CURRICULUM & SYLLABI

M.Tech. POWER SYSTEMS ENGINEERING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department Electrical Engineering

VISION

To excel in education, research and technological services in electrical engineering in tune with societal aspirations.

MISSION

- Engage in research & development in cutting edge and sustainable technologies.
- Impart quality education to produce globally competent electrical engineers capable of extending technological services.
- Nurture scientific temperament, professional ethics and industrial collaboration.

M.Tech. POWER SYSTEMS ENGINEERING

Program Educational Objectives

PEO-1	Design and develop independently innovative products and services in the field of Electrical Power systems
PEO-2	Adopt and utilize latest technologies and tools in design of products and systems
PEO-3	Communicate effectively to propagate ideas and promote teamwork.
PEO-4	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment.

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4
Impart quality education to produce globally competent electrical engineers capable of extending technological services.	3	3	3	2
Engage in research & development in cutting edge and sustainable technologies.	3	3	2	3
Nurture scientific temperament, professional ethics and industrial collaboration.	3	3	2	2

1 - Slightly 2 - Moderately 3 – Substantially

Program Outcomes

PO-1	Engage in critical thinking and pursue research/ investigations and development to solve practical problems
PO-2	Communicate effectively on complex engineering activities with the engineering community and with society at large, write and present substantial technical reports
PO-3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to Power Systems Engineering
PO-4	Develop attitude for self-learning to deliver and develop eco-friendly and sustainable technologies for Power Systems through innovative and entrepreneurial solutions by maintaining professional ethics
PO-5	Cultivate an attitude of self-learning to cope with everchanging tools and technologies and be productive throughout his / her career.
PO-6	Foster a temperament to manage projects, organizations and entrepreneurial ventures maintaining financial integrity and professional ethics

CURRICULUM

M.Tech. in POWER SYSTEMS ENGINEERING

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE26001	Advanced Computational Methods in Power Systems	3-0-0	3
2	EE26003	Data Science Applications in Power Engineering	3-0-0	3
3	EE26005	Power Electronics Applications to Power Systems	3-0-0	3
4	EEXXXX	Professional Elective - I	3-0-0	3
5	EEXXXX	Professional Elective - II	3-0-0	3
6	EE26007	Power Systems Computation Lab-I	0-1-2	2
7	EE26009	Power Engineering Lab	0-1-2	2
			Total Credits	**19**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE26002	Digital Protection of Power Systems	3-0-0	3
2	EE26004	Power System Stability and Control	3-0-0	3
3	EEXXXX	Professional Elective - III	3-0-0	3
4	EEXXXX	Professional Elective - IV	3-0-0	3
5	EEXXXX	Professional Elective - V	3-0-0	3
6	EE26006	Data Science Applications Lab	0-1-2	2
7	EE26008	Power Systems Computation Lab-II	0-1-2	2
8	EE26096	Minor Project	0-0-0	2
			Total Credits	**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE 26089	Seminar and Technical Writing	0-0-0	2
2	EE26091	Summer internship/ Research Experience	0-0-0	2
3	EE 26093	Comprehensive Viva-Voce	0-0-0	2
4	EE 26097	Dissertation: Part-A	0-0-0	8
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE 26098	Dissertation: Part-B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses

Professional Elective – I		
S.No.	**Code**	**Course Title**
1	EE26021	Economic Operation of Power systems
2	EE36021	Restructured Power systems
3	EE36025	Electric Utility Systems Management
4	EE46001	Linear Control System

Professional Elective – II		
S.No.	**Code**	**Course Title**
1	EE16025	Electric Vehicles
2	EE16027	Power Quality Improvement Techniques
3	EE26023	Design and Testing of HV Apparatus
4	EE36027	Signal Processing Techniques in Power Engineering
5	MA16063	Numerical Optimization Techniques

Professional Elective – III		
S.No.	**Code**	**Course Title**
1	EE16026	Control and Integration of Renewable Energy Sources
2	EE26022	Real Time Control of Power Systems
3	EE26024	Distribution System Planning and Automation
4	EE26026	High Voltage Power Transmission
5	EE26028	Power System Reliability and Planning
6	EE46024	Digital Control Systems

Professional Elective – IV		
S.No.	**Code**	**Course Title**
1	EE16028	High Power Inverters
2	EE16030	Power Converters for Microgrids
3	EE26030	Evolutionary Algorithms Applications in Power Engineering
4	EE36028	Industrial Internet of Things

Professional Elective – V		
S.No.	**Code**	**Course Title**
1	EE26032	Machine Learning Applications in Power Engineering
2	EE26034	Energy Auditing and Management
3	EE26036	Flexible AC Transmission Systems
4	EE26038	Development and Evaluation of Power Projects

The Overall Credit Structure

Credits in Each Semester					
	I Sem	**II Sem**	**III Sem**	**IV Sem**	**Total**
Core courses (PCC)	13	10	0	0	23
Elective courses (PEC)	6	9	0	0	15
Seminar and Technical Writing	0	0	2	0	2
Minor Project	0	2	0	0	2
Summer Internship/ Research Experience	0	0	2	0	2
Comprehensive Viva-Voce	0	0	2	0	2
Dissertation: Part-A	0	0	8	0	8
Dissertation: Part-B	0	0	0	12	12
Total credits (Sem. wise)	**19**	**21**	**14**	**12**	**66**

SYLLABI

M.Tech : POWER SYSTEMS ENGINEERING

1st Semester

EE26001 **3-0-0 (3)**

Advanced Computational Methods in Power Systems

Pre-requisites: None

Course Outcomes:

CO-1	Develop mathematical models for load flow studies for Transmission and Distribution systems and Fault analysis
CO-2	Prepare the input data required for load flow analysis and fault calculations
CO-3	Apply appropriate algorithms for load flow studies
CO-4	Develop power system software /implementation of algorithm for static power system studies

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	1	1	1
CO2	1	2	3	1	1	1
CO3	3	3	3	1	1	2
CO4	3	3	3	1	1	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Network Matrices : Concept of incidence matrix, formation of A and Â matrices, list of other types of incidence matrices and their limitations. Representation of Generator, Transmission lines and Transformers, Primitive and Network matrices, Ybus formation by Inspection method and its algorithm. Merits and Demerits of Ybus and Zbus matrices in Power System Analysis – Areas of application

Introduction to Load Flow Analysis : Y-bus based Power System Static Load Flow Equations. Gauss-Seidel (GS) method, PV-bus treatment, Gauss-Seidel load flow algorithm. Need of Sparsity technique for 'well-grown' power systems, Concept of Sparsity technique, Y-bus formation using Sparsity technique. GS with Sparsity technique, Merits and Demerits of GS method

Newton-Raphson (NR) load flow method: and its algorithm. Merits and Demerits of NR method; Newton's Decoupled, Fast Decoupled equation, algorithm of Fast Decoupled (FDC) method. Merits and Demerits of FDC method; Areas of application of load flow study. AC/DC load flow solutions

Distribution system Load Flow methods: Vector based load flow method, Backward-Forward Sweep method and Current injection method

Load flow studies with Renewable Energy Sources: Solar and Wind Energy Sources. Need of short circuit studies – Assumptions in short circuit studies – Areas of application

Formation of Z-bus: using step-by-step approach (Addition of a branch & Addition of a link). Modification of Zbus elements for changes

Symmetrical Sequence Components: significance of symmetrical components, approximations, formation of primitive z^{abc}, y^{abc}, z^{012} and y^{012} for various types of faults

Formation of Zbus^{012} : by step-by-step algorithm. Derivation of relevant equations for E^{012} for LLLG and LG faults

Learning Resources:

Text Books:

1.Stagg and El–Abiad, Computer Methods in Power System Analysis, Medtech scientific international, 2019

2.M A Pai and Dr. Dheeman Chatterjee, Computer techniques in Power System Analysis, , McGraw hill, 2014.

3.Mariesa L Crow, Computational Methods for Electric Power Systems (Electric Power Engineering Series), Taylor and Francis , 2015

Reference Books:

1.Hadi Sadat , Power System Analysis, McGraw Hill – International Edition – 2019

2.J. Arrilaga and NR Watson, Computer Modeling of Electrical Power Systems, John Wiley and Sons, 2010, 1e

3. Dipu Sarkar, Chandan Kumar Chanda, Abhinandan De ,Computational Techniques for Power Systems Analysis Perfect , BSP Books Pvt. Ltd 2024

Other Suggested Readings:

1.https://archive.nptel.ac.in/courses/117/105/117105140/
2.https://nptel.ac.in/courses/108104051
3.https://nptel.ac.in/courses/101104086

EE26003 **3-0-0 (3)**

Data Science Applications in Power Engineering

Pre-requisites: None

Course Outcomes:

CO-1	Distinguish between Algorithmic based methods and Knowledge based Methods
CO-2	Distinguish between Artificial Neural Networks and Fuzzy Logic
CO-3	Adopt Soft Computing techniques for solving Power System Problems
CO-4	Apply appropriate AI framework for solving Power System Problems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	-	1	-
CO2	3	1	-	-	1	-
CO3	3	1	3	-	1	-
CO4	3	1	3	3	1	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Artificial Neural Networks (ANN) -Introduction to Artificial Neural Networks - Definition and Fundamental concepts -Biological Neural Network – Modeling of a Neuron -Activation functions – initialization of weights - Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – XOR Problem - ADALINE and MADALINE

ANN Paradigms- Multi – layer perceptron using Back propagation Algorithm (BPA) -Self – Organizing Map (SOM) -Learning Vector Quantization (LVQ) - Radial Basis Function Network -Functional link network - Hopfield Network -Bidirectional Associate Memory (BAM)

Deep Learning- Deep Architectures – Convolutional Neural Networks – Convolutional Layer – Pooling Layer – Normalization Layer- Fully Connected Layer – Deep belief Networks

Fuzzy Logic -Introduction – Classical and Fuzzy sets- Properties, Operations and relations-Fuzzy sets – Membership function – Basic Fuzzy set operations -Properties of Fuzzy sets – Fuzzy cartesion Product - Operations on Fuzzy relations – Fuzzy logic – Fuzzy Cardinalities - Fuzzy Logic Controller (FLC): Fuzzy Logic System Components: Fuzzification - Inference Engine - Defuzzification methods

Applications of ANN and Fuzzy Logic- Load flow studies - Economic load dispatch - Load frequency control – Single area system and two area systems - Reactive power control. Fuzzy control applications in wide area control – ANN in hybrid state estimation – ANN applications for power system protection.

Learning Resources:

Text Books:

1.Neural Networks, Fuzzy Systems and Evolutionary Algorithms, Synthesis and Applications by S. Rajasekaran, G. A. Vijayalakshmi Pai, Prentice Hall India Pvt., Limited, 2017.

2. Principles of Soft Computing, 2nd ed, by S. N. Sivanandam, S.N. Deepa , Wiley India Pvt. Limited, 2011.

3. Patrick Bangert, , Machine Learning and Data Science in the Power Generation Industry Best Practices, Tools, and Case Studies, Elsevier, 2021

Reference Books:

1. Charu C. Aggarwal, Neural Networks and Deep Learning: Springer International Publishing AG;. 2018 1/e
2. Fuzzy Set Theory Fuzzy Logic and Their Applications, A. K. Bhargava, S. Chand, 2013.
3. Fuzzy Logic with Engineering Applications, 3rd ed., Thimothy J Ross, Wiley Student Edition, 2016.

Other Suggested Readings:

1.https://onlinecourses.nptel.ac.in/noc21_cs69
2.https://nptel.ac.in/courses/106106179

EE26005 **3-0-0 (3)**

Power Electronics Applications to Power Systems

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the role of power electronics in power systems
CO-2	Understand the grid connected inverters for dynamics and control in conventional and renewable energy applications
CO-3	Understand the need for control of Real and Reactive power flows
CO-4	Acquire knowledge on Custom Power devices.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	1	1
CO2	3	1	3	1	2	1
CO3	3	1	3	1	1	2
CO4	3	1	3	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Power electronic converters- Role of power electronics in power systems, Fundamentals of power converter, Voltage-Fed DC–DC Converters, Buck Boost, Buck-Boost converters, Peak Current Mode Control, Average Current-Mode Control. Control Design Issues in Voltage-Fed DC–DC Converters, Developing Switching and Average Models

Three-Phase Grid-Connected Converters- High-Power Semiconductor Devices, High-Power Devices Operated as Simple Switches, PWM algorithms, Three phase voltage source inverter-Operation, Functions and Performance indices (Total Harmonic Distortion (THD), Harmonic Current Factor (HCF), Current Distortion Factor, DC Bus Capacitor within an AC /DC /AC Power Converter.

Line Compensation -Analysis of Uncompensated AC Line, Compensation by a Series Capacitor Connected at the Mid-point of the Line, Passive Compensation, Various FACTs devices; Power Quality Requirements, types of loads, harmonics, Active and Passive filters, Shunt, series and hybrid filters, Power Quality Conditioners,

Principles of Conventional Reactive-Power Compensators- Concepts of SVC Voltage Control, Static Var Compensator (SVC), SVC Controller, Voltage Regulator Design, Harmonics and Filtering, Protection Aspects. Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator.

Uninterruptible Power Supplies- Power electronics in domestic and industrial loads; Power conditioning units for renewable power generation and distributed generation systems. Power Quality and Introduction to Custom Power devices.

Learning Resources:

Text Books:

1. Teuvo Suntio, Tuomas Messo, and Joonas Puukko , Power electronic converters: dynamics and control in conventional and renewable energy applictions , Wiley-VCH Verlag GmbH & Co. KGaA , Germany, 2018
2. A. Ghosh, G. Ledwich, Power Quality Enhancement Using Custom Power Devices, Springer, 2012.
3. Alok Jain, Power Electronics and Its Applications, Penram International Publishing (India) 2016 3/e

Reference Books:

1. Dorin O. Neacsu, powers witching converters: Medium and High Power, CRC Taylor & Francis Group, LLC 2006.
2.R. Teodorescu, M. Liserre, P. Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, Wiley, 2013.
3. K. R. Padiyar, FACTS Controllers in Power Transmission and Distribution, New Age International (P) Ltd, 2007.
4.N. G. Hingorani, L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, Wiley, 2000.

Other Suggested Readings:

https://archive.nptel.ac.in/courses/108/102/108102145/
https://archive.nptel.ac.in/courses/108/105/108105104/

EE26007 **0-1-2 (2)**

Power Systems Computation Lab - I

Pre-Requisites: none

Course Outcomes:

CO1	Analyze the power system data for load-flow studies
CO2	Apply computational methods for large scale power system studies
CO3	Develop software for power system studies
CO4	Learn different power system analysis techniques

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	-
CO2	3	3	3	-	-	-
CO3	3	3	3	-	3	-
CO4	2	2	3	-	3	-

1 - Slightly; 2 - Moderately; 3-Substantially

List of experiments:

1.Solution of Simultaneous Algebraic equations by Gauss Elimination – Crout's method and Cholesky method

2.Solution of Simultaneous differential equations by Range Kutta–4 and Modified Euler's method

3.Program to read and print out the power system load flow data of 5 BUS – IEEE 14 Bus and IEEE 30 Bus systems

4.Formation of YBUS using two dimensional arrays by inspection method

5.Formation of YBUS using Sparsity Technique

6.Load flow studies by Gauss-Seidel method using two– dimensional arrays – sparsity techniques

7.Newton Raphson method based Load flow studies by using two – dimensional arrays – sparsity techniques

8.Fast Decoupled Load flow method using two – dimensional arrays – sparsity techniques

9.Balanced Distribution system load flow using backward forward method

10. Unbalanced Distribution system load flow using backward forward method

11. Radial Harmonic Load Flow

12. DC Load Flow Analysis

Learning Resources:

Text Books:

1.Stagg and El–Abiad , Computer Methods in Power System Analysis , Medtech scientific international, 2019

2. M A Pai and Dr. Dheeman Chatterjee, Computer techniques in Power System Analysis, , McGraw hill, 2014, 3e

3.C. L. Wadhwa, Electrical Power Systems, New Age International, 2009 6/e

EE26009 **0-1-2 (2)**

Power Engineering Lab

Pre-Requisites: none

Course Outcomes:

CO1	Carryout experiments ensuring the safety of equipment and personnel
CO2	Interpret the experimental results by correlating with practical power systems
CO3	Determine electric stress under uniform and non-uniform electric field conditions
CO4	Analyse the performance of different power converters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	Po5	Po5
CO1	-	2	-	-	3	-
CO2	3	2	2	-	2	-
CO3	3	3	3	-	2	-
CO4	3	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3-Substantially

List of experiments:

1. Reactive Power Control Using Tap Changing Transformer
2. Regulation and efficiency characteristics of Artificial Transmission Line
3. Determination of Sequence Reactance's of Power System Elements (Alternator & 3- Φ Transformer)
4. Analysis of unbalanced voltages using Symmetrical Component Analyzer
5. Short circuit studies using DC Network Analyzer
6. Calibration of sphere gap arrangement for High voltage measurement using 100kV Test Transformer
7. Determination of String efficiency of simulated string of insulators
8. Measurement of Fault current of Power System Elements (Alternator & 3-Φ Transformer) under unsymmetrical fault conditions
9. Grounding grid design for a two layer soil model using software simulation
10. Breakdown studies on different electrode configurations under various voltage profiles
11. Determination of Characteristics of PV Array
12. Harmonic analysis of non-linear loads using Power analyzer and its mitigation using passive filters
13. DC-DC converters (a) Buck converter, (b) Boost converter, and (c) Buck- Boost converter
14. Digital simulation of DSTATCOM/ custom power devices

Learning Resources:

Text Books:

1. C L Wadhwa , Electrical; Power Systems, New Age Publishers, 2009, 6/e

2. Ned Mohan and Siddharth Raju, Power Electronics, A First Course: Simulations and Laboratory Implementations, Wiley, 2022, 2/e

2nd Semester

EE26002 **3-0-0 (3)**

Digital Protection of Power Systems

Pre-requisites: none

Course Outcomes:

CO-1	Recognize the advantages of digital relays over conventional relay
CO-2	Apply the suitable signal processing techniques for protection
CO-3	Understand the adaptive criterion for relay decision making
CO-4	Identify the new developments in protective relaying and applications

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	2	2	1
CO4	3	1	3	2	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview: Static relays Transmission line protection, Transformer protection, Need for digital protection

Introduction to Digital Sub-stations

Digital Relays: Basic elements of a digital relay and their functions, signal conditioning subsystem, conversion subsystem, digital relay subsystem

Signal processing techniques: Sinusoidal based algorithms, Fourier analysis-based algorithms, Least squares based algorithm, Discrete Fourier Transforms, Wavelet Transforms, Kalman Filtering

Protection Schemes: Travelling Wave Protection scheme, Digital Protection of Transformers, Infinite Impulse Response Filters, Finite Impulse Response filters.

Correction of errors introduced by Instrument Transformers: PTs and CTs, detection of unsaturated fragment of wave shape, CT saturation correction procedure.

Decision making in Protective Relays: Deterministic decision making, Statistical Hypothesis testing, Decision making with multiple criterions, Adaptive decision schemes, Adaptive Differential protective scheme.

Applications: Fuzzy Logic and ANN for power system protection, Fault location algorithm, Wide Area Monitoring and Protection

Learning Resources:

Text Books:

1.A.G.Phadke, James S.Thorp , Computer Relaying for Power Systems, John-Wiley and sons, 2009, 2/e.

2. Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski, Digital Signal Processing in Power System Protection and Control, Springer Publication, 2011, 1/e.

3. Paithankar Y.G, Fundamentals of Power System Protection, PHI, 2010, 2/e

Reference Books:

1.Singh, Digital Power System Protection, Prentice-Hall of India Pvt. Limited, 2007, 1/e
2.Orhan Gazi, Understanding Digital Signal Processing, Springer, 2017, 2/e
3. Paithankar Y.G, Fundamentals of Power System Protection, PHI, 2010, 2/e

Other Suggested Readings:

1.https://onlinecourses.nptel.ac.in/noc20_ee73
2. https://archive.nptel.ac.in/courses/117/107/117107148
3.https://onlinecourses.nptel.ac.in/noc22_ee46

EE26004 **3-0-0 (3)**

Power System Stability and Control

Pre-Requisites: None

Course Outcomes:

CO1	Develop mathematical models of power system for dynamic studies
CO2	Analyze the performance of single and multi-machine systems under transient, steady and dynamic conditions
CO3	Design stabilizers, dynamic resistors and SMES for the power system
CO4	Identify the methods to improve dynamic & transient stability of power systems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	2	1
CO2	3	2	3	1	1	1
CO3	3	1	3	3	2	2
CO4	3	1	3	2	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Synchronous Machine Modeling:

Parks transformation of flux linkages – Voltage – Current equations and physical interpretation; dq0 equivalent circuits; Synchronous – transient – sub–transient and operational impedances; time constants – Power and torque field & armature current due to sudden short circuit; phasor diagrams. Higher to lower order state space models of Synchronous machines.

Modelling of Power System components:

Low and high order models; excitation systems; exciter voltage regulator models; Hydraulic and steam turbine models; Low frequency oscillation studies – action of proportional and forced action AVR

Steady State and Dynamic Stability Studies:

Normal conditions – steady state stability criteria of single and multi– machine systems – practical stability criteria; Dynamic stability of SMIB system with the aid of Phillips-Heffron model, design of PSS for SMIB system

Transient Stability Studies:

Stability analysis of multi machine systems – Effect of exciter and governor models – Computer solution and flow charts

Methods to Improve Rotor Angle Stability:

Methods to improve steady state, dynamic and transient stability of power systems. Voltage stability

Learning Resources:

Text Books:

1. Vijay Vittal, James D. McCalley, Paul M. Anderson, A. A. Fouad, Power System Control and Stability, 2019, 3/e

2. P.M. Anderson & A.A. Fouad, Power System Control and Stability, Willey IEEE Press, 2003.
3.Prabha Kundur, Power Systems stability and Control, McGraw – Hill Inc. 2006, Indian edition.

Reference Books:

1.K R Padiyar, Power System Dynamics Stability and Control, BS Publications, Hyderabad, 2008.
2.M. A. Pai and Peter W. Sauer, Power system stability, Pearson Education, 2006.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/106/108106026/

2. https://archive.nptel.ac.in/courses/108/105/108105133/

EE26006 **0-1-2 (2)**

Data Science Applications Lab

Pre-Requisites: None

Course Outcomes:

CO1	Analyse and select artificial intelligence techniques for Power Systems
CO2	Employ fuzzy logic, artificial neural networks and ANFIS for power system problems
CO3	Apply Hybrid Techniques in Power Systems
CO4	Demonstrate load forecasting methods

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	-
CO2	3	3	3	-	3	-
CO3	3	3	3	-	-	-
CO4	3	-	3	-	-	-

1 – Slightly; 2 – Moderately; 3 – Substantially

List of Experiments:

1. Load Flow analysis using Neural Networks
2. State Estimation using Neural Networks
3. Contingency Analysis using Neural Networks
4. Power system Security analysis using Neural Networks
5. Fuzzy Logic based Load Frequency Control – Single area system and Two area system
6. Fuzzy Logic based small signal stability analysis
7. Fuzzy logic-based unit commitment.
8. Study of load frequency control problem of Single Area and Two Area Systems with (i) uncontrolled and (ii) controlled cases using PSCAD/POWER WORLD
9. ANN based short term load forecasting
10. Fuzzy based speed control of DC motors
11. Load forecasting using ANFIS

Learning Resources:

Text Books:

1.M A Pai and Dr. Dheeman Chatterjee, Computer techniques in Power System Analysis, , McGraw hill, 2014, 3e

EE26008 **0-1-2 (2)**

Power Systems Computation Lab -II

Pre-Requisites: None

Course Outcomes:

CO1	Asses the different state estimation techniques
CO2	Evaluate the economic dispatch of coordinated thermal unit
CO3	Analyse the power system under fault conditions
CO4	Implementation of various digital filtering algorithms in power system protection

Course Articulation Matrix :

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	-
CO2	3	3	3	-	-	-
CO3	3	3	3	-	-	-
CO4	3	-	3	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Economic Load Dispatch of (i) Thermal Units and (ii) Thermal Plants using Conventional method.
2. MVAR Compensation studies on normal and heavily loaded power systems using PSCAD/POWERWORLD.
3. Transient Stability Analysis of Power Systems using PSCAD/POWER WORLD.
4. State estimation of power system using DC load flow based WLS-SE.
5. State estimation of power system using NR WLS-SE.
6. Contingency evaluation and analysis of power system using simulation package.
7. Fault studies using Zbus matrix.
8. Simulation of three zone protection of a numerical distance relay
9. Simulation of power flow through HVDC transmission system.
10. Implementation of algorithms based on undistorted sine wave approximation with 2 sample technique and 3-sample technique.
11. Implementation of algorithms based on undistorted sine wave approximation with First and second derivative technique.
12. Implementation of Least Square Error (LSQ) Algorithm
13. Implementation of Fourier algorithms using DFT.

Learning Resources:

Text Books:

1.M A Pai and Dr. Dheeman Chatterjee, Computer techniques in Power System Analysis, , McGraw hill, 2014, 3e

2. Haadi A. Sadat, Power System Analysis, McGraw Hill Co. Ltd., India, 2000.

EE26096 **0-0-0 (2)**

Minor Project

Pre-Requisites: None

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	2	1	3	1
CO-2	2	1	2	1	3	1
CO-3	2	3	2	1	3	1
CO-4	2	3	2	1	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project.

Learning Resources:

1.Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.

2.Research Articles / Reports available on the Internet.

3rd Semester

EE26089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	1	1	2	2
CO-2	2	1	1	1	2	2
CO-3	2	1	3	1	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Learning Resources:

1.Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.

2.Research Articles / Reports available on the Internet.

EE26091 **0-0-0 (2)**

Summer Internship/Research Experience

Pre-Requisites: None

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	1	2	2	3	2
CO-2	1	1	2	2	3	3
CO-3	1	2	2	2	3	2
CO-4	1	3	2	2	3	3

1 – Slightly; 2 – Moderately; 3 – Substantially

Description:

Every student has to undergo either a Summer Internship / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Learning Resources:

1.Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.

2.Research Articles / Reports available on the Internet.

EE26093 **0-0-0 (2)**

Comprehensive Viva-voce

Pre-Requisites: None

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	2	1	1	2	-
CO-2	1	2	1	1	2	-
CO-3	1	3	1	1	2	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

Learning Resources:

1.Reading Material of all the courses.

2.Case Studies/Industrial training reports

3.Minor projects taken up.

EE26097 **0-0-0 (8)**

Dissertation : Part-A

Pre-Requisites: None

Course Outcomes:

CO-1	Identify a topic in advanced areas of Electrical Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1	-	3
CO-2	3	2	3	1	-	3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	10
II	Literature Survey	25
III	Defining the Objectives and Solution Methodology	35
IV	Performance of the Task	30

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review, end semester evaluation, etc.

4th Semester

EE26098 **0-0-0 (12)**

Dissertation : Part-B

Pre-Requisites: Dissertation: Part-A

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code.
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions.
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time.
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	3	2	3
CO-2	2	-	3	3	2	3
CO-3	3	-	3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3	-	-	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	Description	Weightages
IV	Performance of the Task	30
V	Dissertation Preparation	20
VI	Review (Presentation & Understanding)	30
VII	Viva-Voce	10
VIII	Publications /Possibility of publication	10

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	**X**	**X**			
V				**X**	
VI			**X**		
VII				**X**	
VIII					**X**

Refer to the M.Tech. – Regulations for any further information regarding mid-term review, end semester evaluation, template for report preparation and plagiarism guidelines etc.

Professional Electives

EE26021 **3-0-0 (3)**

Economic Operation of Power Systems

Pre-Requisites: none

Course Outcomes (COs):

CO1	Analyse the economic operation of Thermal and Hydro generating units
CO2	Apply conventional optimization techniques for evaluation of Unit Commitment problem
CO3	Evaluate Economic Load dispatch, Unit Commitment and Automatic Generation control problems
CO4	Specify strategies for effective planning of power system

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	2	-
CO2	3	1	3	1	2	-
CO3	3	1	3	1	-	-
CO4	3	1	3	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Economic Operation - Economic dispatch problem and methods of solutions – Economic importance – Characteristics of steam units, Economic dispatch of Thermal Units and methods of solutions – problem considering and neglecting transmission losses, Iterative and non- iterative methods of solutions – economic dispatch using dynamic programming

Unit Commitment – Definition – Constraints in Unit Commitment – Unit Commitment solution methods – Priority – List Methods – Dynamic Programming Solution, Economic dispatch versus Unit Commitment – Constraints in thermal and hydro units

Hydro-thermal co-ordination – Hydroelectric plant models – short term hydro thermal scheduling problem – gradient approach – Hydro units in series – pumped storage hydro plants – hydro- scheduling using Dynamic programming and linear programming

Control of generation – Models of power system elements – Modelling of Load Frequency Control (LFC) of single area system and two area systems - with and without PID controllers – static and dynamic analysis – development of state variable model of single area and two area systems – Implementation of Automatic Generation control (AGC) – AGC features

Optimal Power Flow- Introduction-Solution of OPF –gradient method, Newton's method- Linear Sensitivity analysis -linear programming method- Security Constrained OPF- Interior Point OPF- Bus Incremental Coats

Learning Resources:

Textbooks:

1.Allen J.Wood and Bruce.F.Wollenberg, Power Generation Operation and Control, John Wiley & Sons, New York, 2016, 2e.

2.Elgerd.O.I, Electric Energy System Theory – an Introduction, Tata McGraw Hill, New Delhi, 2013

3.Robert H. Miller, James H. Malinowski, Power System Operation, Tata McGraw Hill, 2009.

Reference Books:

1.J. C. Das , Load Flow Optimization and Optimal Power Flow, CRC press, 2017, 1e.

2.Abhijit Chakrabarti and Suita Halder, Power System Analysis, Operation and Control, PHI, 2010, 3rd Edition

3.Robert H. Miller, James H. Malinowski, Power System Operation, Tata McGraw Hill, 2009.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/104/108104052/
2. https://archive.nptel.ac.in/content/storage2/courses/108104051/

EE36021 **3-0-0 (3)**

Restructured Power System

Pre-Requisites: none

Course Outcomes (COs):

CO-1	Understand the need for restructured power system and economics.
CO-2	Analyze transmission congestion and Estimate loss allocation in Power System
CO-3	Analyze Economic operation of power system in restructured environment
CO-4	Understand the need of ancillary services and Demand response in a restructured power system

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**2**	**1**	**1**	**–**	**3**	**–**
CO2	**3**	**1**	**2**	**1**	**1**	**2**
CO3	**3**	**1**	**3**	**3**	**2**	**3**
CO4	**3**	**2**	**3**	**1**	**2**	**3**

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Restructuring of power industry and Fundamentals of Economics- Introduction, Reasons for restructuring / deregulation of power industry, Fundamentals of Deregulation, Motivation of restructuring the power industries, restructuring process – unbundling & privatization, restructuring models, Components of restructured systems, fundamentals of Economics.

Power Market Reforms- Reforms in Indian power sector, Independent System Operator (ISO): Functions and responsibilities, Smart Grid trading arrangements (Pool, bilateral & multilateral), Open Access Transmission Systems, and Open Access Same Time Information system (OASIS)

Transmission Pricing & Congestion Management- Cost components, Postage Stamp Method, Megawatt Mile Method, Contract Path Method. Classification of congestion management methods, Calculation of ATC-TTC-CBM, Non-market methods, Market based methods, Nodal pricing, Inter-zonal Intra-zonal congestion management, Price area congestion management, Locational Marginal Prices.

Economic Operation in restructured Environment - Economic dispatch problem and methods of solutions, Optimal Power flow (OPF), General OPF formulation, Security constrained OPF, Solution techniques, OPF application in Electricity Market.

Risk Management in Restructured Environment- Energy and Reserve Markets, Market Power, Forward and Future market, Smart grid Optimization with risk constraints-General risk measures, Portfolio selection problem, Financial Transmission Rights.

Ancillary Services Management and Demand Response in Restructured Environment -Reactive power as an ancillary service, Energy Storage System, Power Quality, Reliability analysis, Demand

response, Potential benefits of demand response in smart grid, enabling smart technologies for demand response, Demand response for Electric Vehicles.

Impact of Energy Transition on Power System restructuring – Key drivers in energy transition, role of power market in energy transition, re-organizing power systems for the transition.

Learning Resources:

Text Books:

1.L. L. Lai, Power System Restructuring and Deregulation, John Wiley & Sons Ltd., 2012, 1st Edition.
2.K. Bhattacharya, J. E. Daadler, and Math H.J Bollen, Operation of restructured power systems, Kluwer Academic Pub., 2012, 1st Edition (Reprint).
3.D. Kirschen and G. Strbac, Fundamentals of Power System economics, John Wiley & Sons Ltd,2019, 2nd Edition.

Reference Books:

1.S. Hunt,, Making competition work in electricity, John Wiley & Sons, Inc., 2002, 1st Edition.
2.Ashikur Bhuiya: Power System Deregulation: Loss Sharing in Bilateral Contracts and Generator Profit Maximization, VDM Verlag Publisher, 2008

Other Suggested Readings:

1.https://archive.nptel.ac.in/courses/108/104/108104052/
2.https://archive.nptel.ac.in/courses/108/101/108101005/

EE36025 **3-0-0 (3)**

Electric Utility Systems Management

Pre-Requisites: **none**

Course Outcomes:

CO-1	Describe the different electric utility management structures
CO-2	Analyze the operation of transactional markets
CO-3	Formulate short- and long-term forecasts, life-cycle analyses, as well as planning strategies for electric utility operations
CO-4	Formulate cost-benefit analyses for the adoption of new smart grid systems

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	1	1	2	1
CO-2	3	1	2	1	1	2
CO-3	3	1	3	3	2	3
CO-4	3	2	3	1	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Electric utility management structures - vertical integration and horizontal integration and account for the history behind the implementation of these structures through privatization in key jurisdictions throughout the world, Commercial aspects of traditional and modern power systems, Impact of key smart grid technologies on energy, reserve and carbon (CO2) markets and trading

Operation of transactional markets - Transaction-based operation of electric distribution systems, Transactional markets use in achieving optimal management of the exchange (flow) of energy in power systems in different jurisdictions, Blockchain as a distributed computing approach

Planning strategies for electric utility operations – Distribution planning, Formulate short- and long-term forecasts, life-cycle analyses, planning strategies for electric utility operations, infrastructure expansion & investments, risk assessment and reliability analysis, optimal dispatch schemes for a variety of generation sources

Cost-benefit analyses (CBA) in Smart Grid - CBA for the adoption of new smart grid systems and technologies in traditional electric utility systems, Energy efficiency, Cost-benefit risk analysis. Environmental repercussions and the economic structure. Conflict between energy consumption and pollution. Systems Design and quantitative economic policy with particular references to energy. Potential & Economy of sustainable sources. Econometric in the context of multiple objectives, conflicting goals and decisions under uncertainty

Smart Cities: Components of Smart Cities, integrated approaches to smart city modelling, Smart Home Systems: Home automation systems, building energy, smart appliances, Smart lighting.

Learning Resources:

Text Books :

1.Subramanian Vadari, Electric System Operations: Evolving to the Modern Grid, Second edition, Artech, 2012.

2.J Raja , P Aja, D Vimal Raj , S Rajasekar, Practices in Power System Management in India, Springer Nature, 2018

Reference Books:

1.Rao Konidena, William Poppert, Vivek Bhandari, Modern Electricity Systems: Engineering, Operations, and Policy to address Human and Environmental Needs, Wiley, August 2022.
2.Fereidoon P. Sioshansi, “Smart Grid: Integrating Renewable, Distributed and Efficient Energy”, Academic Press, Elsevier, 2012
3.S. McClellan Jesus A. Jimenez, George Koutitas, “Smart Cities”, Springer International Publishing, 2018
4. Homer M. Rustebakke, Electric Utility Systems and Practices, 4th Edition, 1983

Other Suggested Readings:

https://archive.nptel.ac.in/courses/108/107/108107113/

EE46001 **3-0-0 (3)**

Linear Control System

Pre-Requisites: **None**

Course Outcomes:

CO-1	Model the dynamical systems using the state-space concept.
CO-2	Solve the state space equation and perform the stability analysis
CO-3	Design the control systems using state-space methods.
CO-4	Implement the observer based controller concept and optimal control problem

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	2	1	1
CO-2	2	-	3	2	1	1
CO-3	2	-	3	2	1	1
CO-4	2	-	3	2	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Mathematical modelling of LTI control systems - impulse response model, differential equation model, transfer function model, frequency response model, state space model-Introduction to state and state variables – State space - physical systems - Representation using state space approach- Modelling of electrical systems.

Control system Analysis in state space: State space representations of transfer functions, Solution of state space equation - State transition matrix -Matrix exponential-Controllability and observability.

Control system Design in State space: Pole placement approach to Regulator design-Full order observer- Observer based regulator design.

Stability concept: Stability in the sense of Lyapunov - stability of linear systems – Lyapunov equation-Generation of Lyapunov functions-Krasovskii's method Quadratic optimal control-Lyapunov's approach to quadratic optimal regulator design.

Learning Resources:

Text Books:

1.Katsuhiko Ogata, Modern Control Engineering, Pearson Education India, 2020, 5th Edition.
2.M. Gopal, Modern Control Systems Theory, New Age International Publisher, 2023, 5th Edition.

Reference Books:

1.Panos J. Antsaklis, Anthony N. Michel, A Linear Systems Primer, Birkhauser Boston Inc, 2007, 1st Edition.
2.Roy Choudhary, Modern Control Engineering, Prentice Hall India, 2005, 1st Edition.
3.Brogan W. L, Modern Control Theory, Prentice Hall, 2011, 3rd Edition.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108106150
2.https://nptel.ac.in/courses/101108057

EE16025 **3-0-0 (3)**

Electric Vehicles

Pre-Requisites: None

Course Outcomes (COs):

CO1	Understand the concepts of electric vehicles, hybrid electric vehicles and their impact on environment
CO2	Analyze the drive-train topologies and advanced propulsion techniques
CO3	Analyze hybrid energy storage methodologies
CO4	Select suitable power converter topologies for motor control and hybrid energy storage

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3	3	2
CO2	1	2	2	3	3	2
CO3	1	2	3	3	3	2
CO4	2	2	3	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Conventional vehicle, basics of vehicle performance, History of electric vehicles, social and environmental importance of electric vehicles, impact of modern drive- trains on energy supplies.

Hybrid Electric Vehicles: Micro hybrid vehicles, mild hybrid vehicles, full hybrid vehicles, configuration of hybrid electric Vehicles -Parallel hybrid, series Hybrid, Series-Parallel Hybrid ,Complex Configuration. Power flow diagrams Hybrid electric vehicle configurations for various operating modes. Plug-in Hybrid Vehicles: Operating principle, architectures: series-parallel-series-parallel, challenges related to grid connection. Range-extended Electric Vehicles: Classification and configurations, Fuel Cell Electric Vehicles, Solar electric Vehicles, Electric Bi-cycles and their propulsion systems, Vehicle-to-grid, vehicle-to-home concepts, Electric Hybrid electric vehicles-configurations, Solar powered vehicles.

Electric drive-trains: Basic concept of electric traction, introduction to various electric drive- train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis

Electric propulsion unit: Electric components used in electric vehicles, Configuration and control schemes of DC Motor drives, Induction Motor drives, BLDC motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives.

Energy Storage: Storage requirements for Electric Vehicles, Battery energy storage, Fuel Cell based energy storage, Super Capacitor based energy storage and Super Magnetic Energy storage (SMES),. Power pack management systems, Active and passive Cell balancing techniques. Hybridization of different energy storage devices, Flywheel based energy storage, compressed air storage systems, super magnetic storage systems.

Converters for Hybrid Energy Storage Systems: Converter configurations for hybrid energy systems based on Battery and Ultra Capacitors-cascaded converter, multiple parallel- connected converter, dual-active-bridge converter, multiple-input converter, multiple modes single converter, interleaved converter, switched capacitor converter, coupled inductor based configurations.

Fundamentals of Chargers: Charger classifications and standards, selection of AC charging systems, DC charging systems, Converter topologies for charging, wireless chargers.

Learning Resources:

Text Books:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, Taylor & Francis Group 2015.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2021 Third Edition
3.James D. Halderman, Curt Ward, Electric and Hybrid Electric Vehicles, , Pear Son , First Edition 2023

References:

1. Mehrdad Ehsani, Yimi Gao, Stefano Longo, Kamviz Ebrahimi , Modern Electric, Hybrid Electric and Fuel Cell Vehicles:, , 3rd Edition, Reprint 2023.
2. Aunpam Singh, Electric Vehicles and the end of ICE, New Age, , Second Edition, 2022

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/106/108106170/
2.https://nptel.ac.in/courses/108/102/108102121/

EE16027 **3-0-0 (3)**

Power Quality Improvement Techniques

Pre-Requisites: none

Course Outcomes (COs):

CO1	Identify power quality problems in distribution system
CO2	Evaluate power quality indices in distribution system
CO3	Develop mitigation techniques for compensating devices to improve power quality in distribution systems
CO4	Suggest compensating devices to improve power quality in distribution system

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	1	3	2
CO2	1	2	2	1	3	2
CO3	3	2	2	1	3	2
CO4	3	2	2	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Power Quality: Significance of power quality, Power quality terms: Transients, Long-duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage fluctuation, CBEMA and ITI curves. Devices for Overvoltage Protection: Surge arresters and transient voltage surge suppressors, Isolation transformers and Low-impedance power conditioners.

Waveform Distortion: Introduction, Voltage versus current distortion, Harmonics versus transients, Harmonics indices: Total Harmonics Distortion (THD) and Total Demand distortion (TDD); Harmonic standards; Harmonic analysis; Harmonic phase sequence; Triplen harmonics; Inter harmonics.

Harmonic Sources: Introduction; Harmonics generated from electrical machines such as transformers and rotating machines; Arcing devices; Static power conversion: Phase controlled and uncontrolled rectifiers, AC voltage regulators, Pulse width modulated inverters; Converter fed ac and dc drives;

Effects of Harmonic Distortion: Introduction; Resonances; Effects of harmonics on rotating machines; Effect of harmonics on static power plant; Power assessment with distorted waveforms; Effect of harmonics on measuring instruments; Harmonic interference with ripple control systems; Harmonic interference with power system protection; Effect of harmonics on consumer equipment; Interference with communication systems.

Harmonic Elimination: Introduction; Passive power filters: Design, A Shunt active power filters: Configurations, State of the art, Design and control strategies. Three-phase four-wire shunt active power filters

Voltage Quality: Introduction; Sources of Sags, Swell, Unbalance and Flicker; Voltage quality standards; Effects of sags, Swell, Unbalance and Flicker; Voltage sag magnitude due to fault; Voltage sag magnitude calculation based on influence of cross section of conductor, transformer and fault levels; Critical distance for a voltage sag magnitude; Causes of phase- angle jumps in voltage; Classification of voltage sags, voltage sag transformation due to transformers.

Methods for improving Voltage Quality: Introduction; Dynamic Voltage Restorer (DVR): Operating principle, Configurations, State of the art, Design and control strategies. Three- phase four-wire DVR.

Unified Power Quality Conditioner (UPQC): Introduction; design and control; Three-phase three-wire UPQC and three-phase four-wire UPQC topologies, Multilevel inverters based UPQC topologies, Mitigation of Flicker.

Learning Resources:

Text Books:

1.Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Power Quality: Problems and Mitigation Techniques, Wiley, 2015.

2.Math H. J. Bollen, Understanding power quality problems, Wiley-IEEE Press, 2000, 1st Edition.

3.Mahesh Kumar Mishra, Power Quality in Power Distribution Systems Concepts and Applications, CRC Press, 2023.

Reference Books:

1.Ghosh Arindam, Ledwich Gerard, Power Quality Enhancement Using Custom Power Devices, Springer, 2009.

2.Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes, Instantaneous Power Theory and Applications to Power Conditioning, Wiley-IEEE Press, 2017.

3.Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty, Electrical Power Systems Quality, McGraw Hill, 2012, 3rd Edition.

4.J. Arrillaga, N.R. Watson, Power System Harmonics, Wiley, 2003, 2nd Edition.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/107/108107157/
2.https://nptel.ac.in/courses/108/106/108106025/

EE26023 **3-0-0 (3)**

Design and Testing of High Voltage Apparatus

Pre-Requisites: none

Course Outcomes (COs):

CO1	Estimate electric field intensity of electrode configurations for high voltage equipment
CO2	Design compact and economical insulation structures for high voltage equipment
CO3	Analyse circuits for generation, measurement and testing of High Voltage apparatus
CO4	Diagnose the partial discharge activity in power equipment

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	-	-	-
CO2	3	-	3	-	2	-
CO3	3	-	3	-	-	-
CO4	3	-	3	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Basic arrangements of the insulation systems-factors affecting the performance of dielectric materials-Electric field distribution-utilization factor, field in homogeneous and multi-dielectric isotropic material. insulating materials and applications.

Insulation Design of power apparatus & systems:

Design of outdoor insulators, bundle conductor design, Types of bushings, Bushing design, Bushing applications, Insulation schemes in transformer, design of transformer windings, surge phenomena and short circuit forces in transformer windings-effect of series and shunt capacitance and stress control techniques, design of potential and current transformers, Components of insulated power cable, design features, cable joints and terminations-stress control-grading techniques. Gas Insulated Substations: Advantages, properties of SF6, GIS station components and its ratings, design features, estimation of different types of electrical stresses and effect of very fast transient over voltage (VFTO) on the GIS design.

High Voltage Generation, Measurement and Testing Techniques: Generation & measurement of high direct voltages, alternating voltages and impulse voltages, impulse current measurement of time parameters, test of insulation of power equipment- conditions and principles and methods of equipment Condition monitoring and diagnosis, optical fibre based monitoring of high voltage power equipment.

Insulation co-ordination: Lightening & switching Over voltages, Types of surge arresters- gapped and gapless-electrical characteristics–housing materials-pollution performance-modelling of arrestor-insulation co-ordination & lightening shielding.

Learning Resources:

Text Books:

1. Vasily Ya. Ushakov), Alexey V. Mytnikov, Ikromjon U. Rakhmonov , High-Voltage Equipment of Power Systems: Design, Principles of Operation, Testing, Monitoring and Diagnostics, Springer,2023
2. H.M. Ryan, IEE Power & Energy series, High Voltage Engineering & Testing, 2001, Second Edition
3. E Kuffel, W.S. Zaengl, J. Kuffel, High voltage Engineering Fundamentals, Newnes Publishers, 2011.

Reference Books:

1.Ravindra Arora & Wolfgang Mosch: High voltage Insulation Engineering, New Age International Publishers, 2011.

2.M. S. Naidu, V. Kamaraju, High-Voltage Engineering,TMH 2020, sixth edition

3.M.S. Naidu, Gas Insulated Substations, I.K. International Publishing house pvt. Ltd., 2008.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/104/108104048/

EE36027 **3-0-0 (3)**

Signal Processing Techniques in Power Engineering

Pre-Requisites: none

Course Outcomes (COs):

CO1	Understand the applications of Digital signal filtering techniques in power systems
CO2	Apply estimation techniques to evaluate power system parameters
CO3	Analyse different signal decomposition techniques
CO4	Evaluate the WAMS signal processing

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	–	1	–	2	–
CO2	2	1	2	–	1	–
CO3	2	–	3	3	2	2
CO4	3	2	3	–	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Need for Signal Processing in Basics of power quality issues, Inrush Current in Power Transformers; Over-Excitation of Transformers; Transients in Instrument Transformers; Frequency Variation; Voltage Magnitude Variations; Voltage Frequency Variations, power system protection, Wide area dynamic analysis.

Power Systems and signal processing: Stochastic gradient based algorithms – LMS algorithm, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Mean-squared error behaviour, Convergence analysis, Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms- GRLS, Gauss-Newton and RM.

Basic Digital System, Parametric Notch FIR Filters; Sine and Cosine FIR Filters, Parametric Filters applications in smart grid,Filters and Electrical Parameters Estimation.

Forward and backward linear prediction, prediction error filters, AR lattice and ARMA Lattice – Ladder filters, Kalman filters, Wiener filter, Least Square methods for system modelling & Filter Design. Recursive least squares algorithms, Matrix inversion lemma, Spectrum estimation.

Estimation of autocorrelation. Periodogram, Nonparametric and Parametric methods. Estimation Theory; Least-Squares Estimator; Frequency Estimation; Phasor Estimation; Phasor Estimation in Presence of DC Component; Spectrum Estimation; Windows; Frequency-Domain Windowing; Interpolation in Frequency Domain: Multitoned Signal.

Time-Frequency Signal Decomposition: Short-Time Fourier Transform; Sliding Window DFT; Filter Banks; Pattern Recognition, Feature Extraction on the Power Signal; Signal Detection for Electric Power Systems; Detection Theory.

Applications of Signal Processing Techniques: Concepts of wavelet, s-transform, heartly s-transforms; Hillbert transform; Gabor transform and applications in power fluctuations: load fluctuations, wind farm power fluctuations and smart microgrid, Asset Management.

Learning Resources:

Text Books:

1.S. Palani, Principles of Digital Signal Processing: Springer, 2nd Edition 2023, 2nd Edition
2.P. F. Ribeiro, C. A. Duque, P. Marcio da Silveira and A. S. Cerqueira, Power Systems Signal Processing for Smart Grids, John Wiley and Sons Ltd., 2014, 2nd Edition.
3. J.G.Proakis, M. Salehi, Advanced Digital Signal Processing, McGraw –Hill, 2000

Reference Books:

1.S. Haykin, Adaptive Filter Theory,Prentice Hall, 2001, 2nd Edition.
2.S. K. Mitra, Digital Signal Processing – A computer Based Approach,MGH, 2001, 2nd Edition.

Other Suggested Readings:

1.https://archive.nptel.ac.in/courses/117/105/117105149/
2.https://onlinecourses.nptel.ac.in/noc22_ee62/preview

MA16063 **3-0-0 (3)**

Numerical Optimization Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply concepts of convex sets, convex functions, and optimality conditions
CO-2	Implement one-dimensional optimization methods for searching the optimal solution
CO-3	Classify and execute both direct and indirect unconstrained optimization methods
CO-4	Solve constrained optimization problems using direct methods
CO-5	Utilize indirect methods like the penalty function and augmented Lagrange multiplier methods

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	–	–	–	–
CO-2	2	2	–	3	2	2
CO-3	2	2	2	2	2	2
CO-4	2	–	3	3	2	2
CO-5	–	–	3	2	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Convex Analysis: Convex Sets - Convex Hulls - Closure and Interior of a Set - Weierstrass's Theorem - Separation and Support of Sets - Polyhedral Sets, Extreme Points, and Extreme Directions; Convex Functions - Definitions and Basic Properties - Minima and Maxima of Convex Functions - Generalizations of Convex Functions – Linear Programming - The Fritz John and Karush-Kuhn-Tucker Optimality Conditions.

One-Dimensional Optimization: Introduction - Unimodal Function - Unrestricted Search - Search with Fixed Step Size - Search with Accelerated Step Size - Exhaustive Search - Dichotomous Search - Interval Halving Method - Fibonacci Method - Golden Section Method -Comparison of Elimination Methods.

Unconstrained Optimization: Classification of unconstrained optimization methods - General Approach - Rate of Convergence - Scaling of Design Variables. Direct search methods -Random Search Methods - Grid Search Method - Univariate Method - Pattern Directions - Powell's Method - Simplex Method. Indirect search methods - Gradient of a Function - Steepest Descent (Cauchy) Method - Conjugate Gradient Method – Development of Fletcher-Reeves Method - Newton's Method - Marquardt Method - Quasi-Newton Methods – Davidon, Fletcher, and Powell (DFP) Method – Broyden, Fletcher, Goldfarb, Shanno (BFGS) Method.

Constrained Optimization: Characteristics of a Constrained Problem. Direct methods - Random Search Methods - Sequential Linear Programming - Basic Approach in the Methods of Feasible Directions - Zoutendijk's Method of Feasible Directions -Rosen's Gradient Projection Method - Generalized Reduced Gradient Method - Sequential Quadratic Programming. Indirect search methods - Penalty Function Method - Parametric Constraints - Augmented Lagrange Multiplier Method - Convergence of Constrained Optimization Problems.

Learning Resources:

Text books:

1.G. N. Vanderplaats, Numerical optimization techniques for engineering design with applications, McGraw–Hill, 2005, 3rd Edition (Reprint).
2.S. S. Rao, Engineering optimization: theory and practice, Wiley, 2019, 5th Edition.

Reference Books:

1.K.Deb, Optimization for Engineering Design: Algorithms and Examples, PHI Learning, 2012, 2nd Edition.
2.M. S. Bazaraa, H. D. Sherali, C. M. Shetty, Nonlinear programming: theory and algorithms, Wiley, 2013, 3rd Edition.

EE16026 **3-0-0 (3)**

Control and Integration of Renewable Energy Sources

Pre-Requisites: none

Course Outcomes (COs):

CO1	Understand different renewable energy sources and storage devices
CO2	Model and simulate renewable energy sources
CO3	Analyze and simulate control strategies for grid connected and off-grid systems
CO4	Develop converters to comply with grid standards to obtain grid integration

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Electric grid, Utility ideal features, Supply guarantee, power quality, Stability and cost; Importance & Effects of Renewable Energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns.

Dynamic Energy Conversion Technologies: Introduction, types of conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind based generation technologies.

Static Energy Conversion Technologies: Introduction, types of conventional and nonconventional static generation technologies; Principle of operation and analysis of fuel cell, photovoltaic systems and wind generation technologies; MPPT techniques and its classifications, principle of operation and partial shading effects; Storage Technologies - batteries, fly wheels, super capacitors and ultra-capacitors.

Control Issues and Challenges: Linear and nonlinear controllers, predictive controllers and adaptive controllers, Load frequency and Voltage Control, PLL, Modulation Techniques, Control of Diesel, PV, wind and fuel cell based generators, Dimensioning of filters, Fault-ride through Capabilities.

Integration of Energy Conversion Technologies: Introduction & importance, sizing, Optimized integrated systems, Interfacing requirements, Distributed versus Centralized Control, Grid connected Photovoltaic systems –classifications, operation, merits & demerits; Islanding Operations, stability and protection issues, load sharing, operation & control of hybrid energy systems, Solar Photovoltaic applications. IEEE & IEC standards for renewable energy grid integrations.

Learning Resources:

Text Books:

1.G. Masters, Renewable and Efficient Electric Power Systems, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.

2.A. Mahaboob Subahani, G. R. Kanagachidambaresan, M. Kathiresh, Integration of Renewable Energy Sources with Smart Grid, Willey 2021.

3.Felix A. Farret, M. Godoy Simoes, Integration of Renewable Sources of Energy, Wiley, 2017, 2nd Edition.

Reference Books:

1.Chetan Singh Solanki, Fundamentals, Technologies & Applications, Solar Photovoltaic, PHI Publishers, 2019, 3rd Edition.

2Quing-Chang Zhong, Control of Power Inverters in Renewable Energy and Smart Grid Integration, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 1st Edition.

3.Bin Wu, Yongqiang Lang, Navid Zargari, Power Conversion and Control of Wind Energy Systems, IEEE-John Wiley and Sons Ltd. Publishers, 2011, 1st Edition.

4.S. Chowdhury, S. P. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, IET Power Electronics Series, 2012.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/102/108102145/

2.https://nptel.ac.in/courses/103/103/103103206/

EE26022 **3-0-0 (3)**

Real-Time Control of Power Systems

Pre-Requisites: none

Course Outcomes:

CO1	Understand Real Time operation of Power System
CO2	Develop mathematical models for State Estimation and Contingency analysis
CO3	Understand the significance of Power System security
CO4	Investigate the optimal location of measurement devices

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	-	-
CO2	3	1	3	2	3	-
CO3	3	1	3	1	-	-
CO4	3	1	3	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

State Estimation of Power System:

Introduction to State Estimation (SE) in Power Systems: Weighted Least Square Estimation (WLS-SE). SE of AC networks: Types of measurements, Linear WLS–SE theory, DC Load flow based WLS–SE, Linearized model of WLS–SE of Non–linear AC power systems, typical results of SE on an AC network. Detection and Identification of bad measurements, Network Observability and Pseudo–measurements, optimal meter placement. Incorporation of PMU data in WLS-SE

Security Analysis of Power System:

Concept of security, Security analysis and monitoring, Contingency Analysis for Generator and Line Outages by Fast Decoupled Inverse Lemma based approach, Network Sensitivity factors

Real-Time Control of Power Systems:

Introduction, operating states of a Power System

SCADA functions:

Introduction to SCADA: Grid Operation & Control, advantages of SCADA operation. Lay out of substation, Main Equipment's in Sub Station, Instrument Transformers, and necessary parameters for Grid operation: Analog Points, Status Points, Alarms, Transducers & their connectivity.

Data Acquisition, Monitoring and Event Processing, Control Functions, Time tagged data, Disturbance data collection and analysis, Reports and Calculations

Human – Machine Interface (HMI): Operator's Console, VDU Display, Operator Dialogs, Mimic Diagram Functions

Remote Terminal Unit (RTU), Phase angle Measurement unit (PMU) & Communication Practices

Major Components: RTU Panel, Interface Panel, D20M Main Processor, Analog Card, Status Card, Control Card, Modems. Types of Communications: Power Line Carrier

Communications, Microwave, Optical fibre, VSAT Communications. Types of Network Elements in LAN & WAN. Process of Data Communication

Introduction to SCADA PROTOCOLS and Communication Standards

Evolution of Protocol for Communication, Protocols -Modbus, Distributed Network Protocol (DNP), IEC 870-5 and 60870 series, IEC 61850, Benefits from IEC (International Electro technical Commission) communication Standards

Load Dispatch Centers:

Hierarchy of LDCs, Data Flow, Equipment in LDC: Workstations, FEPS, Routers, Functionalities of Sub LDC-Real time software

Functionalities and operations carried out by Sub LDC, State LDC, Regional LDC and National LDC.

Overview of Computer control of Electrical Power Systems
Evolution of System Control, time scale of system control, online computer control, and Software Elements: State Estimation, Monitoring & Prediction, Generation & Load Control, Security Analysis; Software Coordination & Systems Simulation

Learning Resources:

Text Books:

1.Allen J. Wood, Bruce Wollenberg and Gerald B, Power System Generation, Operation and Control, Sheble, John Wiley and Sons, 2013, 3rd Edition.

2.Mini S. Thomas and John D. McDonald, Power System SCADA and Smart GridsCRC Press, 2015, 1st Edition.

3.Tian Seng Ng, Real Time Power Control Engineering: Systems and Automation Springer, 2016 1st Edition,

Reference Books:

1.John J. Grainger and William D Stevenson Jr,Power System Analysis, McGraw Hill, 2017, ISE.

2.Torsten Cegrell, Prentice ,Power System control – Technology,Hall International series in Systems and control Engineering, Prentice Hall International Ltd., 1986.

Other Suggested Readings:

https://archive.nptel.ac.in/courses/108/105/108105133/

https://nptel.ac.in/courses/108104191

EE26024 **3-0-0 (3)**

Distribution System Planning and Automation

Pre-Requisites: none

Course Outcomes (COs):

CO1	Understand and distinguish characteristics of distribution systems from transmission systems
CO2	To design, analyze and evaluate distribution system design based on forecasted data
CO3	Identify and select appropriate sub–station location
CO4	Design and evaluate a distribution system for a given geographical service area from alternate design alternatives

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	1	1
CO2	3	1	3	2	2	1
CO3	3	1	3	1	1	2
CO4	3	1	3	2	2	3

1 – Slightly 2 - Moderately 3 – Substantially

Syllabus :

Distribution System Planning- Planning and forecasting techniques – Present and future – Role of computers- Load Characteristics- Load forecasting using ANN – Load management – tariffs and metering of energy

Distribution Transformers: Types - Three phase and single phase transformers – connections – causes and types of failures in distribution transformers

Primary distribution systems and Distribution Sub–Stations: Distribution substations –Bus schemes –comparison of switching schemes- Substation location and rating- Types of feeders – voltage levels

Voltage Drop and Power Loss Calculations: Three phase primary lines – Copper loss – Distribution feeder costs – Loss reduction and Voltage improvement in rural networks

Capacitors in Distribution Systems: Effects of series and shunt capacitors – justification for capacitors – Procedure to determine optimum capacitor size and location.

Distribution system management: Integrated sub–station metering system – Revenue improvement – issues in multi–year tariff and availability based tariff.

Distribution System Automation: Reforms in power sector – Methods of improvement – Reconfiguration –Automation – Communication systems – Sensors –Basic architecture of Distribution automation system – software and open architecture – RTU and Data communication – SCADA

requirement and application functions –Communication media for distribution system automation- Communication protocols for Distribution systems – IEC 61850 and IEEE 802.3 standards

Learning Resources:

Text Books:

1.Juan M. Gers, Distribution Systems Analysis and Automation, IET power series, 2020

2.James Northcote-Green, Robert G. Wilson, Control and Automation of Electrical Power Distribution Systems: Taylor & Fransis, 2006

3.A. S. PABLA, Electric Power Distribution, , TMH, 2000

Reference Books:

1.Dr. M.K. Khedkar, Dr. G.M. Dhole,A Textbook of Electric Power Distribution Automation, Laxmi Publications Ltd., 2010

2.Turan Gonen, Electric Power Distribution Engineering, Mc-Graw Hill,2014

Other Suggested Readings:

https://onlinecourses.nptel.ac.in/noc22_ee35

EE26026 **3-0-0 (3)**

High Voltage Power Transmission

Pre-Requisites: none

Course Outcomes:

CO1	Analyze and evaluate electric field and interference characteristics of HV AC system
CO2	Design grounding system for HVAC systems
CO3	Evaluate performance metrics for HVDC converter configuration
CO4	Filter design and Power Flow analysis in HVDC system

Course Articulation Matrix :

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	2	1
CO2	3	2	3	2	2	2
CO3	3	2	3	2	1	2
CO4	3	2	3	1	2	2

1 - Slightly; 2 - Moderately 3-Substantially

Syllabus:

Voltage Gradients of Conductors:

Conductors configuration, Bundled conductors, Electrostatics, Field of Sphere, Field of Line Charges and their use, Charge-Potential Relations for Multi-Conductor, Surface Voltage Gradient on Conductors, Examples.

Corona and Radio interference:

Corona loss formula, Audible noise, its characteristics, limits for audio noise, relation between single phase and 3-phase AN levels, radio interference, limits for radio interference fields, CIGRE formula.

Power System Grounding:

Over Voltage in HV Systems -internal and external reasons, Functional Requirements of Earthing System, Equipment Earthing, Neutral Point Earthing, design of Substation grounding System, analysis of simple grounding systems, Measurement of Resistance and Soil Resistivity of Earthing System.

Analysis of HVDC converters:

Introduction, Modern trends, Pulse number, Choice of converter configuration Simplified analysis of Graetz circuit: without overlap, with overlap, Analysis of two and three valve conduction mode, Converter Bridge characteristics.

Converter and HVDC system control:

Principles of DC link control, Converter control characteristics, System control hierarchy, Firing angle control, Current and Extinction angle control, Starting and stopping of DC link, Power control.

Harmonics & Filters- Introduction, Generation of Harmonics, Types of AC Filters.

Power Flow Analysis in AC/DC Systems - Comparison of AC&DC Transmission, General Modeling of DC links, Solutions of AC- DC power flow.

Learning Resources:

Text Books:

1. Rakesh Das Begamudre , Extra High Voltage AC Transmission Engineering, , New Age International publishers, 2014, Fourth Edition.

2. K.R. Padiyar , HVDC Power Transmission System,: New Age Intl. Co, 2015

3. Dragan Jovcic, Khaled Ahmed, High Voltage Direct Current Transmission: Converters, Systems and DC Grids, Wiley Publishers, 2015

Reference Books:

1. Turan Gonen, Electric Power Transmission System Engineering Analysis and Design, CRC Press, 2014, Third Edition.

2. Md. Abdus Salam, Quazi M. Rahman , Power Systems Grounding, , Springer publishers, 2016.

3. Edward Wilson Kimbark, Direct Current Transmission, Vol-1, John Wiley & Sons, 1971

Other Suggested Readings:

https://archive.nptel.ac.in/courses/108/106/108106160/

EE26028 **3-0-0 (3)**

Power System Reliability and Planning

Pre-Requisites: none

Course Outcomes:

CO1	Understand the importance of maintaining reliability of power system components
CO2	Apply the probabilistic methods for evaluating the reliability of generation and transmission systems
CO3	Assess the different models of system components in reliability studies
CO4	Assess the reliability of single area and multi area systems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	-	-	-
CO2	3	-	3	-	2	-
CO3	3	-	3	-	-	-
CO4	3	-	3	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantial

Syllabus:

Reliability Analysis of Generating units – I

Generation system model – capacity outage probability tables – Recursive relation for capacitive model building – sequential addition method – unit removal – Evaluation of loss of load and energy indices – Examples

Reliability Analysis of Generating units – II

Frequency and Duration methods – Evaluation of equivalent transitional rates of identical and non-identical units – Evaluation of cumulative probability and cumulative frequency of non- identical generating units – 2- level daily load representation - merging generation and load models – Examples

Operating Reserve Evaluation

Basic concepts - risk indices – PJM methods – security function approach – rapid start and hot reserve units – Modelling using STPM approach

Bulk Power System Reliability Evaluation

Basic configuration – conditional probability approach – system and load point reliability indices – weather effects on transmission lines – Weighted average rate and Markov model – Common mode failures

Inter Connected System Reliability Analysis

Probability array method – Two inter connected systems with independent loads – effects of limited and unlimited tie capacity - imperfect tie – Two connected Systems with correlated loads – Expression for cumulative probability and cumulative frequency

Distribution System Reliability Analysis – I (Radial configuration)

Basic Techniques – Radial networks –Evaluation of Basic reliability indices, performance indices – load point and system reliability indices – customer oriented, loss and energy oriented indices – Examples

Distribution system reliability analysis – ii (parallel configuration)

Basic techniques – inclusion of bus bar failures, scheduled maintenance – temporary and transient failures – weather effects – common mode failures –Evaluation of various indices – Examples

Substations and Switching Stations:

Effects of short-circuits - breaker operation – Open and Short-circuit failures – Active and Passive failures – switching after faults – circuit breaker model – preventive maintenance – exponential maintenance times

Learning Resources:

Text Books:

1.Jamdade P G , Jamdade S G , Power System Planning and Reliability, Tech-Neo Publishers, 2020

2.Roy Billinton and Ronald N. Allan, Reliability Evaluation of Power Systems, Plenum press, New York and London, 2020 4/e

3.J. Endrenyi, Reliability Modeling in Electric Power Systems, John Wiley and Sons, 2018, 3/e

Reference Books:

1.T. W. Berrie, Electricity Economics & Planning, Peter Peregrinus Ltd., London 2014

2.R.L. Sullivan,Power System Planning ,Tata McGraw Hill Publishing Company Ltd, 2019

Other Suggested Readings:

https://archive.nptel.ac.in/courses/117/103/117103149/

EE46024 **3-0-0 (3)**

Digital Control Systems

Pre-Requisites: EE4601

Course Outcomes:

CO-1	Model the discrete time (DT) system in state space form
CO-2	Perform the stability analysis for DT dynamical system
CO-3	Design the state feedback control for DT system
CO-4	Formulate and solve the DT optimal control problems

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	2	2	1
CO-2	2	-	3	2	2	1
CO-3	2	-	3	2	2	1
CO-4	2	-	3	2	2	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Continuous and Discrete time system-Digital control systems - Quantizing and quantization error, Sampling theorem.

Z-Transform: Z-transforms of elementary functions, important properties and theorems, Inverse Z-transform, Z-transform method of solving difference equations.

Z-Plane Analysis of Discrete-Time Control Systems: Impulse sampling and data hold, Pulse transfer function, Realization of digital controllers and digital filters, Mapping between s-plane and z-plane, Stability analysis of closed loop systems in z-plane, Transient and steady state analyses.

State Space Analysis of digital control systems: Solution of discrete time state space equations, Discretization of continuous time state space equations, Lyapunov stability analysis for Discrete linear system, Controllability, Observability, Pole Placement and Observer Design.

Discrete Optimal Control Systems: Linear Quadratic Regulator (LQR) Design via pole placement, Steady state quadratic optimal control.

Learning Resources:

Text Books:

1.K. Ogata, Discrete time control systems, Pearson Education India, 2015, 2nd Edition.

2.M. Gopal, Digital Control and State Variable Methods, McGraw Hill Education, 2017, 4th Edition.

Reference Books:

1.C.L. Phillips, H.T. Nagle, A. Chakrabortty, Digital Control System Analysis and Design, Pearson, 2014, 4th Edition.

2.B.C. Kuo, Digital Control Systems, Oxford University Press, 2012, 2nd Edition.

3.C.A. Rabbath, N. Lechevin, Discrete-Time Control System Design with Applications, Springer-Verlag New York Inc, 2014, 1st Edition.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108105186
2.https://nptel.ac.in/courses/108103008

EE16028 **3-0-0 (3)**

High Power Inverters

Pre-Requisites: none

Course Outcomes (COs):

CO1	Analyze the Weighted THD and implement SVM based on instantaneous phase reference voltages
CO2	Implement level-shifted, phase-shifted, hybrid and Space Vector PWM schemes for Cascaded H-Bridge Multilevel Inverters
CO3	Develop PWM schemes to balance the neutral point, eliminate common mode voltage and reduce the switching power loss in diode clamped multilevel inverter
CO4	Develop reduced switch count MLIs and PWM current source inverters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	-	3	2
CO2	3	-	3	-	3	2
CO3	3	-	3	-	3	2
CO4	3	-	3	-	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Review of two-level inverters and their PWM schemes. Effect of dead-time and compensation in two-level inverters. Limitations of two-level inverters and introduction to multilevel inverters. Convectional multilevel inverter typologies.

Diode clamped multilevel inverter (DCMLI): 3, 4 and 5 level DCMLIs, level-shifted PWM, Neutral point voltage balance, SVM and discontinuous SVM, Elimination of common mode voltage, Active Neutral Point Clamped Inverter (ANPCI).

Cascade H-bridge (CHB) multilevel inverter (MLI): Symmetrical and asymmetrical topologies, level-shifted PWM, phase-shifted PWM, hybrid PWM and SVM. Concept of coupling transformer-less grid connected applications, Topologies of modular multilevel inverters (MMI).

Reduced switch count MLIs: Introduction, classification, operation of T-type, multilevel dc link, switched series parallel source and other topologies.

PWM current source inverters: Trapezoidal modulation, selective harmonic elimination and SVM, Load-commutated inverters (LCI).

Learning Resources:

Text Books:

1.Bin Wu, High Power Converters and AC Drives, Wiley-Inter science, 2017, 2nd Edition.

2. Quing Chang, Thomas Harnik, Control of Power Inverters in Renewable Energy and Smart Grid Integration,Wiley, 2020

3.D. Grahame Holmes and Thomas A. Lipo, Pulse Width Modulation for Power Converters: Principles and Practice, IEEE Press, 2003.

References Books:

1.Bin Wu ,Mehdi Narimani, High-Power Converters and AC Drives, IEEE Press Series on Power and Energy Systems, 2017

2.Fang Lin Luo, Hong Ye , Advanced DC/AC Inverters, CRC Press, 2017

Other Suggested Readings:

1.https://archive.nptel.ac.in/courses/108/102/108102157/
2.https://archive.nptel.ac.in/noc/courses/noc20/SEM1/noc20-ee02/

EE16030 **3-0-0 (3)**

Power Converters for Microgrids

Pre-Requisites: none

Course Outcomes (COs):

CO1	Compare types of microgrid architectures and their standards.
CO2	Modeling of power electronic converters in microgrid applications.
CO3	Develop power converters and control techniques for micro grid applications.
CO4	Evaluate dynamics and stability of microgrids.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	2	1
CO2	1	1	3	1	3	2
CO3	1	1	3	1	3	2
CO4	1	1	3	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Micro-Grid: Power system resilience, The concept of micro-grids, Types of micro-grids, Autonomous and non- autonomous grids, Sizing of micro-grids, Microgrid Modeling & Analysis, Micro-grids with multiple DGs. Standards and regulation issues associated with AC & DC microgrids, Comparison between AC and DC Microgrids.

Microgrid Control: Centralized control, Hierarchical principle: Primary, secondary and tertiary control – Distributed control, Protection issues and Communication based techniques.

Modeling of Power Electronic Converters in Microgrid application: Modeling of voltage source PWM rectifier, modeling of voltage source inverter in current controlled mode and voltage controlled mode, modeling of boost DC-DC converter and its control, modeling of isolated bidirectional DC-DC converter and its control.

Microgrid Dynamics: Modeling of AC & DC microgrid and its dynamic studies.

Control of grid connected inverter in AC Microgrid: Basics of Voltage-frequency control and P-Q control in AC microgrid, control of grid-forming inverter, control of grid-feeding inverter, control of grid-supporting power inverter, synchronization of inverters in ac microgrids.

Control of DC-DC converter in DC Microgrid: Voltage control and power control in DC microgrid, control of parallel DC-DC converters in a DC microgrid.

Linear and nonlinear Stability system in AC & DC Microgrid: System models and stability analysis of AC & DC Microgrid, stabilization strategies-impedance and admittance stability criteria, stabilization using nonlinear techniques-feedback linearization and sliding mode control, intelligent control of microgrids-fuzzy logic control and ANN control. Future Perspectives.

Learning Resources:

Text Books:

1.Fusheng Li, Ruisheng Li, Fengquan Zhou, Microgrid Technology and Engineering Application, Elsevier, 2015.

2.Nikos Hatziargyriou, Microgrids Architectures and Control, John Wiley Sons, 2014.

3.Hassan Bevrani, BrunoFrançois, Toshifumi Ise, Microgrid Dynamics and Control, John Wiley Sons, 2017.

Reference Books:

1.Manuela Sechilariu, Fabrice Locment, Urban DC Microgrid: Intelligent Control and Power Flow Optimization, Butterworth-Heinemann, 2016.

2.Gevork B. Gharehpetian, S. Mohammad Mousavi Agah, Distributed Generation Systems: Design, Operation and Grid Integration, Butterworth Heinemann, 2017.

3.S. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, Institution of Engineering and Technology, 2009.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/107/108107143/

EE26030 **3-0-0 (3)**

Evolutionary Algorithms Applications in Power Engineering

Pre-Requisites: none

Course Outcomes (COs):

CO1	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems
CO2	Examine the importance of exploration and exploitation of evolutionary algorithm to attain near global optimal solution
CO3	Distinguish the functioning of various evolutionary algorithms
CO4	Employ various bio-inspired algorithms for Power Engineering applications

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	1	1
CO2	3	1	3	1	1	1
CO3	3	1	3	1	2	1
CO4	3	1	3	3	2	1

1- Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fundamentals of Soft Computing Techniques- Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems

Genetic Algorithm and Particle Swarm Optimization-Genetic algorithms: Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem

Artificial Bee Colony Algorithm And Differential Evolution : Artificial bee colony (ABC) algorithms- binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units. The Motivation for Differential Evolution (DE), Introduction to Parameter Optimization, Single-Point, Derivative-Based Optimization, Local Versus Global Optimization, Differential Mutation, Recombination, Selection, Benchmarking Differential Evolution, DE Versus Other Optimizers, DE on Parallel Processors

Shuffled Frog-Leaping Algorithm and Bat Optimization Algorithm- Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation- Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogs-comparison of memes and genes -memeplex

formation- memeple updation- BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem

Multi Objective Optimization- Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution- min-max method-NSGA-II algorithm and applications – Control of Power Converters.

Learning Resources:

Text Books:

1.Xin-She Yang, Recent Advances in Swarm Intelligence and Evolutionary Computation, Springer International Publishing, Switzerland, 2015, 1e

2.Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, 2001, 1e.

3.Altaf Q. H. Badar, Evolutionary Optimization Algorithms, CRC Press, 2022

Reference Books:

1.James Kennedy and Russel E Eberheart, Swarm Intelligence , The Morgan Kaufmann Series in Evolutionary Computation, 2001

2.N P Padhy, Artificial Intelligence and Intelligent Systems, Oxford University Press, 2005

Other Suggested Readings:

https://archive.nptel.ac.in/courses/112/103/112103301/

EE36028 **3-0-0 (3)**

Industrial Internet of Things

Pre-Requisites: None

Course Outcomes:

CO-1	Understand and evaluate the characteristics of Domestic & Industrial appliances.
CO-2	Understand the behavior of Industrial IoT and their applications
CO-3	Manage smart communication systems with multiple sensors and protocols
CO-4	Design and simulate smart homes and smart cities with IoTs and cloud computing

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	–	1	–	2	–
CO-2	3	1	2	–	1	–
CO-3	3	–	3	3	2	2
CO-4	3	2	3	–	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

IoT Communication Technologies: Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications. Interoperability in IoT.

IoT Control Technologies and Programming: Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems. Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

Domestic & Industrial Appliances: Solid State Lamps: Introduction - Review of Light sources - white light generation techniques-Characterization of LEDs for illumination application. Power LEDs- High brightness LEDs-Electrical and optical properties. LED driver considerations-Power management topologies -color issues of white LEDs- Dimming of LED sources, BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment. Industrial IoT applications- Factories and Assembly Line- Power Plants, Plant Safety and Security (Including AR and VR safety applications)- Oil and chemical Industry- Applications of UAVs in Industries.

IoT Cloud Computation and Applications: Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor- Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring, Role of ML and AI in IoT.

Learning Resources:

Text Books:

1.Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy, Anandarup Mukherjee, CRC press,2021.
2.Kostas Siozios, Dimitrios Anagnostos, Dimitrios Soudris, Elias Kosmatopoulos, IoT for Smart Grids: Design Challenges and Paradigms, Springer publishers, 2019.
3.Vinod Kumar Khanna, Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, CRC press, 2014, 1st Edition.

Reference Books:

1.Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress publishers, 2016.
2.Craig Di Louie, Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications, River publishers, 2006, e-book,2021,1st Edition.
3.Chang-liang Xia, Permanent Magnet Brushless DC Motor Drives and Controls, John Wiley & Sons Singapore Pte. Ltd., 2012, 1st Edition.

Other Suggested Readings:

https://nptel.ac.in/courses/106105166

EE26032 **3-0-0 (3)**

Machine Learning Applications in Power Engineering

Pre-Requisites: none

Course Outcomes:

CO1	Understand basic concepts of Machine Learning Techniques
CO2	Distinguish between supervised learning, unsupervised learning and reinforced learning
CO3	Develop the skills in using machine learning software for solving practical problems
CO4	Apply Machine Learning Algorithms for Electrical Engineering problems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	1	1
CO2	3	1	3	1	1	1
CO3	3	1	3	3	2	1
CO4	3	1	3	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Neural networks- Introduction to Neural Networks, Models of Neuron Network, Architectures – Knowledge representation, Artificial Intelligence and Neural Networks – Learning Process, Error Correction Learning, Multi-layer perceptron using Back Propagation Algorithm (BPA)

Learning Theory- Introduction to Machine Learning: What is Learning – Learning Objectives – Data needed – Bayesian inference and Learning – Bayes theorem – inference – naïve Bayes – Regularization – Bias-Variance Decomposition and Trade-off – Concentration Inequalities – Generalization and Uniform Convergence – VC –dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning

Supervised learning- Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis, Naïve Bayes – Kernal Method: Support Vector Machine (SVM) – Kernal function – Kernal SVM - Gaussian Process – Tree Ensembles: Decision Trees- Random Forests – Boosting and Gradient Boosting

Unsupervised learning (clustering)- K –means Clustering Algorithm – Gaussian Mixture Model (GMM) – Expectation Maximization (EM) – Variational Auto Encoder (VAE) – Factor Analysis – Principle Components Analysis (PCA) – Independent Component Analysis (ICA)

Reinforcement learning- Markov Decision Processes (MDP) – Bellman's Equations- Value Iteration and Policy Iteration - Value Function Approximation – Q – Learning

Applications of ML- Load Forecasting – Energy Market forecasting – Renewable energy forecasting, Fault identification and localization – Renewable Uncertainty estimation. ML for solar power MPPT, False data injection attack detection-Control of Power Converters.

Learning Resources:

Text Books:

1.Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2011
2.E. Alpaydin, Machine Learning, MIT Press, 2010
3.Anuradha Srinivasaraghavan , Vincy Joseph , Machine Learning, Wiley 2019

Reference Books:

1. Giuseppe Bonaccorso , Machine Learning Algorithms, Packt Publishing; 2018 2/e
2. Tom M. Mitchell, Machine Learning, McGraw Hill International Edition, 2013

Other Suggested Readings:

1.https://onlinecourses.nptel.ac.in/noc22_cs24
2.https://nptel.ac.in/courses/106106198

EE26034 **3-0-0 (3)**

Energy Auditing and Management

Pre-Requisites: none

Course Outcomes:

CO1	Understand the need and significance of energy audit and management
CO2	Identify the equipment and domain of energy conservation and audit in power system
CO3	Assess the need and type of instruments for energy audit and energy management
CO4	Design, analyse and evaluate an energy audit and the benefits of different energy management techniques

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	2	1
CO2	3	2	3	2	1	1
CO3	3	1	3	2	1	2
CO4	3	1	3	2	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Energy Audit And Demand Side Management (DSM) In Power Utilities:

Energy Scenario & Conservation -Demand Forecasting Techniques- Integrated Optimal Strategy for Reduction of T&D Losses - DSM Techniques and Methodologies- Loss Reduction in Primary and Secondary Distribution system and capacitors - Energy Management – Role of Energy Managers - Energy Audit – Metering

Energy Audit: Energy audit concepts, Basic elements and measurements, Mass and energy balances, Scope of energy auditing in industries

Energy Audit of Electrical Equipment: Evaluation of energy conservation opportunities and environmental management- Preparation and presentation of energy audit reports, case studies for Induction motors, Transformers, Cables, Lighting, AC systems, Pumps, Capacitor banks and potential energy savings

Instrumentation: Evaluation and instrumentation techniques for renewable energy systems (solar thermal, photovoltaic and wind energy); energy management devices; micro controller based systems

Energy Conservation: Energy conservation in HVAC systems and thermal power plants, Solar systems, Fan and Lighting Systems - Different light sources and luminous efficacy, Energy conservation in electrical devices and systems, Economic evaluation of energy conservation measures, Electric motors and transformers, Inverters and UPS, Voltages stabilizers

Learning Resources:

Text Books:

1.Dr. Subhash Gadhave , Anup Goel , Siddu Patil , Laxmikant D. Jathar , Energy Audit & Management RePrint , Aug 2020

2.Amlan Chakrabarti, Energy Engineering and management, PHI, 2018

3.Rajiv Shanker, Energy auditing in Electrical utilities, Viva books Pvt.Ltd., 2015

Reference Books:

1.Roosa, S., Doty, S., & Turner, W, Energy management handbook, River Publishers, 2020

2.Hodge B.K, Analysis and Design of Energy Systems, Prentice Hall, 2002

Other Suggested Readings:

1.https://nptel.ac.in/courses/108106022
2.https://nptel.ac.in/courses/112105221

EE26036 **3-0-0 (3)**

Flexible AC Transmission Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the need for control of Real and Reactive power flows
CO-2	Identify the objectives of series and shunt compensation of power systems
CO-3	Analyse the performance of Series, Shunt and combined FACTS controllers
CO-4	Evaluate the performance and stability of power systems with FACTS controllers

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	-	1	1
CO-2	3	1	3	-	1	1
CO-3	3	3	3	-	1	1
CO-4	3	3	3	-	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers. Overview of power converters used in FACTS controllers.

Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, FC-TCR configurations, STATCOM, basic operating principle, control approaches and characteristics.

Objectives of series compensator, variable impedance type of series compensators, switching converter type compensators, TCSC, TSSC- operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating.

Static Phase Angle Regulators – power flow control by phase angle regulator and improvement of transient stability.

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Control structure of UPFC, Interline power flow controller.

Virtual and Synthetic Inertia: Introduction to virtual Synchronous machine, Virtual and synthetic Inertia. Estimating the inertia of traditional and RES power systems. Modeling of virtual and synthetic inertia for frequency control. Effects of fast acting storage units on fast frequency control of micro grid.

Learning Resources:

Text Books:

1.Suman Bhowmick, Flexible AC Transmission Systems (FACTS), CRC Press, 2023, 1st Edition.

2.Yong Hua Song & Allan T Johns, Flexible AC Transmission Systems (FACTS), IEE power and energy series, 2008

3.Narain G.Honorani, Laszlo Gyugyi, Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 1999

Reference Books:

1.K.R. Padiyar, FACTS Controllers in Power Transmission and Distribution, New Age International Publishers, 2016.

2.R. Mohan Mathur and Rajiv K. Varma, Thyristor- Based FACTS controllers for electrical transmission systems, IEEE Press, 2002.

Other Suggested Readings:

1.https://nptel.ac.in/courses/108/107/108107114/

2.Prachal Jadeja and Vijay K Sood, “Synthetic/virtual Inertia in RES Grid, A Review”, IEEE explore, 2023.

EE26038 **3-0-0 (3)**

Development and Evaluation of Power Projects

Pre-Requisites: **None**

Course Outcomes:

CO-1	Do a basic cost-benefit analysis of power projects in generation, transmission, and distribution
CO-2	Study the different business models in power systems
CO-3	Study the different metering techniques
CO-4	Analyze and evaluate the economics of power projects through case studies

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	1	-	-
CO2	3	-	3	2	-	-
CO3	3	-	3	2	-	-
CO4	3	-	3	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Considerations in Project Development and Evaluation

Value of Electricity – Integrated Resource Planning – Environmental Concerns and Efficiency – Energy Return on Energy Invested – Capacity Factor – Rehabilitating, Retrofitting and Repowering of Existing Power Facilities - Global Electrical Power Scene - Project Selection and Evaluation – Project Development – Pre-investment stage – Investment Stage –Operational Stage – Post Operational Phase

Evaluation of Power Generation Projects

Cost of Power Generation – Levelized Cost of Energy – Generation Planning – Investment Analysis– Time Value of Money – Net Present Value – Benefit/cost Ratio – Payback Period - Profit/investment Ratio – Business Economic Feasibility Study – Power Purchase Agreements – Case studies on development and evaluation of renewable and non-renewable energy projects.

Investing in Transmission

Nature of the Transmission Business – Barriers to transmission development – Macrogrid proposals - Cost-Based Transmission Expansion – Value-Based Transmission Expansion – TSO economics – Interregional coordination – Cost-Benefit Analysis

Distribution System Finance

Tariff and Energy Bills – Financing Distributed Generation Projects – Net Metering – Net Feed-in - Rooftop Solar PV Business models – Grid-Connected and Stand-alone PV systems - Customer Savings Analysis – Grid Parity – Utility and DSO economics.

Learning Resources:

Text Books:

1. Hisham Khatib, Economic Evaluation of Projects in the Electricity Supply Industry, 3rd edition, IET, 2014.

2. Marcelino Madrigal and Steven Stoft, Transmission Expansion for Renewable Energy Scale-Up, 2012, Washington DC, World Bank.

3.Santosh Raikar, Seabron Adamson, Renewable Energy Finance: Theory and Practice, Elsevier, 2019.

Reference Books:

1. Daniel S. Kirschen, Goran Strbac, Fundamentals of Power System Economics, Wiley, 2018.

2. Steven Stoft, Power System Economics: Designing Markets for Electricity, Wiley-IEEE Press, 2002.

Other Suggested Readings:

https://nptel.ac.in/courses/127103236

https://onlinecourses.nptel.ac.in/noc24_me57/preview

Power finance corporation of India https://pfcindia.com/