS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                       |   |   |   |          |
| <b>COURSE OUTCOMES:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                       |   |   |   |          |
| CO1: Explain the architecture of smart grids, communication technologies, cyber-physical systems, cybersecurity principles, and threat landscapes associated with modern power systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                       |   |   |   |          |



CO2: Apply cybersecurity standards, regulatory frameworks, governance policies, and risk management techniques to secure smart grid infrastructure.

CO3: Analyze smart grid data using machine learning and data analytics techniques for cyber threat detection, anomaly identification, and fault diagnosis.

CO4: Evaluate cyberattack scenarios and develop effective intrusion detection, secure state estimation, attack mitigation, and resilient defense strategies for smart grids.

CO5: Design secure and resilient smart grid solutions by integrating blockchain, federated learning, edge AI, digital twins, quantum-safe cryptography, and cybersecurity technologies.

**WEIGHTAGE:** Continuous Assessment: 40%, End Semester Examinations: 60%

**TEXTBOOKS:**

1. Gilbert N. Sorebo and Michael C. Echols, Smart Grid Security: An End-to-End View of Security in the New Electrical Grid, CRC Press, First Edition, 2012.

2. Siddhartha Kumar Khaitan and James D. McCalley, Cyber Security and Resilience for Smart Grids, Wiley-IEEE Press, First Edition, 2021.

**REFERENCES:**

1. S. Sridhar, A. Hahn, and M. Govindarasu, Cyber-Physical System Security for Smart Grid, Springer, 2016.[ISBN: 9783319449294]

2. NIST IR 7628 Rev. 1: Guidelines for Smart Grid Cybersecurity (2014)

3. K. Liyanage, J. Wu, E. W. Gunawardena, Smart Grid Technology and Data Analytics, Wiley-IEEE Press, 2022.[ISBN: 9781119885036]

4. Y. Mo, T. H.-J. Kim, K. Brancik, et al., "Cyber-Physical Security of a Smart Grid Infrastructure," Proceedings of the IEEE, Vol. 100, 2012.

5. A. Gupta, A. Singhal, Smart Grid Cybersecurity: Security and Privacy Issues, CRC Press, 2020.[ISBN: 9780367334951]

6. Zita Vale, Tiago Pinto, "Intelligent data mining and analysis in power and energy systems", IEEE Press, John Wiley and Sons, first edition, 2023.

7. Ali Tajar, Samir M. Perlaza, H. Vincent Poor, "Advanced data analytics for power systems", Cambridge University Press, 2021.

**CO's-PO's & PSO's MAPPING**

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| CO3 | 3   | 2   | 3   | 3    | 3    |
| CO4 | 3   | 2   | 3   | 3    | 3    |
| CO5 | 3   | 3   | 3   | 3    | 3    |
| AVG | 2.8 | 2   | 3   | 2.8  | 2.4  |

**Correlation Levels:** 1 – Low, 2 – Medium, 3 – High

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