NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL



RULES AND REGULATIONS

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Program in

POWER SYSTEMS ENGINEERING

(Effective from AY 2021-22)

DEPARTMENT OF ELECTRICAL ENGINEERING

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

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

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

MISSION

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

Department of Electrical Engineering:

Brief about the Department:

The Department of Electrical Engineering was established in the year 1959 in the Regional Engineering College Warangal, which was converted into a National Institute of Technology in the year 2003.

Since the inception of the Institute, the department has been developing state-of-the-art Infrastructure to cater to the needs of technical education and cutting-edge research. In its formative years, the department received considerable financial and logistical support from UNESCO. Later, the Department was funded principally by the MHRD, GOI, which is augmented by aid from various other agencies such as the Institutional Network Scheme (INS) and TEQIP.

Well-qualified, well-trained and dedicated faculty propels the development of the department. The department enjoys a position of eminence in the field of technical education and research. The Department of Electrical Engineering started offering postgraduate programs since the year 1964. Currently, the Department offers three PG programs in Power Systems Engineering, Power Electronics and Drives, and Smart Electric Grid.

The establishment of postgraduate courses has significantly contributed towards the advancement of research and consultancy activities of the department. To fulfill the objectives stated in the mission and vision of the institute, the department organized several faculty development programs, conferences, and refresher courses, which cater to the needs of industries and utilities (DRDO, BHEL, TATA power companies, VSP to name a few).

The department also organized several continuing education programs in emerging areas for faculty of educational institutions throughout the country. The Department is recognized as a QIP center for M. Tech programs in Electrical Engineering.

The Department of Electrical Engineering has always been a hub of active research. Several research projects, sponsored by MHRD, CSIR, DST, DRDO, SPARC, and other private and governmental organizations have successfully been executed by the faculty of the department. Currently, about 65 doctoral students are pursuing their Ph.D. degrees in various areas of research.

In its sixty-two years of journey, the department had quite a few academic and research accomplishments. A few of them are enumerated below:

- Several funded research projects, to the tune of Rs. 300 Lakhs, are currently under execution, promising high research outcomes.
- A Power System Study Cell was established by the erstwhile APSEB to train their engineers in software pertaining to power systems.
- A sponsored research project was successfully executed, which aims to study the impact of the electrical load of the Vizag Steel Plant on the grid. This project was awarded to the department despite stiff competition from several institutes of higher learning.
- The department has been awarded a center of excellence in power and energy systems, which is in the process of being established.
- All academic programs offered by the department had been accredited by NBA for a full-time period of 5 years in the years 2008 and 2013
- As many as 26 consultancy projects were completed for the vetting of electromechanical designs for lift irrigation projects by the Governments of Telangana and Andhra Pradesh.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Electrical and Electronics Engineering
BTech (Hons.)	Electrical and Electronics Engineering
	Minor in Electrical Engineering
M.Tech.	Power Electronics and Drives
	Power Systems Engineering
	Smart Electric Grid
PG diploma	Power Electronics and Drives
	Power Systems Engineering
	Smart Electric Grid
Ph.D.	Electrical Engineering

Note: Refer to the Rules and Regulations for M.Tech. program (https://oldweb.nitw.ac.in/media/uploads/2022/01/17/m-tech_rules-and-regulations-2021-22.pdf) given in the institute website.

M.Tech. – POWER SYSTEMS ENGINEERING

Program Educational Objectives (PEOs)

PEO1	Design and develop independently innovative products and services in the field of Electrical Power systems
PEO2	Adopt and utilize latest technologies and tools in design of products and systems
PEO3	Communicate effectively to propagate ideas and promote teamwork
PEO4	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment

Program Articulation Matrix

PEO / Mission Statements	PEO1	PEO2	PEO3	PEO4
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 (POs)

At the end of the program, the student will be able to:

PO1	Engage in critical thinking and pursue research/ investigations and development to solve practical problems
PO2	Communicate effectively on complex engineering activities with the engineering community and with society at large, write and present substantial technical reports
PO3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to Power Systems Engineering
PO4	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
PO5	Cultivate an attitude of self-learning to cope with everchanging tools and technologies and be productive throughout his / her career.
PO6	Foster a temperament to manage projects, organizations and entrepreneurial ventures maintaining financial integrity and professional ethics.

SCHEME OF INSTRUCTION

M.Tech. (Power Systems Engineering) Course Structure

I – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	EE5201	Advanced Computational Methods in Power Systems	3	0	0	3	PCC
2	EE5202	Data Science Applications in Power Engineering	3	0	0	3	PCC
3	EE5101	Analysis of Power Converters	3	0	0	3	PCC
4	EE5104	Control and Integration of Renewable Energy Sources	3	0	0	3	PCC
5		Elective – I	3	0	0	3	PEC
6		Elective – II	3	0	0	3	PEC
7	EE5203	Power Systems Computation Lab-I	0	1	2	2	PCC
8	EE5204	Power Engineering Lab	0	1	2	2	PCC
9	EE5248	Seminar-I	0	0	2	1	SEM
Total			18	2	6	23	

I – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	EE5251	Digital Protection of Power Systems	3	0	0	3	PCC
2	EE5252	Real-Time Control of Power Systems	3	0	0	3	PCC
3	EE5253	Power Systems Stability and Control	3	0	0	3	PCC
4		Elective – III	3	0	0	3	PEC
5		Elective – IV	3	0	0	3	PEC
6		Elective – V	3	0	0	3	PEC
7	EE5254	Data Science Lab	0	1	2	2	PCC
8	EE5255	Power System Computation Lab-II	0	1	2	2	PCC
9	EE5298	Seminar – II	0	0	2	1	SEM
Total			18	2	6	23	

II – Year: I – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1.	EE6247	Comprehensive Viva-voce	2	CVV
2.	EE6249	Dissertation-Part-A	12	DW
Total			14	

II – Year: II – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
1.	EE6299	Dissertation-Part-B	20	DW
Total			20	

Note: PCC – Professional Core Courses and PEC – Professional Elective Courses

Professional Elective Courses:

I Year I Semester

S.No	Course Code	Course Title
1	EE5211	Design & Testing of HV Apparatus
2	EE5212	Economic Operation of Power systems
3	EE5213	HVDC Transmission
4	EE5214	Instrumentation & Automation
5	EE5215	Machine Learning and Applications
6	EE5216	Smart Grid Technologies
7	EE5111	Modern Control Theory
8	EE5112	Power Quality Improvement Techniques
9	EE5114	Electric Vehicles
10	EE5304	Restructured Power systems
11	EE5315	Signal Processing Techniques
12	MA5331	Numerical Optimization Techniques

I Year II Semester

S.No	Course Code	Course Title
1	EE5261	Distribution System Planning and Automation
2	EE5262	EHVAC Transmission
3	EE5263	Energy Auditing and Management
4	EE5264	Evolutionary Algorithms Applications in Power Engineering
5	EE5265	Flexible AC Transmission Systems
6	EE5266	Power System Reliability and Planning
7	EE5163	High Power Inverters
8	EE5165	Advanced Control Techniques for Power Converters
9	EE5166	Power Converters and Control Techniques for Micro-grids
10	EE5363	Smart Appliances and Internet of Things

Open Elective Courses (offered to other departments):

Semester	Elective Number	Course Code	Course Title

Special Notes/Instructions:

In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of timetable

Credits in Each Semester					
	I Sem	II Sem	III Sem	IV Sem	Total
Core courses (PCC)	16	13	0	0	29
Elective courses (PEC)	6	9	0	0	15
Seminar	1	1	0	0	2
Comprehensive Viva-voce	0	0	2	0	2
Dissertation	0	0	12	20	32
Total credits (Sem. wise)	23	23	14	20	80

DETAILED SYLLABUS

M.Tech. – Power Systems Engineering

EE5201	ADVANCED COMPUTATIONAL METHODS IN POWER SYSTEMS	3-0-0: 3

Course Outcomes (COs):

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

CO1	Develop mathematical models for load flow studies for Transmission and Distribution systems and Fault analysis
CO2	Prepare the input data required for load flow analysis and fault calculations
CO3	Apply appropriate algorithms for load flow studies
CO4	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	0	3	0	0	0
CO2	0	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction, 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, Y_{bus} formation by Inspection method and its algorithm. Merits and Demerits of Y_{bus} and Z_{bus} 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 Z_{bus} 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 $Z_{bus}{}^{012}$ by step-by-step algorithm. Derivation of relevant equations for E^{012} for LLLG and LG faults

Learning Resources:

Text Books:

1. Computer Methods in Power System Analysis, Stagg and El – Abiad , McGraw Hill, ISE, 1986
2. Computer techniques in Power System Analysis, M A Pai and Dr. Dheeman Chatterjee, McGraw hill, 2014, 3e

Reference Books:

1. Power System Analysis, Hadi Sadat, McGraw Hill – International Edition – 1999
2. Computer Modeling of Electrical Power Systems, J. Arrilaga and NR Watson, John Wiley and Sons, 2001, 1e

Online Resources:

1. https://www.engineeringonline.ncsu.edu/course/ece-753-computational-methods-for-power-systems/
2. https://www.youtube.com/playlist?list=PL36A60B630E8C7B56
3. https://www.youtube.com/playlist?list=PL-uxPiMl0_6GWFPGXgVapb1yjVAZs9YGz

EE5202	DATA SCIENCE APPLICATIONS IN POWER ENGINEERING	3-0-0: 3

Course Outcomes (COs):

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

CO1	Distinguish between Algorithmic based methods and Knowledge based Methods
CO2	Able to distinguish between Artificial Neural Networks and Fuzzy Logic
CO3	Adopt Soft Computing techniques for solving Power System Problems
CO4	Apply appropriate AI frame work for solving Power System Problems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	0	0	3	0	0	0
CO2	3	0	0	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	3	0	0

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 - Speed control of DC and AC Motors. 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 Logic & Genetic Algorithms, S. Rajasekaran and G.A.V. Pai, PHI, New Delhi, 2008
2. Fuzzy Logic with Fuzzy applications, T.J. Ross, Mc Graw Hill Inc, 1997

Reference Books:

1. Neural Networks: A Comprehensive Foundations Simon Haykin, Pearson Edition, 2003
2. Fuzzy sets, Uncertainty and Information, G.J.Klir and T.A.Folger, PHI, Pvt.Ltd,1994
3. Neural Network & Fuzzy System, Bart Kosko, Prentice Hall, 1992
4. Neural Computing Theory & Practice, P. D .Wasserman, Van Nostrand Reinhold, New York, 1989

Online Resources:

1. https://smartgridcenter.tamu.edu/index.php/data-science-and-machine-learning-for-modern-power-systems/

EE5101	ANALYSIS OF POWER CONVERTERS	3-0-0: 3

Course Outcomes (COs):

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

CO1	Select appropriate switching devices for power converters
CO2	Analyse and design power converter configurations for specific applications
CO3	Select control techniques for low and medium power converters
CO4	Design power electronic converters to improve power quality

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	3	1	2	2
CO2	2	0	3	1	2	2
CO3	2	0	3	1	2	2
CO4	2	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT, MOSFET, IGBT, GTO, Wide band gap devices (GaN, SiC) - Design of driver and snubber circuit

DC-DC Converters: Non-isolated DC-DC converters: buck, boost, buck-boost, CUK converters under continuous and discontinuous conduction operation - Isolated DC-DC converters: forward, fly-back, push-pull, half-bridge and full-bridge converters - Relationship between I/P and O/P voltages- design of filter inductor and capacitors

Inverters: Single-phase and three-phase inverters- PWM techniques: single, multiple and sinusoidal PWM techniques- selective harmonic elimination, space vector modulation, current source inverter- High power inverters: Multi-pulse inverters, multi-level inverters - Diode-clamped, cascaded and Flying capacitor types, Carrier and Vector based multi-level modulation schemes -Concept of active power filters

Front-End (AC-DC) Converters: Conventional methods of power factor improvements: Semi-converter, extinction angle control, symmetrical angle control – active front-end converters- Single phase: Boost, voltage doubler and PWM rectifiers –voltage and current controlled three-phase PWM rectifiers

Learning Resources:

Text Books:

1. Power Electronics Handbook, M.H. Rashid, Butterworth-Heinemann, 2017, 4th edition.
2. Power Electronics: Converters, Applications & Design, N Mohan, T.M. Undeland, WP. Robbins, John Wiley & Sons, 2003, 3rd edition.

Reference Books:

1. Power Electronics: Essentials and Applications, Umanand, L, John Wiley India, 2009, 1st Edition
2. Fundamentals of Power Semiconductor Devices, Jayant Baliga B, Springer, 2008, 1st Edition

Online Resources:

1. https://nptel.ac.in/courses/108/102/108102157/

EE5104	CONTROL AND INTEGRATION OF RENEWABLE ENERGY SOURCES	3 –0– 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

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. Renewable and Efficient Electric Power Systems, G. Masters, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.
2. Microgrids and Active Distribution Networks, S. Chowdhury, S. P. Chowdhury, P. Crossley, IET Power Electronics Series, 2012.
3. Integration and Control of Renewable Energy in Electric Power System, Ali Keyhani Mohammad Marwali and Min Dai, John Wiley publishing company, 2010, 2nd Edition.

Reference Books:

1. Fundamentals, technologies & Applications, Chetan Singh Solanki, Solar Photovoltaic, PHI Publishers, 2019, 3rd Edition.
2. Control of Power Inverters in Renewable Energy and Smart Grid Integration, Quing-Chang Zhong, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 1St Edition.
3. Power Conversion and Control of Wind Energy Systems, Bin Wu, Yongqiang Lang, Navid Zargari, IEEE- John Wiley and Sons Ltd. Publishers, 2011, 1st Edition.
4. Report on “Large Scale Grid Integration of Renewable Energy Sources - Way Forward” Central Electricity Authority, GoI, 2013.

EE5203	POWER SYSTEMS COMPUTATION LAB - I	0-1-2: 2

Course Outcomes (COs):

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

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 technique

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	0	0	0
CO2	3	3	3	0	0	0
CO3	3	3	3	0	3	0
CO4	2	2	3	0	3	0

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 Y_{BUS} using two dimensional arrays by inspection method

5. Formation of Y_{BUS} 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. Distribution system load flow using backward forward method

EE5204	POWER ENGINEERING LAB	0-1-2: 2

Course Outcomes (COs):

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

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	0	2	0	0	3	0
CO2	3	2	2	0	2	0
CO3	3	3	3	0	2	0
CO4	3	3	3	0	0	0

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. Analysis of DC-DC converters (a) Buck converter, (b) Boost converter, and (c) Buck- Boost converter
14. Closed loop control of Buck and Boost converter
15. Unipolar and bipolar PWM techniques for single-phase half-bridge and full-bridge inverters
16. Single phase Five level cascaded H-Bridge inverter

EE5248	Seminar–I	0 – 0– 2: 1

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Identify and chose appropriate topic of relevance.
CO2	Assimilate literature on technical articles of specified topic
CO3	Write technical report.
CO4	Present a technical talk on the chosen topic

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	0	0	3	0
CO2	3	0	2	0	3	0
CO3	3	3	3	0	0	0
CO4	3	3	3	0	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no specific syllabus for this course. Student can choose any topic, of his / her choice, pertaining to Power Systems Engineering. Topic should be a relevant and currently researched one. Students are advised to refer articles published in current journals in the area of Power Systems Engineering for choosing their seminar topics. Student should review minimum of 10 to 15 research papers relevant to the topic chosen, in addition to standard textbooks. Students are required to prepare a seminar report, in the standard format and give presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. It is mandatory for all the students to attend the presentations of their classmates.

Learning Resources:

1. Journal papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE5251	DIGITAL PROTECTION OF POWER SYSTEMS	3-0-0: 3

Course Outcomes (COs):

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

CO1	Recognize the advantages of digital relays over conventional relay
CO2	Apply the suitable signal processing techniques for protection
CO3	Understand the adaptive criterion for relay decision making
CO4	Identify the new developments in protective relaying and applications

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	2	0
CO2	3	0	3	0	2	0
CO3	3	0	3	0	2	0
CO4	3	0	3	0	3	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

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

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 criterion, Adaptive decision schemes, Adaptive Differential protective scheme

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

Learning Resources:

Text Books:

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

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

Reference Books:

1. Digital Protection for Power Systems, A.T.Johns and S.K.Salman, IEE Power Series 15, 1997.
2. Digital Power System Protection, Singh, Prentice-Hall of India Pvt. Limited, 2007, 1/e
3. Understanding Digital Signal Processing, Orhan Gazi, Springer, 2017, 2/e
4. Fundamentals of Power System Protection, Paithankar Y.G, PHI, 2010, 2/e
5. Protective Relays-their Theory and Practice, A R C Warrington, Chapman & Hall Ltd., 1968

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc20_ee73/preview
2. NPTEL :: Electrical Engineering - Power System Protection
3. NPTEL :: Electrical Engineering - NOC:Power System Protection and Switchgear

EE5252	REAL-TIME CONTROL OF POWER SYSTEMS	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	3	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

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

Man – Machine Communication: 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, Benefits from IEC (International Electro technical Commission) communication Standards

Sub-load Dispatch Centre (Sub- LDC)
Equipment in Sub LDC: Work Stations, FEPS, Routers, Functionalities of Sub LDC- Real Time Software
Classification of Programs, Structure of Real time Programs, Construction Techniques & Tools, Programming Language Requirements for Process Control

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

State Load Dispatch Centre (SLDC): Inter Connectivity of Sub-LDCs & SLDCs, Hierarchy of Data Transfer, Functions & Responsibilities of SLDC, Real Time Operation carried at SLDC

Southern Regional Load Dispatch Centres (SRLDC) and National Load Dispatch Centre (NLDC**)-** Functions & Responsibilities of SRLDC, Operations carried at SRLDC, Overview of SCADA, Real Time operation in detail Operations carried out NLDC

Learning Resources:

Text Books:

1. Power System Generation, Operation and Control, Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble, John Wiley and Sons, 2013, 3rd Edition.
2. Power System SCADA and Smart Grids, Mini S. Thomas and John D. McDonald, CRC Press, 2015, 1st Edition.

Reference Books:

1. Power System Analysis, John J. Grainger and William D Stevenson Jr.: McGraw Hill, 2017, ISE.
2. Power System control – Technology, Torsten Cegrell, Prentice –Hall International series in Systems and control Engineering, Prentice Hall International Ltd., 1986.
3. Real – Time Computer Control, S. Bennett and D.A. Linkens (Editors): IEE Control Engineering series (24), Peter Peregrinus Ltd., 1984.
4. Real – Time Systems, C.M. Krishna and Kangg. Shin: Mc Graw-Hill international companies.
5. Special Issue on Computer Control of Power Systems, IEEE Proc. July 1974.

EE5253	POWER SYSTEMS STABILITY AND CONTROL	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	3	0	0
CO4	3	0	3	0	0	0

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

Basic Models For Power System Studies:

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

Reference Books:

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

Online Resources:

1. https://nptel.ac.in/courses/108/106/108106026/
2. https://www.youtube.com/playlist?list=PLuv3GM6-gsE2WXbxLSnqKHf5gcnedXCZH

EE5254	DATA SCIENCE LAB	0-1-2: 2

Course Outcomes (COs):

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

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	0	0	0
CO2	3	3	3	0	3	0
CO3	3	3	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Load Flow analysis using Neural Network
2. State Estimation using Neural Network
3. Contingency Analysis using Neural Network
4. Power system Security analysis using Neural Network
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

EE5255	POWER SYSTEM COMPUTATION LAB -II	0-1-2: 2

Course Outcomes (COs):

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

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	Demonstrate contingency analysis

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	0	0	0
CO2	3	3	3	0	0	0
CO3	3	3	3	0	0	0
CO4	3	0	3	0	0	0

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/POWER WORLD.
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.

EE5298	Seminar–II	0 – 0– 2: 1

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Identify and chose appropriate topic of relevance.
CO2	Assimilate literature on technical articles of specified topic
CO3	Write technical report.
CO4	Present a technical talk on the chosen topic

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	0	0	3	0
CO2	3	0	2	0	3	0
CO3	3	3	3	0	0	0
CO4	3	3	3	0	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no specific syllabus for this course. Student can choose any topic, of his / her choice, pertaining to Power Systems Engineering. Topic should be a relevant and currently researched one. Students are advised to refer articles published in current journals in the area of Power Systems for choosing their seminar topics. Student should review minimum of 10 to 15 research papers relevant to the topic chosen, in addition to standard textbooks. Students are required to prepare a seminar report, in the standard format and give presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. It is mandatory for all the students to attend the presentations of their classmates.

Learning Resources:

1. Journal papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE5211	DESIGN AND TESTING OF HIGH VOLTAGE APPARATUS	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	2	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

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

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

Design of insulators, bushings and capacitors

Basic configurations, Classification based on insulating materials and application, design principles

Insulation Design 0f power Transformers And Gis : Insulation schemes in transformer, design of transformer windings, surge phenomena in transformer windings-effect of series and shunt capacitance and stress control techniques

Design of Instrument Transformers and Cable Joints: Classification based on insulating materials and design of potential and current transformers, Types of cable joints and terminations-capacitive grading-non-linear resistive grading

Surge Arrester: Types of surge arresters-gapped and gapless-electrical characteristics–housing materials -pollution performance-modelling of arrestor-insulation co-ordination

Learning Resources:

Text Books:

1. High Voltage Engineering & Testing, H.M. Ryan, IEE Power & Energy series, 2001, Second Edition.
2. Gas Insulated Substations, M. S. Naidu, I.K. International publishers, 2008.

Reference Books:

1. Transformer Engineering: Design, Technology, and Diagnostics, S.V. Kulkarni, S.A. Khaparde, CRC Press, 2013, Second Edition.
2. High voltage Engineering Fundamentals, E. Kuffel, W.S. Zaengl, J. Kuffel, , Newnes Publishers, 2011.
3. High Voltage Engineering Fundamentals, Kuffel, E., Zaengl, W.S. and Kuffel J., Elsvier India Pvt. Ltd, 2005.
4. High Voltage Technology, Alston, L.L, Oxford University Press, London 1968.
5. Large Power Transformers, Karsai, K.Kerenyi, D. and Kiss. L., Elsevier, Armsterdam, 1987.
6. Modern Power Transformer Practice, Feinberg, R., The Macmillan Press Ltd., New York, 1979.
7. The J & P Transformer Book, A.C.Franklin and J.S.C.Franklin, Butterworth-Heinmann, 1995, Eleventh edition.

Online Resources:

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

EE5212	ECONOMIC OPERATION OF POWER SYSTEMS	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	2	0
CO2	3	0	3	0	2	0
CO3	3	0	3	0	0	0
CO4	3	0	3	2	0	0

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-Leniar Sensitivity analysis -linear programming method- Security Constrained OPF- Interior Point OPF- Bus Incremental Coats

Learning Resources:

Text Books:

1. Power Generation Operation and Control, Allen J.Wood and Bruce.F.Wollenberg, John Wiley & Sons, New York, 2016, 2e.
2. Electric Energy System Theory – an Introduction, Elgerd.O.I, Tata McGraw Hill, New Delhi, 2013.

Reference Books:

1. Load Flow Optimization and Optimal Power Flow, J. C. Das, CRC press, 2017, 1e.
2. Power System Analysis, Operation and Control, Abhijit Chakrabarti and Suita Halder, PHI, 2010, 3rd Edition
3. Power System Operation, Robert H. Miller, James H. Malinowski, Tata McGraw Hill, 2009.

Online Resources:

1. https://www.youtube.com/playlist?list=PL4BFB13CCDB954BCF
2. https://www.youtube.com/playlist?list=PL4BFB13CCDB954BCF
3. https://nptel.ac.in/courses/108/104/108104052/

EE5213	HVDC TRANSMISSION	3-0-0: 3

Course Outcomes (COs):

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

CO1	Distinguish HVDC Transmission and EHVAC transmission system
CO2	Analyse HVDC transmission with Current Source Converters and Voltage Source Converters
CO3	Evaluate performance metrics for HVDC converter configuration
CO4	Synthesize controllers for Voltage Source Converters based HVDC under DC fault conditions

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

DC Power Transmission Technology

Introduction, Comparison of AC&DC Transmission, Applications of DC Transmission, Description of DC Transmission System, Modern Trends in DC Transmission

HVDC with Current Source Converters

ANALYSIS OF HVDC CONVERTERS: Choice of converter configuration, Simplified analysis of Graetz circuit: without overlap, with overlap, Converter Bridge characteristics. Equivalent circuit of HVDC link, power factor and reactive power of converters

Converter And HVDC System Control: Principles of DC link control ,Converter control characteristics, power reversal in DC link, voltage dependent current order limit(VDCOL), System control hierarchy, Firing angle control , constant current control and Extinction angle control, Power control

LCC HVDC System Harmonics: Harmonic Performance Criteria, Harmonic Limits, Harmonic Filters, Noncharacteristic Harmonic Reduction Using HVDC Controls

HVDC with Voltage Source Converters

VSC HVDC Applications and Topologies, Performance and Cost Comparison with LCC HVDC: Voltage Source Converters (VSC), Comparison with Line-Commutated Converter (LCC) HVDC, Overhead and Subsea/Underground VSC HVDC Transmission, DC Cable Types with VSC HVDC, Monopolar and Bipolar VSC HVDC Systems, VSC HVDC Converter Topologies, VSC HVDC Station Components, AC Reactors, DC Reactors

Two-Level PWM VSC HVDC Modelling, Control and Interaction with AC Systems: Various Two-Level Converter Models, VSC Converter Control Principles, Complete VSC Converter Controller. Power Exchange between Two AC Voltage Sources , Converter Phasor Model and Power Exchange with an AC System and Operation with Very Weak AC Systems

VSC HVDC under AC and DC Fault Conditions and applications: Introduction, DC Faults with Two-Level VSC, Influence of DC Capacitors, VSC Converter Modelling under DC Faults conditions. VSC HVDC High-Level Controls and AC Grid Support, HVDC Embedded AC Grid, HVDC Connecting Two Separate AC Grids, HVDC in Parallel with a Passive AC System and VSC HVDC Operation with Offshore Wind Farms

Learning Resources:

Text Books:

1. HVDC Power Transmission System, K.R. Padiyar: New Age Intl. Co, 2015
2. High Voltage Direct Current Transmission: Converters, Systems and DC Grids, Dragan Jovcic, Khaled Ahmed, Wiley Publishers, 2015

Reference Books:

1. Direct Current Transmission, Edward Wilson Kimbark, Vol-1, John Wiley & Sons, 1971
2. Self-Commutating Converters for High Power Applications, Jos Arrillaga, Yonghe H. Liu, Neville R. Watson, Nicholas J. Murray, Wiley Publishers, 2009
3. HVDC Transmission: Power Conversion Applications in Power Systems, Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, Wiley Publishers 2009

Online Resources:

1. https://www.youtube.com/playlist?list=PL4B78E9972172086A

EE5214	INSTRUMENTATION AND AUTOMATION	3-0-0: 3

Course Outcomes (COs):

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

CO1	Analyze the performance of physical systems for measurement of physical quantities
CO2	Understand Signal operations and design systems for Conditioning measurement and instrumentation
CO3	Synthesize Industrial Automation and Control technologies
CO4	Implement PLCs for Industrial Automation

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Static and Dynamic characteristics of Instrument, measurement of translational and rotational displacement, resistive potentiometers, strain gauges, Linear Variable Differential Transformer (LVDT), Synchros, induction potentiometers, piezoelectric transducers, electro optical devices, digital displacement transducers (translational and rotary encoders), magnetic and photoelectric pulse counting for speed, transducers for torque, voltage, current, power, frequency, power factor and phase angle measurement and microprocessor based measurement

Signal Conditioning: Instrumentation amplifiers: Basic characteristics. Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Fundamentals of 4-20 mA current loops, Regulators and power supplies for industrial instrumentation. Estimation of errors and Calibration, Bus standard for communication between instruments - GPIB (IEEE-488 bus), RS 232 and RS 485 interface, Optical Fiber Based Signal Transmission-Piezoelectric Couplers-Intelligent transmitters. Interrupt-based Data Acquisition. Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques

Impact of Automation on Manufacturing and Process Industries; Architecture of Industrial Automation Systems. Data Acquisition systems and PC based automation

Automatic Control, P-I-D Control, Controller Tuning, Special Control Structures: Feed forward and Ratio Control, Predictive Control, Control of Systems with Inverse Response, Cascade Control. Process and Instrumentation Diagrams

Sequence Control: PLCs and Relay Ladder Logic, Scan Cycle, RLL Syntax, Structured Design Approach, Advanced RLL Programming, Hardware environment, Timers and counters: Types of timers, programming timers, ON and OFF- delay timers, pulse timers, forms of counter, programming, up and down counters, timers with counters and sequencer

Learning Resources:

Text Books:

1. Industrial Instrumentation, Control and Automation, S. Mukhopadhyay, S. Sen and A. K. Deb, Jaico Publishing House, 2013
2. Measurement Systems, Applications and Design, Doebelin, Tata McGraw Hill, 2008

Reference Books:

1. Programmable Logic controllers, W Bolton, Elsevier- newness, 2009, 5th edition
2. Fundamentals of Industrial Instrumentation, Alok Barua, Wiley India Pvt. Ltd., 2011
3. Measurement & Instrumentation: Trends & Applications, M.K. Ghosh, S. Sen and S. Mukhopadhyay, Ane Books, 2010
4. Chemical Process Control, An Introduction to Theory and Practice, George Stephanopoulos, Prentice Hall India, 2012
5. Programmable Logic Controllers, Frank. D, Petruzella, Tata McGraw Hill 2010, Third Edition

Online Resources:

1. https://paktechpoint.com/free-courses-of-instrumentation-control-automation-scada-electrical/

EE5215	MACHINE LEARNING AND APPLICATIONS	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	3	2	0
CO4	3	0	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 – Fault identification and localization – Renewable Uncertainty estimation

Learning Resources:

Text Books:

1. Pattern Recognition and Machine Learning, Christopher Bishop, Springer, 2011
2. Machine Learning, E. Alpaydin, MIT Press, 2010

Reference Books:

1. Machine Learning, Tom M. Mitchell, McGraw Hill International Edition, 1997

Online Resources:

1. https://www.learndatasci.com/best-machine-learning-courses/

EE5216	SMART GRID TECHNOLOGIES	3– 0 –0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand the features of Smart Grid.
CO2	Assess the role of automation in Transmission and Distribution
CO3	Apply Evolutionary Algorithms for the Smart Grid and Distribution Generation.
CO4	Understand operation and importance of PMUs, PDCs, WAMS, Voltage and Frequency control in Micro Grids.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO-1	3	0	3	0	0	0
CO-2	3	0	3	0	0	0
CO-3	3	0	3	0	2	0
CO-4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Smart Grid: Introduction to Smart Grid - Working definitions of Smart Grid and Associated Concepts – Smart Grid Functions – Traditional Power Grid and Smart Grid – New Technologies for Smart Grid – Advantages – Indian Smart Grid – Key Challenges for Smart Grid.

Smart Grid Architecture: Components and Architecture of Smart Grid Design – Review of the proposed architectures for Smart Grid. The fundamental components of Smart Grid designs – Transmission Automation – Distribution Automation – Renewable Integration

Tools and Techniques for Smart Grid: Computational Techniques – Static and Dynamic Optimization Techniques – Computational Intelligence Techniques – Evolutionary Algorithms – Artificial Intelligence techniques.

Distribution Generation Technologies: Introduction to Renewable Energy Technologies – Micro grids – Storage Technologies –Electric Vehicles and plug – in hybrids – Environmental impact and Climate Change – Economic Issues.

Communication Technologies and Smart Grid: Introduction to Communication Technology – Synchro-Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS)- Introduction to Internet of things (IOT)- Applications of IOT in Smart Grid

Control of Smart Power Grid System: Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids.

Learning Resources:

Text Books:

1. Smart Grids, Infrastructure, Technology and Solutions, Stuart Borlase, CRC Press, 2013, 1st Edition.
2. Renewable and Efficient Electric Power System, Gil Masters, Wiley–IEEE Press, 2013, 2nd Edition.

Reference Books:

1. Synchronized Phasor Measurements and their Applications, A.G. Phadke and J.S. Thorp, Springer Edition, 2017, 2nd Edition.
2. Wind Power in Power Systems, T. Ackermann, Hoboken, NJ, USA, John Wiley, 2012, 2nd Edition.

EE5111	MODERN CONTROL THEORY	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Develop mathematical models of physical systems
CO2	Design optimal controllers for power electronic converters and power systems
CO3	Analyze the issues related to the stability of automatic control systems
CO4	Design complex nonlinear systems with linearization

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	0	2	1	2	2
CO2	2	0	2	1	2	2
CO3	2	0	3	1	2	2
CO4	2	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Introduction to linear control systems

System representation: Introduction to state and state variables - system representation in state variable form - transformations - Phase variable form - Canonical forms – Physical systems - Plant models – Representation using state function - Lagrange linearization

Time response: State transition matrix – Properties and methods of valuation - Time response of linear systems -State diagrams - Resolvant matrix - Resolvant algorithm

Controllability and observability: Definition and concepts - Criteria for controllability and observability - State variable feedback - Pole placement - Luenberg observer design

Stability: Introduction - definition of stability - stability in the sense of Lyapunov - stability of linear systems - transient response - Behavior of estimation - stability of nonlinear systems - generation of Lyapunov functions

Optimal control: Formulation of the optimal control problem - method of calculus of variations - use of Hamiltonian method - Pontryagin's minimum principle - Optimal control problem - Hamilton – Jacobi approach - Continuous time linear state regulator matrix riccati equation - Methods of solution – State variable feedback design.

Introduction to non-linear control systems

Learning Resources:

Text Books:

1. Modern control Engineering, Katsuhiko Ogata, Pearson Education India, 2015, 5th Edition.
2. Modern Control Systems Theory, M. Gopal, New Age International Private Limited, 2014, 3rd Edition.

Reference Books:

1. Modern Control Theory, Z. Bubnicki, Springer, 2010, 1st Edition.
2. State functions & linear control systems, Schultz &Melsa, McGraw Hill Book Co. New York, 1998.

EE5112	POWER QUALITY IMPROVEMENT TECHNIQUES	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

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, Cycloconverters, 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:

TextBooks:

1. Power Quality: Problems and Mitigation Techniques, Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Wiley, 2015.
2. Understanding power quality problems, Math H.J. Bollen, Wiley-IEEEPress, 2000, 1st Edition.
3. Power Quality Enhancement Using Custom Power Devices, Ghosh Arindam, Ledwich Gerard, Springer, 2009.

References Books:

1. Instantaneous Power Theory and Applications to Power Conditioning, Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes, Wiley-IEEEPress,2017.
2. Electrical Power Systems Quality, Roger C. Dugan, Mark F. Mc Granaghan, Surya Santoso and H. Wayne Beaty, McGrawHill, 2012, 3rd Edition.
3. Power System Harmonics, J. Arrillaga, N.R.Watson, Wiley, 2003, 2nd Edition.

Online Resources:

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

EE5114	ELECTRIC VEHICLES	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

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, Parallel hybrid vehicles, series Hybrid Vehicles, Series-Parallel Hybrid vehicles, plug-in hybrid vehicles, power flow diagrams 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, Concept of Hybrid Electric 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 of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives, Drive system efficiency.

Energy Storage: Storage requirements for Electric Vehicles, Battery based energy storage, Fuel Cell based energy storage, Super Capacitor based energy storage and their analysis. Power pack management systems, Cell balancing techniques, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices, compressed air storage systems, super conducting magnetic storage systems and Energy management 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, converters for coupled inductor based hybridization. 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. Advanced Electric Drive Vehicles, Ali Emadi, CRC Press, Taylor & Francis Group 2015.
2. Electric and Hybrid Vehicles: Design Fundamentals, Iqbal Hussein, CRC Press, 2003, 2nd Edition.

References:

1. Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, CRC Press, 2005.
2. Electric Vehicle Technology Explained, James Larminie, John Lowry, Wiley, 2003.

EE5304	RESTRUCTURED POWER SYSTEMS	3-0-0: 3

Course Outcomes (COs):

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

CO1	Understand the need for restructured power system and economics.
CO2	Analyse transmission congestion and Estimate loss allocation in Power System
CO3	Analyse demand response in smart grid systems
CO4	Evaluate economics and ancillary services within the Smart Grid

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	2	0

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.

Transmission Pricing

Cost components, Postage Stamp Method, Megawatt Mile Method, Contract Path Method

Smart Grid in Power Market:

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)

Definitions transfer capability issues: ATC, TTC, TRM, CBM calculations, methodologies to calculate ATC, Electricity Pricing

Smart Grid Bidding Strategies: Forward and Future market; Operation and control: Old vs New, Integrated bidding strategy in smart multi energy system, Smart grid Optimization with risk constraints-General risk measures, Portfolio selection problem, penalty formulation.

Transmission Congestion Management: 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.

Demand Response in Smart Grid: Demand response, Potential benefits of demand response in smart grid, enabling smart technologies for demand response, control devices for demand response, Monitoring and communication system. Demand response for Electric Vehicles, Examples

Ancillary Services within Smart Grid framework: Reactive power as an ancillary services, Energy Storage System, Power Quality, Reliability analysis.

Smart Grid Economic and market operations: Energy and Reserve Markets, Market Power, Generation Firms, Locational Marginal Prices, Financial Transmission Rights. Concepts of block chain technologies in energy trading and power purchase agreements (PPA).

Learning Resources:

Text Books:

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

Reference Books:

1. Making competition work in electricity, S. Hunt, John Wiley & Sons, Inc., 2002, 1st Edition.
2. Power System Deregulation: Loss Sharing in Bilateral Contracts and Generator Profit Maximization, Ashikur Bhuiya: Publisher VDM Verlag, 2008
3. Restructured Electrical Power Systems, Mohammad Shahidehpour and Muwaffaqalomoush, Marcel Dekker, Inc., 2001, 1st Edition

Online Resources:

1. NPTEL – Restructured Power Systems – Prof. S.A. Khaparde, Dr. A.R. Abhyankar, IIT Delhi
2. www.isgf.com
3. www.iexindia.com
4. www.posoco.in
5. http://www.ferc.fed.us
6. http://www.nordpool.no
7. http://www.statnett.no
8. http://www.ofaem.gov.uk
9. http://www.caiso.com
10. http://www.nationalgrid.com
11. http://www.bmreports.com/bwx_home.htm
12. http://www.elexon.co.uk/
13. http://www.fingrid.fi
14. http://www.svk.se
15. http://www.ucei.berkeley.edu/ucei/datamine/datamine.htm

EE5315	SIGNAL PROCESSING TECHNIQUES	3-0-0: 3

Course Outcomes (COs):

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

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	3	0	3	0	0	0
CO2	3	0	3	0	2	0
CO3	3	0	3	0	2	0
CO4	3	0	3	0	2	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Power Systems signals in terms of Smart Grid

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.

Signal Processing Techniques Applications
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. Advanced Digital Signal Processing, J.G.Proakis, M. Salehi, 1992, McGraw –Hill.
2. Power Systems Signal Processing for Smart Grids, P. F. Ribeiro, C. A. Duque, P. Marcio da Silveira and A. S. Cerqueira, John Wiley and Sons Ltd., 2014, 2nd Edition.

Reference Books:

1. Adaptive Filter Theory, S. Haykin, Prentice Hall, 2001, 2nd Edition.
2. Signal Processing: The Model Based Approach, J. V. Candy, McGraw-Hill Book Company, 1987.
3. Statistical Digital Signal Processing and modeling, M. H. Hayes, John Wiley & Sons, 1996.
4. Handouts on DSP Processors.
5. Digital Signal Processing – A computer Based Approach, S. K. Mitra, MGH, 2001, 2nd Edition.

MA5331	NUMERICAL OPTIMIZATION TECHNIQUES	3-0-0: 3

Course Outcomes (COs):

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

CO1	Understand fundamentals of linear and non-linear optimization.
CO2	Analyse and solve single and multi-dimensional optimization problems
CO3	Apply the Simplex method to the linear programming
CO4	Apply the KKT conditions for non-linear optimization
CO5	Apply the distributed and stochastic optimization tools to real world problems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	2	2
CO2	2	0	3	1	2	2
CO3	2	0	2	1	2	2
CO4	2	0	3	1	2	2
CO5	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Basic Concepts: Formulating an Optimization Problem, review of Linear Algebra and Analysis, one dimensional optimality conditions, Convex Sets and Convex Functions.

Unconstrained Optimization: Multi-dimensional optimality conditions and conceptual algorithm, Line Search Methods, Steepest Descent method, Conjugate gradient method, Classical Newton Method, Trust-region and quasi-Newton methods, Nonlinear Least Squares Problem and Algorithms.

Linear Programming: Geometric Solution, Basic feasible solution, The Simplex Method, Dual problem and duality theorems, Karmarkar's Algorithm.

Constrained non-linear optimization: Local and global solutions, Feasible and descent directions; First Order KKT Conditions, Constraint Qualification, Second Order KKT Conditions; Quadratic Programming; Penalty, Barrier and Augmented Lagrangian Methods; Sequential Quadratic Programming; Interior-Point Methods; Distributed optimization; Stochastic programming.

Power System Optimization

Unit commitment, Economic load dispatch, Optimal power flow, Security constrained optimal power flow, State estimation problems.

Learning Resources:

Text Books:

1. Numerical Optimization, J. Nocedal, & S. Wright, Springer Science & Business Media, 2006, Second Edition.
2. Linear and Nonlinear Programming, D. G. Luenberger & Y. Ye, 2016, Springer, Fourth Edition.

Reference Books:

1. Nonlinear programming: Theory and Algorithms, M. S. Bazaraa, H. D. Sherali, & C. M. Shetty, John Wiley & Sons, 2013, Third Edition.

2. Numerical Optimization with Applications, Suresh Chandra, Jayadeva, & Aparna Mehra, 2013, Alpha Science International Ltd, First Edition.
3. Engineering optimization: Theory and Practice, S. S. Rao, John Wiley & Sons, 2019, Fifth Edition.

EE5261	DISTRIBUTION SYSTEM PLANNING AND AUTOMATION	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	2	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	2	0

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 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

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

Learning Resources:

Text Books:

1. Electric Power Distribution, Automation, Protection and Control, James A Momoh, CRC press, 2001
2. Electric Power Distribution, A. S. PABLA, TMH,2000

Reference Books:

1. Electric Power Distribution Engineering, Turan Gonen, Mc-Graw Hill,1986
2. A Textbook of Electric Power Distribution Automation, Dr. M.K. Khedkar, Dr. G.M. Dhole, Laxmi Publications Ltd., 2010

Online Resources:

1. https://www.youtube.com/channel/UCWKPXSjLRz-TAFgFWCfMmGg/videos

EE5262	EHV AC TRANSMISSION	3-0-0: 3

Course Outcomes (COs):

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

CO1	Evaluate parameters of EHV line modelling
CO2	Understand the over-voltage phenomena and methods to limit in EHV AC systems
CO3	Analyze and evaluate electric field and interference characteristics of EHV AC system
CO4	Design grounding system for EHVAC systems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	2	0
CO4	3	0	3	0	2	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to EHV AC Transmission: Calculations of line and ground parameters: Properties of bundled conductors, inductance and capacitance calculations line parameters for modes of propagation resistance and inductance of ground returns, equivalent circuit of line model

Voltage Gradients of Conductors: Electrostatics, Field of Sphere, Field of Line Charges and Their , Charge-Potential Relations for Multi-Conductor, Surface Voltage Gradient on Conductors, Examples of Conductors and Maximum Gradients on Actual Lines, Gradient Factors and Their Use, Distribution of Voltage Gradient on Sub-conductors of Bundle

Corona and Radio interference: corona loss formula factors affecting corona. 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

Over Voltage in EHV Systems: Switching surges, causes of switching surge over voltages, recovery voltage, restriking transients, over voltages caused by interruption of low inductance currents, line energization transients, Ferro-resonance over voltages, lightning over voltages, protection against switching and lightning surges, VFTO in GIS, insulation coordination, design example

Power System Grounding: Functional Requirements of Earthing System, Equipment Earthing, Neutral Point Earthing, design of Substation grounding System, analysis of simple grounding systems, dimensioning of Earth Conductors, Step Potential and Touch Potential, body currents due to touch and step voltages, grounding system safety assessment and Earth Mat design. Measurement of Resistance and Soil Resistivity of Earthing System

Learning Resources:

Text Books:

1. Extra High Voltage AC Transmission Engineering, Rakesh Das Begamudre, New Age International publishers, 2014, Fourth Edition.
2. Power Generation Operation & Control, Allen J Wood & Bruce Wollenberg, 2016, Third Edition.

Reference Books:

1. Electric Power Transmission System Engineering Analysis and Design, Turan Gonen, CRC Press, 2014, Third Edition
2. Power Systems Grounding, Md. Abdus Salam, Quazi M. Rahman, Springer publishers, 2016.
3. Performance, Operation and Control of EHV Power Transmission Systems, A Chakraborti, D.P. Kothari and A.K. Mukhopadyay, T.M.H. (Pub) 1992.

Online Resources:

1. https://www.youtube.com/channel/UCWKPXSjLRz-TAFgFWCfMmGg/videos

EE5263	ENERGY AUDITING AND MANAGEMENT	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	2	2	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. Energy Engineering and management, Amlan Chakrabarti, PHI, 2018
2. Energy auditing in Electrical utilities, Rajiv Shanker, Viva books Pvt.Ltd., 2015

Reference Books:

1. Industrial energy management and utilization, Larry C. Witte, Schmidt & Brown, Hemisphere publishing Co., New York, 1988
2. Energy management handbook, Wayne. C Turner, Wiley Inter-science publications, New York, 1982
3. Analysis and Design of Energy Systems, Hodge B.K, Prentice Hall, 2002

Online Resources:

1. NPTEL :: Electrical Engineering - Energy Management Systems and SCADA

EE5264	EVOLUTIONARY ALGORITHMS APPLICATIONS IN POWER ENGINEERING	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	2	0
CO4	3	0	3	0	0	0

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.

Learning Resources:

Text Books:

1. Recent Advances in Swarm Intelligence and Evolutionary Computation, Xin-She Yang, Springer International Publishing, Switzerland, 2015, 1e
2. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley & Sons, 2001, 1e.

Reference Books:

1. Swarm Intelligence-From natural to Artificial Systems, Eric Bonabeau, Marco Dorigo and Guy Theraulaz, Oxford university Press, 1999
2. Swarm Intelligence, James Kennedy and Russel E Eberheart, The Morgan Kaufmann Series in Evolutionary Computation, 2001
3. Artificial Intelligence and Intelligent Systems, N P Padhy, Oxford University Press, 2005

Online Resources:

1. https://www.youtube.com/playlist?list=PLJ5C_6qdAvBFqAYS0P9INAogIMklG8E-9

2. https://www.youtube.com/playlist?list=PL53BE265CE4A6C056

EE5265	FLEXIBLE AC TRANSMISSION SYSTEMS	3-0-0: 3

Course Outcomes (COs):

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

CO1	Understand the need for control of Real and Reactive power flows
CO2	Identify the objectives of series and shunt compensation of power systems
CO3	Analyse the performance of Series, Shunt and combined FACTS controllers
CO4	Evaluate the performance and stability of power systems with FACTS controllers

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

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

Learning Resources:

Text Books:

1. Flexible AC Transmission Systems (FACTS), Yong Hua Song & Allan T Johns, IEE power and energy series, 2008
2. Understanding FACTS – Concepts and Technology of Flexibile AC Transmission Systems, NarainG.Honorani, Laszlo Gyugyi, Wiley-IEEE Press, 1999

Reference Books:

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

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

Online Resources:

1. https://www.youtube.com/playlist?list=PLLy_2iUCG87AVyRAN4QwVQrC8vSg1vWa6
2. https://nptel.ac.in/courses/108/107/108107114/

EE5266	POWER SYSTEM RELIABILITY AND PLANNING	3-0-0: 3

Course Outcomes (COs):

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

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	0	3	0	0	0
CO2	3	0	3	0	2	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Generating System Reliability Analysis – 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

Generating System Reliability Analysis – 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. Reliability Evaluation of Power Systems, Roy Billinton and Ronald N. Allan, Plenum press, New York and London, 1996 Second Edition
2. Reliability Modeling in Electric Power Systems, J. Endrenyi, John Wiley and Sons, 1978, First Edition

Reference Books:

1. Electricity Economics & Planning, T. W. Berrie, Peter Peregrinus Ltd., London
2. Power System Planning, R.L. Sullivan, Tata McGraw Hill Publishing Company Ltd

Online Resources:

1. https://www.youtube.com/watch?v=sbZ2sY_E4QU

EE5163	HIGH POWER INVERTERS	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

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	0	3	0	3	2
CO2	3	0	3	0	3	2
CO3	3	0	3	0	3	2
CO4	3	0	3	0	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. High Power Converters and AC Drives, Bin Wu, Wiley-Inter science, 2017, 2nd Edition.
2. Pulse Width Modulation for Power Converters: Principles and Practice, D. Grahame Holmes and Thomas A. Lipo, IEEE Press, 2003.

References Books:

1. Research publications.

EE5165	ADVANCED CONTROL TECHNIQUES FOR POWER CONVERTERS	3-0-0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand and analyze the different types of converter model and its usage
CO2	Design the advanced PID controller with its fractional version and resonant controller for converters
CO3	Design the robust controller for converter using the loop-shaping methods and the Sliding mode control
CO4	Design the controller using fuzzy logic and AI techniques for converters and drives

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	3	2
CO2	3	0	3	1	3	2
CO3	2	0	3	1	3	2
CO4	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Modeling of Power converters: Types of Models- Linearized Averaged models- Large signal and Small signal models- Switched models- Relation between various model types- Control goals in converter operation- Review of classical control methods.

Advanced PID controller: PID controller-Tuning methods of PID controller- Set point weighting- Integrator Windup- Controller degrees of freedom- Model based Design methods: Direct Synthesis (DS) method, Internal Model Control (IMC) method- Fractional Control System (FOS) -Design of Fractional PID controller- Case Study: PID controller design for DC-DC boost converter.

Resonant Controller: Necessity of resonant controller- Principle of Proportional Resonant (PR) control- Design methods of PR controller- Example of PR controller design for DC-DC boost converter.

Loop-shaping design: Concept of Loop shaping- Robust controller design using the loop shaping methods: H∞ Control, Quantitative feedback theory (QFT)- Case Study: Loop shaping methods to design the robust controller for DC-DC converter.

Sliding mode controller (SMC): Nonlinear control preliminaries-Types of Uncertainty-Sliding surface design- Stability of SMC- Equivalent control concept- Integral Sliding Mode Control (ISMC) design- Case study: Application of SMC to design the robust controller for DC-DC converter.

Fuzzy logic control and artificial Intelligence (AI) techniques: Introduction to fuzzy logic and AI techniques, application of fuzzy logic to power converters and electric drives, hardware system description, application of AI techniques to electric machines and drives.

Learning Resources:

Text Books:

1. Power Electronic Converters Modeling and Control with Case Studies, S. Bacha, I. Munteanu, A.I. Bratcu, Springer- Verlag London, 2014, 1st Edition.
2. PID and Predictive control of Electrical Drives and Power Converters using MATLAB/Simulink, L. Wang, S. Chai, D. Yoo, L. Gan, K. Ng, Wiley Press, 2015, 1st Edition.
3. Robust Linear Control of DC-DC Converters: A Practical Approach to the Synthesis of Robust Controllers, C. Olalla, Ramon Leyva, I. Queinnec, VDM Verlag- Dr. Muller, 2010, 1st Edition.
4. Sliding Mode controllers for Power Electronic Converters, A. Mehta, B. Naik, Springer Nature, 2019.

Reference Books:

1. Sliding Mode Control of Switching Power Converters: Techniques and Implementation, S-C. Tan, Y-M. Lai, C.K. Tse, CRC Press, 2012, 1st Edition.
2. Control Design Techniques in Power Electronic Devices, Hebertt Sira-Ramirez, Ramon Silva-Ortigoza, Springer- Verlag London, 2006, 1st Edition.
3. Control of Power Electronic Converters and Systems, Freede Blaabjerg, Academic Press, 2018. 1st Edition.
4. Control of Power Inverters in Renewable Energy and Smart Grid Integration, Q- C. Zhong, T. Hornik, Wiley Press, 2013, 1st Edition.

EE5166	POWER CONVERTERS AND CONTROL TECHNIQUES FOR MICROGRIDS	3-0-0:3

Course Outcomes (COs): At the end of the course, student will be able :

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	0	2	1	2	1
CO2	1	0	3	1	3	2
CO3	1	0	3	1	3	2
CO4	1	0	3	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Concepts of Microgrid: Overview of microgrids, concept of microgrids, microgrid vs conventional power system, AC and DC microgrid with distributed energy resources, standards and regulation issues associated with AC&DC microgrids, comparison between AC and DC microgrids.

Modeling of Renewable Energy Systems: Modeling of wind energy system-wind turbine model and electrical generator model with MPPT control, modeling of photovoltaic system-PV cell model with MPPT control, modeling of energy storage system-super capacitors model with control, and modeling of battery system with control .

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, modelling 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 Converters 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.

Learning Resources:

Text Books:

1. Microgrid Technology and Engineering Application, Fusheng Li, Ruisheng Li, Fengquan Zhou, Elsevier, 2015.
2. Microgrids and Active Distribution Networks, S. Chowdhury, P. Crossley, Institution of Engineering and Technology, 2009.
3. Microgrids Architectures and Control, Nikos Hatziargyriou, John Wiley Sons, 2014.
4. Microgrid Dynamics and Control, Hassan Bevrani, BrunoFrançois, Toshifumi Ise, John Wiley Sons, 2017.

Reference Books:

1. Intelligent Control and Power Flow Optimization, Manuela Sechilariu, Fabrice Locment, Urban DC Microgrid, Butterworth-Heinemann, 2016 .
2. Distributed Generation Systems:Design, Operation and Grid Integration, Gevork B. Gharehpetian, S. Mohammad Mousavi Agah, Butterworth Heinemann, 2017.

EE5363	SMART APPLIANCES AND INTERNET OF THINGS	3-0-0: 3

Course Outcomes (COs):

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

CO1	Understand and evaluate the characteristics of smart home appliances.
CO2	Understand the behaviour of IoT and their applications
CO3	Manage smart communication systems with multiple sensors and protocols
CO4	Design and simulate smart homes and smart cities with IoTs and cloud computing

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	2	0
CO4	3	0	3	2	2	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Modern Domestic 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.

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.

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. Fundamentals of Solid-State Lighting, Vinod Kumar Khanna, CRC press, 2014, 1st Edition.
2. Permanent Magnet Brushless DC Motor Drives and Controls, Chang-liang Xia, John Wiley & Sons Singapore Pte. Ltd., 2012, 1st Edition.
3. IoT for Smart Grids Design Challenges and Paradigms, K. Siozios, D. Anagnostos, D. Soudris, E. Kosmatopoulos, Springer, 2019, 1st Edition.

Reference Books:

1. Advanced Lighting Controls: Energy Saving Productivity, Technology & Applications, Craig Di Louie, Fairmont Press, Inc., 2006, 1st Edition.
2. Lighting Control: Technology and Applications, Robert S Simpson, Focal Press, 2003, 1st Edition.
3. Introduction to solid state lighting, Arturas Zukauskus, Michael S. Shur & Remis Gaska, Wiley- Interscience, 2002, 1st Edition.
4. Power Electronics: Converters, Applications and Design, Mohan, Undeland and Robbins, John Wiley and Sons, 1989, 1st Edition.

Online Resources:

1. www.aboutlightingcontrols.org.
2. www.ti.com

EE6247	Comprehensive Viva-Voce	2 Credits

Pre-requisites: Both I & II Semester course work of I year.

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Assimilate knowledge of different courses studied.
CO2	Develop overall comprehension about power systems area.
CO3	Analyze real life Power Systems engineering problems with theoretical knowledge learned.
CO4	Interpret and Articulate solutions to real life Electrical engineering problems in general and Power Systems Engineering problems in particular.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	2	2	0
CO3	3	0	3	2	2	0
CO4	3	0	3	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: Entire course of study (All the required courses studied) up to II Semester of I Year

Learning Resources:

1. Reading Material of all the courses.
2. Case Studies/Industrial training reports
3. Mini projects taken up.

EE6249	DISSERTATION PART – A	12 Credits

Pre-requisites: Both I & II Semester course work of I year.

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Define Research Problem Statement.
CO2	Critically evaluate literature in chosen area of research & establish scope of work.
CO3	Develop a detailed study methodology.
CO4	Carryout pilot theoretical study/experiment

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	2
CO2	3	2	3	0	0	2
CO3	3	0	3	0	2	2
CO4	3	0	3	0	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no prescribed syllabus. Students are required to search, collect, and review various research articles published in chosen area of research. A student must select a topic for his / her dissertation, based on his/her interest and the available facilities at the commencement of dissertation work. Students are required to submit a dissertation report on the research work carried out by him/her.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE6299	DISSERTATION PART – B	20 Credits

Pre-requisites: Both I & II Semester course work of I year, Dissertation Part-A.

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Expand on the defined Research Problem statement
CO2	Formulate the objectives and plan experimental / theoretical study
CO3	Conduct Laboratory/analytical studies
CO4	Analyze Data, develop models and offer solutions

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no prescribed syllabus. Students are required to search, collect, and review various research articles published in chosen area of research. A student must select a topic for his / her dissertation, based on his/her interest and the available facilities at the commencement of dissertation work. Students are required to submit a dissertation report on the research work carried out by him/her.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

NOTE: Refer to the following link for the guidelines to prepare dissertation report: https://www.nitw.ac.in/path/?dept=/nitwForms