**SYLLABUS**

**FOR**

**TWO-YEAR M. TECH. PROGRAMME**

**IN**

**POWER SYSTEM ENGINEERING**



|  |
| --- |
| **NAAC – A Grade** |

**DEPARTMENT OF ELECTRICAL ENGINEERING**

**COLLEGE OF ENGINEERING & TECHNOLOGY**

**(An Autonomous and Constituent College of BPUT, Odisha)**

**Techno Campus, Mahalaxmi Vihar, Ghatikia,**

**Bhubaneswar-751029, Odisha, INDIA**

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**COURSE: M. Tech. (EE – Power Systems Engineering), Duration: 2 years (Four Semesters)**

**Abbreviations Used: U= UG, I= Integrated, P= PG**

**PC= Professional Core PE= Professional Elective OE= Open Elective**

**LC= Lab Course MC= Mandatory Course AC= Audit Course**

**L= Lectures P= Practical/Laboratory IA\*= Internal Assessment**

**T= Tutorial PA= Practical Assessment EA=End-Semester Assessment**

**\*Internal Assessment Max. Mark (30 marks) consists of Mid Semester (20 marks) and Quiz+Assignment (10 marks)**

**Subject Code Format:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Prog (U/I/P)** | **Type (PC/PE/OE/LC/MC/AC)** | **Department (CE/EE/IE/ME/…)** | **Semester (1/2/…/0)** | **Serial No. (1/2/3/…/99)** |

**1st SEMESTER**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject** **Type** | **Subject Code** | **Subject****Name** | **Teaching Hours** | **Credit** | **Maximum Marks** |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Core 1 | PPCEE101 | Power System Analysis | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 2 | PPCEE102 | Power System Dynamics & Control | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 1(Any One) | PPEEE101 | Power System Transients | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE102 | Power Electronics Converters |
| 4 | Professional Elective 2(Any One) | PPEEE105 | FACTS & Custom Power Devices | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE106 | Advanced Control Systems |
| 5 | Mandatory  | PMCMH101 | Research Methodology & IPR | 2 | 0 | 0 | 2 | 30 | 70 | - | 100 |
| 6 | Lab 1 | PLCEE101 | Power System Simulation Lab  | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 2 | PLCEE102 | Power Electronics Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| **Total** | **14** | **0** | **8** | **18** | **150** | **350** | **200** | **700** |
| 8 | Audit 1 | Any one subject from Appendix-I | 100 |
| **Grand Total** | **800** |

**2nd SEMESTER**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject** **Type** | **Subject Code** | **Subject****Name** | **Teaching Hours** | **Credit** | **Maximum Marks** |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Core 3 | PPCEE201 | Power System Protection | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 4 | PPCEE202 | Power Quality | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 3(Any One) | PPEEE201 | Electric Power Systems Market | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE202 | AI & Machine Learning |
| 4 | Professional Elective 4(Any One) | PPEEE205 | Distribution Systems Engineering | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE206 | Smart Grid Technology |
| PPEEE207 | Electrical Energy Sources |
| 5 | Practical 1 | PPREE201 | Mini Project with Seminar | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 6 | Lab 3 | PLCEE201 | Power Systems Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 4 | PLCEE202 | Renewable Systems Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| **Total** | **12** | **0** | **12** | **18** | **120** | **280** | **300** | **700** |
| 8 | Audit 2 | Any one subject from Appendix-II | 100 |
| **Grand Total** | **800** |

**3rd SEMESTER**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Type** | **Subject Code** | **Subject****Name** | **Teaching Hours** | **Credit** | **Maximum Marks** |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Professional Elective 5(Any One) | PPEEE301 | Grid Integration of Renewable Sources | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE302 | Reliability of Power Systems |
| PPEEE303 | Modelling and Simulation |
| 2 | Open Elective  | Any one subject from Appendix-III | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Project 1 | PPREE301 | Phase-I Dissertation | 0 | 0 | 20 | 10 | - | - | 100 | 100 |
| **Total** | **6** | **0** | **20** | **16** | **60** | **140** | **100** | **300** |

**4th SEMESTER**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Type** | **Subject Code** | **Subject****Name** | **Teaching Hours** | **Credit** | **Maximum Marks** |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Project 2 | PPREE401 | Phase-II Dissertation | 0 | 0 | 32 | 16 | - | - | 100 | 100 |
| **Total** | **0** | **0** | **32** | **16** | **-** | **-** | **100** | **100** |

**Abstract of Credit and Marks Distribution**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl. No.** | **Semester** | **Maximum Credits** | **Maximum Marks** |
| 1 | 1st Semester | 18 | 800 |
| 2 | 2nd Semester | 18 | 800 |
| 3 | 3rd Semester | 16 | 300 |
| 4 | 4th Semester | 16 | 100 |
| **Total** | **68** | **2000** |

**NB:**

* **Any one of the Courses in Appendix-I is to be Decided by the Concerned Department for Audit-1 (1st Sem)**
* **Any one of the Courses in Appendix-II is to be Decided by the Concerned Department for Audit-2 (2nd Sem)**
* **Any one of the Courses in Appendix-III is to be Decided by the Concerned Department for Open Elective (3rd Sem)**

**Semester-1**

**Core 1: Power System Analysis (PPCEE101)**

**COURSE OBJECTIVES:**

Students will be able to:

1. To impart knowledge on formation of suitable mathematical model of a given power system network for short circuit studies and load flow analysis.
2. To impart knowledge on system contingencies and behavior of system to ensure security for the system operation
3. To impart knowledge on formation of suitable mathematical model for obtaining optimal performance during planning and operational conditions.

**Module 1:**

**Load flow:** Overview of Newton-Raphson, Gauss-Siedel, Fast Decoupled methods, convergence properties, sparsity techniques, handling Q-max violations in constant matrix, inclusion in frequency effects, AVR in load flow, handling of discrete variable in load flow.

**Fault Analysis:** Simultaneous faults, open conductor faults, generalized method of fault analysis.

**Security Analysis:** Security state diagram, contingency analysis, generator shift distribution factors, line outage distribution factor, multiple line outages, overload index ranking

**Module 2:**

**Optimal Power Flow:** Power flow analysis, Optimal power flow, Solution of OPF by Gradient method, Newton’s method, LP method, Security constrained OPF, Continuation power flow, Sparse matrix techniques for large scale system problems.

**Optimal System Operation:** Generation allocation problem formulation, Loss Coefficients, Optimal load flow solution, Hydrothermal Coordination, constraints in Unit- commitment, Unit commitment solution methods.

**Module 3:**

**State Estimation:** Sources of errors in measurement, Virtual and Pseudo, Measurement, Observability, Tracking state estimation, WLS method, bad data correction.

**Suggested Books:**

1. J.J. Grainger &W.D. Stevenson, “Power system analysis”, McGraw Hill ,2003
2. A. R. Bergen & Vijay Vittal, “Power System Analysis”, Pearson, 2000
3. L.P. Singh, “Advanced Power System Analysis and Dynamics”, New Age International, 2006
4. G.L. Kusic, “Computer aided power system analysis”, Prentice Hall India, 1986
5. A.J. Wood, “Power generation, operation and control”, John Wiley, 1994
6. P.M. Anderson, “Faulted power system analysis”, IEEE Press, 1995

**COURSE OUTCOMES:**

At the end of the course, students will be able to:

1. gain knowledge on formation of suitable mathematical model of a given power system

 network for short circuit studies and load flow analysis.

1. gain knowledge on system contingencies and behavior of system to ensure security for

 the system operation.

1. gain knowledge on formation of suitable mathematical model for obtaining optimal

 performance during planning and operational conditions.

**Core 2: Power System Dynamics & Control (PPCEE102)**

**COURSE OBJECTIVES:**

1. To impart knowledge on formation of suitable mathematical model of a given power system stability and Automatic Generation Control of single and multi-area systems.
2. To impart knowledge on large signal and small signal stability aspects.
3. To impart knowledge on voltage stability issues and methods for finding various stability indicators.

**Syllabus:**

**Module 1:**

**Power System Stability Problems:** Basic concepts and definitions, rotor angle stability, synchronous machine characteristics, power versus angle relationship, modeling of synchronous machines and various loads (composite load model), modeling of excitation systems, turbine and governor systems

**Generation Control Loops:**Automatic Voltage Regulator (AVR) loop, Performance and response of AVR, Automatic Generation Control (AGC) of single and multi-area systems, Static and dynamic response of AGC loops.

**Small Signal Stability:** State space concepts, basic linearization techniques, participation factors, eigen properties of state matrix, small signal stability of a single machine infinite bus system, hoft-bifurcation, electromechanical oscillatory modes

**Module 2:**

**Large Perturbation Stability:** Transient stability: time domain simulation and direct stability analysis techniques (extended equal area criterion), energy function methods: physical and mathematical aspects of the problem, Lyapunov’s method, modeling issues, energy function formulation, potential energy boundary surface (PEBS), energy function formulation of a single machine infinite bus system, equal area criterion and energy function, Transient stability analysis of multi machine systems.

**Low Frequency Oscillations:** Power system model for low frequency oscillation study, Eigen value analysis, Improvement of system damping characteristics, Power system stabilizer (PSS) model, Turbine-generator torsional characteristics, shaft system model, torsional natural frequencies and mode shapes, torsional interaction with power system controls; Sub Synchronous Resonance (SSR) and remedial measures.

**Module 3:**

**Voltage Stability Analysis:**Real and reactive power flow in long transmission lines, Effect of On Load Tap Changing (OLTC) transformers and load characteristics on voltage stability, Voltage stability assessment by P-V curves, Voltage stability limit, Static and dynamic modelling of power systems. Voltage Collapse Proximity Indicators (VCPI), Voltage stability enhancement techniques.

**Suggested Books:**

1. P. Kundur, “Power system stability and control”, McGraw Hill, NY, 1994
2. P.Sauer and M.Pai, “Power System Dynamics an Stability”, Prentice Hall, 1998.
3. A.J. Wood,B.F.Wollenberg “Power generation, operation and control”, John Wiley, 1994
4. K.R.Padiyar, “Power System Dynamics, stability and control”, Interline Publishing, Bangalore, India, 1999
5. M.A.Pai, D.P.Sengupta, K.R.Padiyar, “Small signal analysis of power systems”, Narosa Series in Power and Energy Systems, 2004
6. C.VanCustem, T.Vournas, “Voltage stability of electric power systems”, Riever Academic Press (UK), 1999
7. I.J.Nagrath, D.P.Kothari, “Power system engineering”, Tata McGraw Hill Publishing Co, NewDelhi, India, 1994

**COURSE OUTCOMES:**

At the end of the course, students will be able to

1. gain knowledge on formation of suitable mathematical model of a given power system

stability and Automatic Generation Control of single and multi-area systems.

1. gain knowledge on large signal and small signal stability aspects.
2. gain knowledge on voltage stability issues and methods for finding various stability

indicators.

**PE 1: Power System Transients (PPEEE101)**

**COURSE OBJECTIVES:**

1. To learn the reasons for occurrence of transients in a power system
2. To understand the change in parameters like voltage & frequency during transients
3. To know about the lightning phenomenon and its effect on power system

**Syllabus:**

**Module 1:**

Fundamental circuit analysis of electrical transients, Laplace Transform method of solving simple Switching transients, Damping circuits -Abnormal switching transients, Three-phase circuits and transients, Computation of power system transients.

**Module 2:**

Lightning, switching and temporary over voltages, Lightning, Physical phenomena of lightning, Interaction between lightning and power system, Influence of tower footing resistance and Earth Resistance Switching: Short line or kilometric fault, energizing transients - closing and re-closing of lines, line dropping, load rejection – over voltages induced by faults

**Module 3:**

Travelling waves on transmission line, Circuits with distributed Parameters Wave Equation, Reflection, Refraction, Behaviour of Travelling waves at the line terminations, Lattice Diagrams – Attenuation and Distortion, Multi-conductor system and Velocity wave

Insulation co-ordination: Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS) Co-ordination between insulation and protection level, Statistical approach

Protective devices, Protection of system against over voltages, lightning arresters, substation earthing

**Suggested Books:**

Allan Greenwood, “Electrical Transients in Power System”, Wiley & Sons Inc. New York, 1991

Lou Van der Sluis, “Transients in power Systems”, John Wiley & Sons Ltd, 2001

**COURSE OUTCOMES:**

At the end of the course, students will be able to:

1. Analyze various transients that could occur in power system and their mathematical formulation
2. design various protective devices in power system for protecting equipment and personnel
3. know about coordinating the insulation of various equipments in power system
4. Model the power system for transient analysis

**PE 1: Power Electronic Converters (PPEEE102)**

**COURSE OBJECTIVES:**

1. Understand the operation of different Phase controlled rectifier topologies.
2. Understand the concepts and basic operation of SPWM inverters.
3. Understand different switch mode topologies of DC-DC converters.

**Module I:**

**Power devices:** Switching characteristics and gate driver of Power BJT, IGBT and Power MOSFET

**Phase controlled rectifiers**– Single phase half wave and full wave controlled rectifier with R, R-L and R-L-E Loads. Single phase half controlled bridge rectifier-Input line current harmonics and power factor-Inverter mode of operation of full converter.

Three phase half wave controlled rectifier with R, R-L an R-L-E loads. Three phase semi and full converters with RL and RLE loads. Input side current harmonics and power factor. Dual Converters-Circulating current mode and Non circulating current mode operation

**Module-II**

**Switch-mode dc-ac inverters**. Basic concepts, Sine PWM in single phase full bridge voltage source inverters, Unipolar and Bipolar switching, DC side current, Ripple in the inverter output, Spectral content in the output.

Three phase SPWM inverters, Voltage control and harmonic minimization in inverters, Effect of blanking time on inverter output voltage, DC side current, Ripple in the inverter output, Spectral content in the output.

**Module III**

**DC-DC Converters:** Buck, Boost, Buck-Boost and Cuk SMPS Topologies. Basic Operation- Waveforms - modes of operation – Output voltage ripple, linear power supplies

Push-Pull and Forward Converter Topologies - Basic Operation. Waveforms - Voltage Mode Control. Flyback Converter Topology- discontinuous mode operation-waveforms .and Control - Continuous Mode Operation-Waveforms and control

**AC voltage regulators**- Types of ac voltage regulators-single phase full wave ac voltage controllers. Three phase ac voltage regulators.3-Phase cycloconverter

**COURSE OUTCOMES:**

At the end of the course, students will be able to

1. Understand and Analyze Power Electronic Converters.
2. Design the switching scheme of SPWM inverters.
3. Acquire the knowledge of controlling DC-DC converters.

**Suggested Books:**

* + - 1. Ned Mohan et. al: Power Electronics, John Wiley and Sons
			2. B K Bose: Modern Power Electronics and AC Drives, Pearson Edn (Asia)
			3. M.H Rashid: Power Electronics, Pearson

**References:**

* + - 1. G K Dubey et. al: Thyristorised Power Controllers, Wiley Eastern Ltd.
			2. P C Sen: Power Electronics, TMH

**PE 2: FACTS and Custom Power Devices (PPEEE105)**

**COURSE OBJECTIVES:**

1. To impart knowledge on flexible AC transmission system criteria, advantages, and control parameters.
2. To impart knowledge on various compensation techniques for control of FACTs devices.
3. To impart knowledge on various practices being followed in the real system scenario.

**Syllabus:**

**Module 1:**

**Flexible AC Transmission System:** Transmission inter connections, flow of power in ac systems, loading capability, dynamic stability considerations, basic types of FACTS controllers.

**Module 2:**

**Static Shunt and Series Compensators:** Objectives of shunt compensation, Static VAR compensators (SVCs), STATCOM configuration, Characteristics and control, Comparison between STATCOM and SVC.Objectives of series compensation, Variable Impedance type series compensators, switching converter type series compensators, external control for series reactive compensators.

**Module 3:**

**Power Flow Control Techniques:** Principle of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the series compensators and phase angle regulators, Principle of operation, characteristics and control aspects of IPFC.

**Custom Power Devices:** Introduction to custom power devices, DSTATCOM and DVR operating principles, Applications of DSTATCOM and DVRs in Distribution Systems.

**Suggested Books:**

1. Hingorani ,L.Gyugyi, ‘ Concepts and Technology of Flexible AC transmission system’, IEEE Press New York, 2000.
2. K.R.Padiyar, “FACTS controllers in power transmission and distribution”, New Age International Publishers, Delhi, 2007.

**COURSE OUTCOMES (CO’S)**

At the end of the course, the students will be able to

1. gain knowledge on flexible AC transmission system criteria, advantages, and control parameters.
2. gain knowledge on various compensation techniques for control of FACTs devices.
3. gain knowledge on various practices being followed in the real system scenario.

**PE 2: Advanced Control Systems (PPEEE106)**

**Objectives of the course**

|  |  |
| --- | --- |
| OB1 | To provide a concept on Advanced Control system analysis and design techniques using state variable method for Continuous-Time and Discrete-Time Systems |
| OB2 | To analyse the behaviour of nonlinear control and adaptive control systems |

***Module 1 Discrete-Time Systems***

State Space Representations of Discrete Time Systems, Solution of Discrete Time State Equations, Discretization of Continuous Time State Equations, Digital PID Controller Controllability, Observability, Pole Placement by State feedback, Deadbeat response

***Module 2: Optimal Control***

***(Continuous-Time and Discrete-Time Systems)***

Performance Indices, Quadratic Optimal Regulator / Control Problems, Formulation of Algebraic Riccati Equation (ARE) for continuous and discrete time systems. Solution of Quadratic Optimal Control Problem using Lagrange Multiplies for continuous and discrete-time Systems, Evaluation of the minimum performance Index, Optimal Observer, The Linear Quadratic Gaussian (LQG) Problem, Pole Placement by State feedback using Optimal feedback Gain for Quadratic Regulator and LQG problem, Introduction to H∞ Control.

***Module 3: Nonlinear and Adaptive Control***

Stability: Basic concepts, Stability definitions and theorems, Lyapunov functions for LTI systems, Fractional Differentiation and its application

Model Reference Adaptive Control (using MIT Rule and Lyapunov Theory), Recursive Least Square Estimation, stochastic Self-Tuning Control (Minimum Variance and Pole-placement Control), Sliding Mode Control, Sliding mode control algorithms

**Text Books**

1. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 3rd Edition, 2009
2. J. J. E. Slotine and W. Li, Applied Nonlinear Control, Prentice Hall, 1991.
3. D. S. Naidu, Optimal Control Systems, CRC Press, 2002.
4. K.J. Astrom and B. Wittenmark, Adaptive Control, Pearson, 2006.
5. R. T. Stefani, B. Shahian, C.J. Savant, G.H. Hostetter, Design of Feedback Control Systems, OUP, 2002.

**Reference Books**

1. K. Ogata, Modern Control Engineering, Prentice-Hall of India, 5th Edition, 2010
2. K. Ogata, Discrete-Time Control System, 2nd edition (2001), Pearson Education Publication
3. H.K. Khallil, Non Linear Systems, 3rd edition (2002), Pearson Education
4. B. Friedland, *Control System Design - An Introduction to State-Space Methods*, McGraw-Hill, 2007
5. S.H. Zak, Systems and Control, Oxford Univ. Press, 2003

**COURSE OUTCOMES.**

On successful completion, students will have the ability to

**CO 1:** Analyse the stability of discrete system and nonlinear system

**CO 2:** Design compensators using classical techniques and Optimal Control Law

**CO 3:** Analyse both linear and nonlinear system using state space methods

**CO 4:** Understand the concept and implementation of Adaptive Control

**MAPPING OF CO’S WITH PO’S**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** | **PO-6** | **PO-7** | **PO-8** |
| **CO-1** | High | High | High | Medium | High | Medium | Medium | Low |
| **CO-2** | High | High | High | Medium | High | Medium | Medium | Low |
| **CO-3** | High | High | High | Medium | High | Medium | High | Low |
| **CO-4** | High | High | High | Medium | High | Medium | High | Low |

**MC: Research Methodology & IPR (PMCMH101)**

**Module I:**

Introduction to RM: Meaning and significance of research. Importance of scientific research in decision making. Types of research and research process. Identification of research problem and formulation of hypothesis. Research Designs.

Types of Data: Primary data Secondary data, Design of questionnaire; Sampling fundamentals ad sample designs, Methods of data collection, Measurements and Scaling Techniques, Validity & Reliability Test.

**Module II:**

Data Processing and Data Analysis-I, Data editing, Coding, Classification and Tabulation, Descriptive and Inferential Analysis, Hypothesis Testing- Parametric Test (z test, t test, F test) and non-parametric test (Chi square Test, sign test, Run test, Krushall-wallis test).

**Module III:**

Data Analysis II: Multivariate Analysis- Factor Analysis, Multiple Regression Analysis. Discriminant Analysis, Use of Statistical Packages.

**Reference Books:**

1. Research Methodology, Chawla and Sondhi, Vikas

2. Research Methodology, Paneerselvam, PHI

**Course Outcomes:**

**CO1:** Understood the Meaning of research problem, Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

**CO2:** Got the knowledge of How to get new ideas (Criticizing a paper) through the Literature Survey (i.e. Gap Analysis).

**CO3:** Understood the Filing patent applications- processes, Patent Search, Various tools of IPR, Copyright, Trademarks.

**CO4:** Understood How to apply for Research grants and Significance of Report Writing, Steps in Report Writing, Mechanics and Precautions of Report Writing, Layout of Research Report.

**CO5:** Got the knowledge of How to write scientific paper & Research Proposal - Structure of a conference and journal paper, how (and How Not) to write a Good Systems Paper:

**Lab 1: Power System Simulation Lab (PLCEE101)**

**COURSE OBJECTIVES**: Students will be able to:

1. Understand and Simulate different types of faults
2. Study and simulate different traditional load flow methods in power system.
3. Understand novel methods of load flow studies and market analysis.
4. Simulate and observe different security analysis studies.

|  |  |  |
| --- | --- | --- |
| Sl.No | Experiments | Hours |
| 1 | Simulation of Fault Studies with and without fault and neutral impedance(LG/LLG/LLL). | 3×2 |
| 2 | Simulation of Load Flow Studies (GS/NRLF/FDLF/Participation factor based load flow) | 3×2 |
| 3 | Simulation of State Estimation Studies. | 3×1 |
| 4 | Simulation of Continuation power flow | 3×1 |
|  5  |  Simulation for overload security Analysis  | 3×1 |
|  6 | Simulation for voltage security Analysis | 3×1 |
|  7 | Simulation of power system market clearing/ economic dispatch/ OPF | 3×2 |

(All these would be exercised based on MATLAB programs with some IEEE system data. A student would be asked to do exercises by changing the input data of the given system and observing what is the output. The student will also have to analyze as to why this output is being observed)

**COURSE OUTCOMES:**

Students will be able to:

1. Analyze and calculate the different fault currents in different types of fault and comment on the difference in different network conditions.
2. Evaluate the voltage phasors in different load flow solution and comparing the speediness of operation and accuracy as compared to other methods.
3. Rank various contingencies according to their severity by the use of security analysis.
4. Estimate the voltage phasors according to the given network measurements.
5. Estimate the pricing of electric commodities according to market situations

**Lab 2: Power Electronics Lab (PLCEE102)**

**COURSE OBJECTIVES:**

Students should be able to

1. Understand the working of Controlled rectifiers, Choppers and AC Regulators
2. Understand multi quadrant operation of a Dual Converter.
3. Understand the different PWM schemes of inverters.

|  |  |  |
| --- | --- | --- |
| Sl. No | Experiments | Hours |
| 1 | To Study single-phase (i) fully controlled (ii) Half controlled bridge rectifiers with resistive and inductive loads |  |
| 2 | To Study three-phase (i) fully controlled (ii) Half controlled bridge rectifiers with resistive and inductive loads. |  |
| 3 | To study operation of IGBT/MOSFET based Buck chopper |  |
| 4 | To study operation Dual Converter with resistive and inductive loads. |  |
| 5 | To Study single-phase AC voltage regulator with resistive and inductive loads |  |
| 6 | To Study Three-phase AC voltage regulator with resistive and inductive loads  |  |
| 7 | To Study various pwm based single-phase bridge inverter |  |
| 8 | To Study pwm based three-phase bridge inverter  |  |
| 9 | Calculation of input power factor and displacement factor for single phase rectifier circuit |  |
|  | Development of firing angle table for +ve, -veand zero sequence voltage for 3 ph inverter circuits |  |
| 10 | Performance calculation of various rectifier circuit |  |

**COURSE OUTCOMES:**

Students will be able to

1. Understand and Analyze the performance parameters of converters.
2. Analyze Spectral content for Various PWM schemes.
3. Design the firing circuits employed for Power Electronic Converters.

**Audit -1**

**[To be decided by the Department]: Refer Appendix-I**

**Semester-2**

**Core 3: Power System Protection (PPCEE201)**

**COURSE OBJECTIVES:**

Students will be able to:

1. Study of basic power system protection
2. Study of numerical and digital relays
3. Developing mathematical approach towards protection
4. Study of algorithms for numerical protection

**Syllabus:**

**Module 1:**

Power system protection and its attributes, principle of operation of electromechanical relays, over current, differential, distance relaying concepts for power apparatus, reach setting of the relay, Distance relaying and R-X trajectories, Impedance, Reactance, MHO relay characteristic, balanced beam implementation of impedance relay, impact of infeed, arc resistance, power swing, line compensation on distance relay operation, out of step relay, loadability limit, loadability limit, differential and biased differential protection for transformer, Inrush phenomena and 2nd harmonic restraint protection.

**Module 2:**

Evolution of digital relays from electromechanical relays, Performance and operational characteristics of digital protection, Mathematical background to protection algorithms. Basic elements of digital protection, Signal conditioning: transducers, surge protection, analog filtering, analog multiplexers, Conversion subsystem: the sampling theorem, signal aliasing, Error, sample and hold circuits, multiplexers, analog to digital conversion.

**Module 3:**

Digital filtering concepts, the digital relay as a unit consisting of hardware and software, Sinusoidal wave based algorithms, Sample and first derivative (Mann and Morrison) algorithm, Fourier and Walsh based algorithms, Fourier Algorithm: Full cycle window algorithm, fractional cycle, window algorithm, Walsh function based algorithm, Least Squares based algorithms. Interpolation formulae, forward, backward and central difference interpolation, Numerical differentiation, Curve fitting and smoothing,

Finite difference techniques, Differential equation based algorithms, Traveling Wave based Techniques, Digital Differential Protection of Transformers, Digital Line Differential Protection, Recent Advances in Digital Protection of Power Systems, Wide-area protection systems, concept of intelligent and adaptive protection schemes.

**Suggested Books:**

1. A.G. Phadke and J. S. Thorp, “Computer Relaying for Power Systems”, Wiley/Research studies Press, 2009
2. A.T. Johns and S. K. Salman, “Digital Protection of Power Systems”, IEEE Press,1999
3. Gerhard Zeigler, “Numerical Distance Protection”, Siemens Publicis Corporate Publishing, 2006
4. S.R. Bhide “Digital Power System Protection” PHI Learning Pvt.Ltd.2014

**COURSE OUTCOMES:**

At the end of the course, students will be able to:

1. Analyze the working and importance of different types of relays
2. Learn the importance of Digital Relays
3. Apply Mathematical approach towards protection
4. Learn to develop various Protection algorithms

**Core 4: Power Quality (PPCEE202)**

**COURSE OBJECTIVES:**

* To impart knowledge on issues of power quality and factors governing it.
* To impart knowledge on impacts of poor power quality on the system and the consumers.
* To impart knowledge on harmonics (cause, effect and compensating techniques).

**Module 1:**

**Electric Power Quality Phenomena:** Impacts of power quality problems on end users, Power quality standards, power quality monitoring.

**Power Quality Disturbances:** Transients, short duration voltage variations,long duration voltage variations, voltage imbalance, wave-form distortions, voltage fluctuations, power frequency variations, power acceptability curves.

**Module 2:**

**Power Quality Problems in Power Systems:** Poor load power factor, loads containing harmonics, notching in load voltage, dc offset in loads, unbalanced loads, disturbances in supply voltage.

**Transients:** Origin and classification- capacitor switching transient-lighting-load switching-impact on users, Protection and mitigation of transients.

**Module 3:**

**Harmonics:** Harmonic distortion standards, power system quantities under non sinusoidal conditions-harmonic indices-source ofharmonics-system response characteristics-effects of harmonic distortion on power system apparatus –principles for controllingharmonics, reducing harmonic currents in loads, filtering, modifying the system frequency response- Devices for controllingharmonic distortion, inline reactors or chokes, zigzag transformers, passive filters, active filters.

**Power Quality Conditioners:** Shunt and series compensators, Distribution STATCOMS (DSTATCOMS) and Dynamic Voltage Restorers (DVRs), Rectifier supported DVR, DC Capacitor supported DVR, DVR Structure,Voltage Restoration – Series Active Filter – Unified power quality conditioners.

**Suggested Books:**

Ghosh Arindam and Ledwich Gerard, ‘Power quality enhancement using custom power devices’ Springer.

Arrillaga J., Watson N. R. and Chen S., ‘Power System Quality Assessment’ Wiley.

Caramia P, Carpinelli G and Verde P, ‘Power quality indices in liberalized markets’ – Wiley

Angelo Baggini ‘Handbook of Power Quality’ – Wiley.

G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition)

R.C. Duggan, ‘Power Quality’, TMH Publication, 2002

**COURSE OUTCOMES (CO’S)**

At the end of the course, students will be able to:

1. gain knowledge on issues of power quality and factors governing it.
2. gain knowledge on impacts of poor power quality on the system and the consumers.
3. gain knowledge on harmonics (cause, effect and compensating techniques).

**PE 3: Electric Power Systems Market (PPEEE201)**

**COURSE OBJECTIVES:**

Students will be able to:

* Understand the economics related to power system market.
* Understand what is meant by restructuring of the electricity market
* Understand the need behind requirement for deregulation of the electricity market
* Understand the money, power & information flow in a deregulated power system

**Module 1:**

Introduction to power system operation and planning problems - economic dispatch, unit commitment, optimal power flow, security constrained optimization, maintenance scheduling, expansion planning, etc. and associated linkages with time frames, optimization basics and techniques for convex and non-convex optimization problems, fundamentals of restructured system, market architecture

**Module 2:**

Fundamentals of Economics, load elasticity, social welfare maximization, day ahead and real time market clearing, day ahead security constrained unit commitment, locational marginal prices, transmission congestion management, financial transmission rights

Ancillary service management, optimal bidding, Risk assessment, Hedging, Transmission pricing, Tracing of power, standard market design, Distributed generation in restructured markets, loss allocation, expansion planning under restructured environment

**Module 3:**

Market power, US and European market evolution, developments in India, IT applications in restructured markets, Working of restructured power systems, PJM, California, Australia and New Zealand models, recent trends in Restructuring

**Suggested Books:**

1. Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheble, “Power Generation, Operation and Control” 3rd edition, Wiley
2. Daniel S. Kirschen and Goran Strbac, “Fundamentals of Power System Economics” 1st edition, Wiley
3. Lorrin Philipson, H. Lee Willis, “Understanding electric utilities and de-regulation”, Marcel Dekker Pub.,1998.
4. Steven Stoft, “Power system economics: designing markets for electricity”, John Wiley and Sons, 2002.
5. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen, “Operation of restructured power systems”, Kluwer Academic Pub., 2001.
6. Mohammad Shahidehpour, MuwaffaqAlomoush, “Restructured electrical power systems: operation, trading and volatility”, Marcel Dekker.

**Course Outcomes:**

At the end of the course, students will be able to:

1. Describe various types of regulations in power systems.
2. Identify the need of regulation and deregulation.
3. Define and describe the Technical and Non-technical issues in Deregulated Power Industry.
4. Identify and give examples of existing electricity markets.
5. Classify different market mechanisms and summarize the role of various entities in the market.

**PE 3: Artificial Intelligence and Machine Learning (PPEEE202)**

**COURSE OBJECTIVES:**

1. To learn about biological foundations of Intelligent Systems
2. To learn about Artificial Neural Network
3. To learn about Fuzzy Logic
4. To know about GA and other Evolutionary Algorithms

**Module 1**

**Artificial Neural Networks and Deep Learning**

Neural Network representations, appropriate problems for neural network learning

Supervised Learning: Perceptrons, representational power of perceptrons, perceptron training rule, Gradient Descent and Delta rule, Multilayer perceptron and backpropagation algorithm

Linear Regression: Linear regression and prediction of continuous data values, Recurrent Neural Networks, RBFN

Unsupervised Learning: Competitive Learning, K-Means clustering, Hierarchical Clustering

Support Vector machines: Classification of data points using support vectors

**Module 2**

**Fuzzy Inference Systems:**

Basic Concepts of Fuzzy Logic, Fuzzy vs Crisp Set, Linguistic variables, Membership Functions, Operations of Fuzzy Sets, Fuzzy If-Then Rules, Variable Inference Techniques, Defuzzification, Basic Fuzzy Inference Algorithm, Fuzzy Neural Network, System Identification using Fuzzy and Neural Networks

**Module 3:**

**Genetic Algorithm:**

Representing Hypothesis, Genetic operators, Population Evolution, Genetic programming,

Introduction to other evolutionary Algorithms like PSO, BFO etc

**Text Books**

1. Tom M Mitchell, Machine Learning, PHI LEARNING PVT. LTD-NEW DELHI, 2015
2. [Ethem Alpaydin](http://www.amazon.in/s/ref%3Ddp_byline_sr_book_1?ie=UTF8&field-author=ETHEM+ALPAYDIN&search-alias=stripbooks), Introduction to Machine Learning , The MIT Press, 3rd Edition, 2015
3. Simon Haykins, Neural Networks, Prentice Hall
4. Timothy Ross, Fuzzy Logic with Engineering Application- McGraw Hill Publishers

**Reference Books**

1. R. Duda, P. Hart, and D. Stork. "Pattern Classification", 2nd edition, Wiley Interscience, 2001.
2. C. M. Bishop. "Neural Networks for Pattern Recognition", Oxford University Press, 1995.
3. T. Hastie, R. Tibshirani and J. Friedman, "Elements of Statistical Learning: Data Mining, Inference and Prediction". Springer-Verlag, 2001.
4. T. Cover and J. Thomas. "Elements of Information theory", Wiley Interscience, 1991.
5. Golding, “Genetic Algorithms”, Addison Wesley
6. Junhong NIE & Derek Linkers, “Fuzzy Neural Control”, PHI

**COURSE OUTCOME.**

On successful completion, students will have the ability to

1. Apply the concepts of Neural network for pattern recognition andclassification
2. Apply Fuzzy logic principles to take decisions and design controllers
3. Apply GA principles for solving optimization problems

**MAPPING OF CO WITH PO:**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** | **PO-6** | **PO-7** | **PO-8** | **PO-9** | **PO-10** |
| **CO-1** | High | High | Medium | High | High | High | Medium | Low | High | Medium |
| **CO-2** | High | High | High | High | High | High | Medium | Low | High | Medium |
| **CO-3** | High | High | Medium | High | Medium | High | Medium | Low | High | Medium |

**PE 4: Distribution Systems Engineering (PPEEE205)**

COURSE OBJECTIVES

* To provide the general concept of distribution system design planning, operation and control.
* To impact the knowledge of distributed generation definition, technologies and operation.
* To train the students about automation and control of distribution system.
* To train the students to do short-term and long-term power system planning.

**Syllabus:**

**Module 1:**

Distribution system layout: modeling of components, sub-transmission network configurations, load profiles, selection of distribution class transformers, breakers, overhead vs underground cables, aerially bunched cables.

Distribution system power flow analysis and fault studies, Distribution system performance and operation, Distribution automation and control, Voltage drop calculation for distribution networks, Volt/ Var control in distribution systems, DSTATCOMs and DVRs, feeder reconfiguration for loss minimization and service restoration.

**Module 2:**

Distribution system planning: Short term planning, Long term planning, Dynamic planning.

Distributed Generation: Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economic impacts. DG Technologies, DG from renewable and non-renewable energy sources, Optimization with DGs, Microgrids - islanded and grid connected modes, Demand side management.

**Module 3:**

IT applications in distribution systems, smart meters, AMR, AMI, SCADA, State estimation, automation in billing, use of GPRS, consumer indexing, system reliability improvement, use of RMUs, auto reclosures, sectionalizers, islanding detection in microgrids.

Energy accounting and audit.

**Suggested Books**

1. Anthony J. Pansini“Electrical Distribution Engineering”, CRC Press.
2. H Lee Willis, “Distributed Power Generation Planning and Evaluation”, CRC Press.
3. James A Momoh, “Electric Power Distribution Automation Protection And Control” CRC Press
4. James J. Burke “Power distribution engineering: fundamentals and applications”, CRC Press
5. T. Gonen, “Electric Power Distribution System Engineering”, McGraw-Hill, 1986

Course Outcomes

At the end of the course, the students will be able to

1. learn the methodology of short-term and long-term planning of distribution system.
2. perform various calculation related to service area.
3. understand the technology and control of distributed generation.
4. design the primary and secondary distribution system with different load condition.
5. determine the power flow solution of distribution system with voltage control.
6. understand the automation and control of distribution systems.

**PE 4: Smart Grid Technology (PPEEE206)**

**COURSE OBJECTIVES**

* To Study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
* To familiarize with the power quality management issues in Smart Grid.
* To familiarize with the high performance computing for Smart Grid applications

**Syllabus:**

**Module 1:**

Evolution of Electric Power Grid, introduction to smart Grid, Concept, definitions, architecture and functions of Smart Grid. Need of Smart Grid. Difference between conventional & smart grid. Opportunities & Challenges of Smart Grid,

Introduction to Smart Meters, Real Time Pricing, Smart Appliances. Automatic Meter Reading (AMR). Outage Management System (OMS). Home & Building Automation, Substation Automation, Feeder Automation, Smart Sensors, Phase Shifting Transformers, Volt/VAr control, High Efficiency Distribution Transformers

**Module 2:**

Geographic Information System (GIS). Intelligent Electronic Devices (IED) & their application for Monitoring & Protection, Storage systems including Battery, SMES, Pumped Hydro. Compressed Air Energy Storage.

Phasor Measurement Units (PMU), Wide Area Measurement System (WAMS), Wide-Area based Protection and Control

Micro-grid concepts, evolution of microgrid, need and application, Issues of Interconnection. Protection & control systems for micro-grid.

Variable speed wind generators, fuel-cells, micro-turbines. Captive power plants, Integration of renewables and issues involved, Advantages and disadvantages of Distributed Generation.

**Module 4:**

Power Quality & EMC in smart Grid. Power Quality issues of Grid connected Renewable Energy Sources. Power Quality Conditioners for micro-grid. Web based Power Quality monitoring, Power Quality Audit.

Advanced Metering Infrastructure (AMI). Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Energy Management Systems (SCADA).

**COURSE OUTCOMES:**

After successfully completing this course a student will able to:

**CO 1:** Understand the fundamental element of the smart grid

**CO 2:** Explain various communication, networking, and sensing technologies involved in smart grid

**CO 3:** Explain various integration aspects of conventional and non-conventional energy sources.

**CO 4:** Explain distributed generation coordination including monitoring of smart grid using modern communication infrastructure

**CO 5:** Analyze Micro-grid as a hybrid power system with advantages and challenges in future.

**CO 6:** Be able to apply this knowledge in analysis and problem solving of smart grid architectures needs and challenges

**Suggested Books:**

1. Ali Keyhani, “Design of Smart power grid renewable energy systems”, Wiley IEEE,2011.
2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press, 2009.
3. Stuart Borlase, “Smart Grid: Infrastructure, Technology and solutions” CRC Press.
4. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley.
5. Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability: 1”, Artech House Publishers July 2011

**PE 4: Electrical Energy Sources (PPEEE207)**

**COURSE OBJECTIVES:**

* To provide knowledge, understanding and application oriented skills on conventional and non-conventional sources of energy and relevant technologies towards their effective utilization for meeting energy demand.
* To understand the present scenario for energy conservation and utilization of renewable energy sources for both domestic and industrial applications.
* Analyze the environmental aspects of electrical energy resources.

**MODULE I**

**INTRODUCTION:** Energy and development, units and measurement, conventional and non-conventional sources of energy, fossil, non-fossil and renewable energy resources, Importance of electrical energy in modern industrial society, Usefulness, advantages and disadvantages of energy sources and need of alternative energy sources.

**SOLAR ENERGY:** solar radiation, Solar thermal systems: solar collectors, solar active and passive heating and cooling, solar desalination, solar drying, solar cooking; Applications of solar energy.

**MODULE II**

**FOSSIL FUEL AND HYDRO POWER SOURCES**: Production of Electricity using fossil fuels such as coal, oil and natural gas. Its principle of generation, advantages and disadvantages, Production of Electricity from Hydro resources, Classification of hydropower schemes. Its principle of generation, advantages and disadvantages

**BIOMASS:** Sources, energy plantation, production of fuel wood, conversion techniques; Bio-conversion processes, bio-gas, bio-diesel and ethanol production and utilization; Thermo-chemical processes, biomass gasification, process, types of reactors, utilization of producer gas for thermal and electricity generation.

**MODULE III**

**RENEWABLE SOURCES:** Production of Electricity from Renewable and non-conventional sources such as wind energy, solar energy, biomass, waste, ocean thermal, ocean wave, geothermal, Principle of working of various types of fuel cells, performance and limitations.

**IMPACTS OF ELECTRICAL ENERGY RESOURCES**: Impact of Electrical Energy Generation on Environment and control of pollution from Energy and Electrical Energy Storage systems.

**Text books/ References:**

1. J. Twidell and T Weir, “Renewable energy Resources”, Taylor and Francis group 2007.
2. Renewable Energy- Power for a Sustainable Future, Godfrey Boyle, Oxford University Press.
3. B.H. Khan, Non-Conventional Energy Resources, Tata McGraw Hill, 2009.
4. J.A. Duffie and W A Beckman, “Solar Engineering and Thermal Process”, 2nd Edition John Wiley and sons 2001.
5. SP Sukhatme, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill,1984
6. G. N. Tiwari and MK Ghosal, “Renewable Energy Resources Basic principles and Application”, Narosa Publishing House 2005.

**COURSE OUTCOMES:**

At the end of this course, students will be able to

**CO 1:** Know the need of renewable energy resources, historical and latest developments.

**CO 2:** Describe the use of solar energy and various components used in the energy production

 with respect to applications like- heating, cooling, desalination, power generation etc.

**CO 3:** Acquire the knowledge of hydro power, biomass, waste to energy, wind, wave power,

 geothermal and fuel cells principles and applications.

**CO 4:** Describe the environmental aspects of non-conventional energy resources. In comparison

 with various conventional energy systems, their prospects and limitations.

**Mini Project with Seminar (PPREE201)**

**[To be decided by the Department]**

**Lab 3: Power Systems Lab (PLCEE201)**

**Course Objectives**: Students will be able to:

1. Understand the operation and working of different relays
2. Study the parameters and effects associated with transmission line.
3. Study the sequence components.
4. Understand the capacitance measurements associated with underground cables.

|  |  |  |
| --- | --- | --- |
| Sl. No | Experiments |  |
| 1 | To the study operating time vs. current characteristics of IDMT induction relay |  |
| 2 | Analysis of Differential Relay (1-phase) |  |
| 3 | Analysis of Differential Relay (3-phase) |  |
| 4 | Principle of Reverse Power Protection |  |
| 5 | Principle of directional overcurrent Relay |  |
| 6 | ABCD Parameters calculation for transmission line |  |
| 7 | Study of Ferranti Effect in transmission line |  |
| 8 | Sequence component analysis  |  |
| 9 | String efficiency for the lines |  |
| 10 | Capacitance measurement for underground cables  |  |

**Course Outcomes:**

Students will be able to:

1. Analyze the working of different types of relay and comment on the use of the relays in whichever specific purpose in the power system.
2. Evaluate the parameters associated with transmission line and analyze the use of the parameters to judge the efficiency and regulation of the system.
3. Evaluate the value of different sequence components and comment on the difference in the values of different sequence components of a static equipment as compared to a rotating equipment.
4. Evaluate the capacitances associated with underground cables and determinate the capacity of these cables.

**Lab 4: Renewable Systems Laboratory (PLCEE202)**

COURSE OBJECTIVES:
1. To educate students on different sources of energy (conventional, non-conventional, renewable, etc.) and their energy content.
2. To give an exposure of solar energy, wind energy, bio-mass and battery system.
3. To impart knowledge about the types of load and its generated harmonics.
4. To train the students for integration of renewable electrical energy sources to the electrical grid and minimise the harmonics for better power quality.

Lists of Experiments

|  |  |
| --- | --- |
| Sl. No. | Name of the Experiment |
| 1. | Calculate the efficiency of solar PV module of your laboratory. |
| 2. | Calculate the fill factor of a solar PV cell. |
| 3. | Develop the P-V and I-V graphs at different insolations / irradiances. |
| 4. | Develop the P-V and I-V graphs at different insolations/irradiances. |
| 5. | Realise the hot spot effect of your laboratory solar PV module. |
| 6. | Calculate the performance parameter of the solar cooker system of your laboratory. |
| 7. | Study and performance analysis of wind power system under various loads. |
| 8. | Study the supply side and load side power factors of a solar PV system. |
| 9. | Study the harmonics present in grid tied solar PV system. |
| 10. | Develop the power curve of wind turbine at various wind velocities.  |
| 11. | Study of various softwares related to laboratory experiments |
| 12. | Simulation of power flow of a standalone PV system with a DC load and battery |
| 13. | Simulation of power flow of a standalone PV system with a AC load and battery |
| 14. | Develop the energy density of various energy crops and residues. |
| 15. | Calculate the GCV and NCV of a wood specimen. |

COURSE OUTCOMES:

At the end of the course, the student will be able to

1. Gain knowledge of different renewable sources and its energy content.
2. Perform experiments to measure energy content.
3. Develop the characteristics and performance of renewable technologies especially devoted to production of electricity.
4. Design various loads and characterise its better performance.

**Audit-2**

**[To be decided by the Department]: Refer Appendix-II**

**Semester-3**

**PE 5: Grid Integration of Renewable Sources (PPEEE301)**

**COURSE OBJECTIVES:**

1. The main objective of the course is to provide students with the knowledge of the impacts caused by the integration of distributed renewable generation in the power system.
2. To provide student with the ability to use modern simulation tools to evaluate the performance of electric power systems with high penetration of renewable energy.

**MODULE-I**

Introduction to distributed generation/Micro Grid: General introduction to the concept of distributed generation, Standalone System, Integration of distributed renewable generation into the electricity system (Current status, challenges and prospects) and its impacts on the electrical system.

Network topologies with distributed generation: Description of the different network topologies where distributed renewable generation (Wind, Solar, Hydro, Tidal power) can be connected. Principles of design, operation.

**MODULE-II**

Power system Performance:

Impact of distributed generation on power system in terms of changes taking place and severity imposed, power quality issues, voltage quality issues, design of distributed generation.

Impact of distributed generation on power system in terms of overloading and losses, radial distribution networks, redundancy and meshed operation, losses, increasing the hosting capacity.

**MODULE-III**

Control of standalone system and Grid connected system (Voltage and frequency control). Phase Locked Loop, Islanding and reconnecting. Primary frequency control in large systems, Fault ride through.

Transmission system operation: Fundamental operation, Frequency control, Balancing and Reserves, Prediction of production and consumption, Restoration, Voltage stability, Angular stability.

**Textbooks:**

1. Bollen M.H.J., Hassan F., Integration of distributed generation in the power system. IEEE Press Series on Power Engineering. Wiley. Hoboken 2011.
2. Jenkins N., Allan R., Crossley P., Kirschen D., Strbac G., Embedded generation. IEE Power and Energy Series 31. London, 2000.
3. Jenkins N., Ekanayake J.B., Strbac G., Distributed generation. IET Renewable Energy Series 1. London 2010.
4. Keyhani A., Marwali M.N., Dai M., Integration of green and renewable energy in electric power systems. Wiley. Hoboken 2010.

PE 5: Reliability of Power System (PPEEE302)

Course objective

1. A student will learn different methodologies of techniques for determining the reliability of power system.
2. The student will be able to analyze the impact of operational activities on reliability indices.
3. The students will be able to comprehensively analyze the effect of different technical and nontechnical aspects of reliability of generation, transmission and distribution system.

Syllabus

MODULE-I

*Generating Capacity Basic Probability Methods:* The generation system model, Loss of load indices, Equivalent forced outage rate, Capacity expansion analysis, scheduled outages, Evaluation methods on period basis, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices.

*Generating Capacity Frequency & Duration Method:* The generation model, System risk indices.

MODULE-II

*Interconnected Systems:* Probability error method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected systems, multi connected system, Frequency & duration approach.

*Operating Reserve:* General concepts, PJM method, Extension to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems.

MODULE-III

*Composite Generation & Transmission Systems:* Radial configurations, Conditional probability approach, Network configurations, State selection, System & load point indices, Application to practical systems, Data requirements for composite system reliability.

*Distribution Systems Basic Techniques & Radial Networks:* Evaluation techniques, Additional interruption indices, Application to radial systems, effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, effect of transferring loads, Probability distributions of reliability indices.

Recommended books

1. Billinton Roy& Allan Ronald *“Reliability of Power system”,* Pitman Pub. 1984
2. Richard Elect. Brown, *“Electric Power Distribution Reliability”,* CRC Press.

Course outcomes

1. Studentslearn basic probabilistic method and frequency and duration method for calculation of reliability of generating capacity.
2. Students are able to evaluate the reliability of interconnected system, operating reserves.
3. Students are able to calculate the reliability of composite generation and transmission system and effect of plant and station availability.
4. Students are able to determine reliability indices of simple radial distribution network and parallel and meshed network with the effect of various operational measures.
5. The students are able to evaluate the reliability of comprehensive power system.
6. The students are able to study the impact of various technical operational activities of power system, socio-political factors, weather and environmental factors, consumer behavior.

**PE 5: Modeling and Simulation (PPEEE303)**

COURSE OBJECTIVEs:

1. To provide a basic understanding of Probability Theory,
2. To provide a basic understanding of applied Linear Algebra and optimization problems, viz., their formulation, analytic and computational tools for their solutions,
3. To learn about applications of Linear Algebra and Probability Theory in modelling and simulation environment

Syllabus:

**Module 1:**

Probability and Random Process: Introduction, The Concept of a Random Variable, Functions of One Random Variable, Two Random Variables, Sequence of Random Variables, Statistics, Markov Chains

**Module 2:**

Linear Algebra: The geometry of linear equations, Elimination with matrices, Matrix operations and inverses, Vector spaces and subspaces, Orthogonality, Linear operators and matrix inverses: The LU factorization, The Cholesky factorization, Unitary matrices and the QR factorization, Projections and subspaces, Least squares approximations

**Module 3:**

Linear Algebra: Eigenvalues and eigenvectors, Linear dependence of eigenvectors, Diagonalization, Computation of eigenvalues and eigenvectors, Singular value decomposition: Matrix structure from the SVD, Pseudo-inverses and the SVD

Convex Optimization: Convex Sets, Convex Functions, Convex Optimization Problems, Unconstrained minimization, Equality Constrained Minimization

**Text Book:**

1. Probability, Random Variables and Stochastic Processes, by Papoulis and Unnikrishnan, Fourth Edition, 2002
2. Introduction to Linear Algebra, by Strang, Gilbert. 5th ed. Wellesley-Cambridge Press, 2016
3. Convex Optimization, by Stephen Boyd and Lieven Vandenberghe, Cambridge University Press, 2004

COURSE OUTCOMES:

1. Convert an Engineering statement problem into a precise mathematical probabilistic Statement
2. To understand matrix manipulations, vector space or subspace and orthogonal complement of a subspace
3. Use of various computational algorithms for unconstrained optimization, including steepest descent, Newton's method, conjugate-direction methods, and direct search methods

**Open Elective**

**[To be decided by the Department]: Refer Appendix-III**

**Project 1: (PPREE301)**

**[To be decided by the Department]: Dissertation (Phase-I)**

**Semester-4**

**Project 2: (PPREE401)**

**[To be decided by the Department]: Dissertation (Phase-II)**