NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

FOR

M.TECH PROGRAM IN POWER SYSTEMS ENGINEERING

Effective from 2019-20

DEPARTMENT OF ELECTRICAL ENGINEERING

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 center to serve the societal needs.

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

M.TECH IN POWER SYSTEMS ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES

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

Mapping of Mission statements with program educational objectives

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

PROGRAM OUTCOMES: 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

Mapping of program outcomes with program educational objectives

Programme outcomes	**PEO1**	**PEO2**	**PEO3**	**PEO4**
PO 1	3	3	2	3
PO 2	2	2	3	3
PO 3	3	3	2	3
PO 4	3	3	2	3

CURRICULAR COMPONENTS

The total course package M.Tech. Degree program will typically consist of the following components.

a) Core Courses ≥ 24 Credits
b) Elective Courses ≥ 15 Credits
c) Dissertation = 27 Credits

Degree Requirements for M. Tech in POWER SYSTEMS ENGINEERING

Category of Courses	Credits Offered	Min. credits to be earned
Program Core Courses (PCC)	30	30
Departmental Elective Courses (DEC)	18	18
Dissertation	27	27
Total	75	75

SCHEME OF INSTRUCTION

M.Tech. (Power Systems Engineering) Course Structure

M. Tech. 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	EE5101	Analysis of Power Converters	3	0	0	3	PCC
3	EE5202	Digital Protection of Power Systems	3	0	0	3	PCC
4		Elective-I	3	0	0	3	DEC
5		Elective –II	3	0	0	3	DEC
6		Elective-III	3	0	0	3	DEC
7	EE5203	Power Engineering Lab	0	1	2	2	PCC
8	EE5204	Power Systems Computation Lab-I	0	1	2	2	PCC
9	EE5241	Seminar-I	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. I - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	EE5167	Distributed Power Generation and Grid Integration	3	0	0	3	PCC
2	EE5252	Real-Time Control of Power Systems	3	0	0	3	PCC
3	EE5253	Power System Stability and Control	3	0	0	3	PCC
4		Elective –IV	3	0	0	3	DEC
5		Elective – V	3	0	0	3	DEC
6		Elective – VI	3	0	0	3	DEC
7	EE5254	Soft Computing Lab	0	1	2	2	PCC
8	EE5255	Power Systems Computation Lab-II	0	1	2	2	PCC
9	EE5291	Seminar – II	0	0	2	1	PCC
		TOTAL	**20**	**2**	**6**	**23**	

M. Tech. II - Year I - Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1	EE6242	Comprehensive Viva-voce	2	PCC
2	EE6249	Dissertation-Part-A	9	PCC
		TOTAL	11	

M. Tech. II - Year II - Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	EE6299	Dissertation-Part-B	18	PCC
		TOTAL	18	

List of Electives

I Year I Semester

S.No	Course Code	Course Title
1.	EE5211	Data Science Applications in Power Engineering
2.	EE5212	Economic Operation of Power systems
3.	EE5213	HVDC Transmission
4.	EE5214	Smart Grid Technologies
5.	EE5215	Design & Testing of HV Apparatus
6.	EE5216	Instrumentation & Automation.
7.	EE5217	Machine Learning and Deep Learning
8.	EE5111	Modern Control Theory
9.	EE 5114	High Power Inverters
10.	EE 5115	Digital Signal Processors

Elective-I: EE5211, EE5217, EE 5216, EE5214
Elective-II: EE5212, EE5213, EE5215
Elective-III: EE5111, EE 5114, EE 5115

I Year II Semester

S.No.	Course Code	Course Title
1.	EE5261	Power System Deregulation
2.	EE5262	Distribution System Planning and Automation
3.	EE5263	Flexible AC Transmission Systems
4.	EE5265	Energy Auditing and Management
5.	EE5266	Power System Reliability and Planning
6.	EE5267	EHVAC Transmission
7.	EE5268	Evolutionary Algorithms Applications in Power Engineering
8.	EE5163	Power Quality Improvement Techniques
9.	EE5164	Electric Vehicles

Note: 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.

Elective-IV: EE5262, EE5263, EE5267
Elective-V: EE5163, EE5164, EE5265
Elective-VI: EE5268, EE5261, EE5266

DETAILED SYLLABUS

EE 5201	Advanced Computational Methods in Power Systems	PCC	3– 0 – 0	3 Credits

Course Outcomes:

After completion 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.

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	2	2	2	3
CO-2	2	2	2	3
CO-3	3	2	2	2
CO-4	2	2	2	3

Detailed 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_f^{abc}, y_f^{abc}, z_f^{012} and y_f^{012} for various types of faults

Formation of Z_{bus}^{012} by step-by-step algorithm. Derivation of relevant equations for $I_{p(f)}^{012}$, $E_{p(f)}^{012}$ and $E_{i(f)}^{012}$ for LLLG and LG faults.

Text Books:

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

References Books:

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

EE5101	Analysis of Power Converters	PCC	3 – 0 – 0	3 Credits

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

CO1	Select appropriate switching devices for power converters
CO2	Analyze 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

CO-PO Mapping:

	PO1	PO2	PO3	PO4
CO1	2	2	3	2
CO2	2	2	3	2
CO3	2	2	3	2
CO4	2	2	3	3

Detailed 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

Text Books:

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

Reference Books:

1. Umanand, L.: Power Electronics: Essentials and Applications, John Wiley India, 1st Edition, 2009.
2. Jayant Baliga B: Fundamentals of Power Semiconductor Devices, Springer, 1st Edition2008.

EE 5202	Digital Protection of Power systems	PCC	3- 0 - 0	3 Credits

Course Outcomes:

After completion of the course, the student will be able to

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

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO1	3	2	2	1
CO2	3	2	2	1
CO3	1	2	2	3
CO4	2	2	2	3

Detailed 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.

Text Books:

1. A.G.Phadke, James S.Thorp – "Computer Relaying for Power Systems", John-Wiley and sons, 2/e, 2009.
2. Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski- "Digital Signal Processing in Power System Protection and Control" –Springer Publication-1/e, 2011.

3. A.T.Johns and S.K.Salman- "Digital Protection for Power Systems" IEE Power Series 15, 1997.

Reference Books:

1. Singh- “Digital Power System Protection” Prentice-Hall of India Pvt. Limited, 1/e, 2007.
2. Orhan Gazi– “Understanding Digital Signal Processing” Springer, 2/e, 2017.
3. Paithankar Y.G –“Fundamentals of Power System Protection”-PHI, 2/e, 2010
4. A R C Warrington-“Protective Relays-their Theory and Practice”-Chapman & Hall Ltd., 1968

EE 5203	Power Engineering Lab	PCC	0 – 1 – 2	2 Credits

Course Outcomes: After completion 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.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	2	2	2	1
CO2	3	2	2	3
CO3	3	2	3	3

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.

EE 5204	Power System Computation Lab - I	PCC	0 – 1 – 2	2 Credits

Course Outcomes:

After completion of the course, the students 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.

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	1	3
CO-2	3	2	3	2
CO-3	2	2	2	3

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.

EE 5211	Data Science Applications in Power Engineering	DEC	3 – 0 – 0	3 Credits

Course Outcomes:

After completion 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 Systems and Power Electronics and Drives Problems
CO4	Apply appropriate AI frame work for solving power systems and Power Electronics & Drives Problems

CO-PO Mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	2	2	2	2
CO-2	2	2	3	3
CO-3	3	2	3	3
CO-4	3	2	3	3

Detailed 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)

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 & 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.- PWM Vector controlled drive -Speed estimation and flux estimation of induction motor

Text Books:

1.S. Rajasekaran and G.A.V. Pai, “Neural Networks, Fuzzy Logic & Genetic Algorithms”, PHI, New Delhi, 2008.
2.T.J. Ross, “Fuzzy Logic with Fuzzy applications”, Mc Graw Hill Inc, 1997

Reference Books:

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

EE 5212	Economic Operation of Power Systems	DEC	3 – 0 – 0	3 Credits

Course Outcomes: After completion of the course, the student will be able to

CO1	Analyze 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	Spcify strategies for effective planning of power system.

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	2	2	1	2
CO-2	1	2	3	3
CO-3	2	2	3	3
CO-4	3	2	2	3

Detailed 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 – Hydro electric 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.

Text Books:

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

References Books:

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

EE 5213	HVDC Transmission	DEC	3 – 0 – 0	3 Credits

Course Outcomes:
After completion of the course, the student will be able to

CO1	Distinguish HVDC Transmission and EHVAC transmission system.
CO2	Analyze 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.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	2	3
CO3	3	2	3	3
CO4	3	2	3	2

Detailed 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.

Text Books:

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

Reference Books:

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

EE 5214	Smart Grid Technologies	DEC	3– 0 –0	3 Credits

Course Outcomes:

After completion of the course, the 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.

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	2	2
CO-2	1	2	3	3
CO-3	2	2	3	2
CO-4	3	2	3	2

Detailed 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.

Text Books:

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

Reference Books:

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

EE5215	Design And Testing of High Voltage Apparatus	DEC	3 – 0 – 0	3 Credits

Course Outcomes:
After completion of the course, the student will be able to

CO 1	Estimate electric field intensity of electrode configurations for high voltage equipment.
CO 2	Design compact and economical insulation structures for high voltage equipment.
CO 3	Analyze circuits for generation, measurement and testing of High Voltage apparatus.
CO 4	Diagnose the partial discharge activity in power equipment

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	2	3
CO3	2	2	3	3
CO4	3	2	3	3

Detailed 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 capacitanceand stress control techniques.

Design of Instrument Transformers and Cable Joints: Classification based on insulating materialsand 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–housingmaterials -pollution performance-modeling of arrestor-insulation co-ordination.

Text Books:

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

Reference Books:

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

EE5216	Instrumentation and Automation	DEC	3-0-0	3 Credits

Course Outcomes:

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 Conditioning operations and design systems for measurement and instrumentation.
CO3	Synthesize Industrial Automation and Control technologies
CO4	Implement PLCs for Industrial Automation.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	3	3
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	2	3

Detailed 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.

Text Books:

1) Industrial Instrumentation, Control and Automation, S. Mukhopadhyay, S. Sen and A. K. Deb, Jaico Publishing House, 2013

2) Doebelin, Measurement Systems, Applications and Design, Tata McGraw Hill, 2008.

3) W Bolton, "Programmable Logic controllers", Elsevier- newness, 5th edition, 2009.

Reference Books:

1) Alok Barua, "Fundamentals of Industrial Instrumentation", Wiley India Pvt. Ltd., 2011.

2) M.K. Ghosh, S. Sen and S. Mukhopadhyay, "Measurement & Instrumentation: Trends & Applications", Ane Books, 2010.

3) George Stephanopoulos, "Chemical Process Control, An Introduction to Theory and Practice", Prentice Hall India, 2012.

4) Frank. D, Petruzella, “Programmable Logic Controllers”, Tata McGraw Hill Third Edition-2010

EE 5217	Machine Learning and Deep Learning	DEC	3– 0 –0	3 Credits

Course Outcomes:

After completion of the course, the student will be able to

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

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	3	3
CO-2	3	2	3	3
CO-3	2	2	3	3
CO-4	3	2	3	3

Detailed Syllabus:

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

DEEP LEARNING

Neural Networks – Back propagation Algorithm (BPA) – Deep Architectures – Convolutional Neural Networks – Convolutional Layer – Pooling Layer – Normalization Layer- Fully Connected Layer – Deep belief Networks – Recurrent Neural Networks.

Text Books:

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

References Books:

1.Ian Goodfelow, Yoshua Bengio, and Aaron Courville, “Deep Learning” , MIT Press, Cambridge, Massachusetts, London, England, 2016
2.Tom M. Mitchell, “Machine Learning”, McGraw Hill International Edition, 1997

EE5111	Modern Control Theory	DEC	3 – 0 – 0	3 Credits

Course Outcomes:
After completion of the course, the 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

CO-PO Mapping:

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

Detailed Syllabus:

Introduction to linear control system.

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 non linear 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 system.

Text Books:

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

Reference Books:

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

EE5114	High Power Inverters	DEC	3 – 0 – 0	3 Credits

Course Outcomes:
At the end of the course, the 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

CO-PO Mapping:

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

Detailed Syllabus:

Introduction: Double Fourier integral analysis of two-level inverter PWM waveform, Weighted THD, effect of dead-time and compensation, space vector modulation (SVM) of two-level inverter, Implementation of SVM based on instantaneous phase reference voltages, even order harmonic elimination, overmodulation, and discontinuous SVM.

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).

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

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).

Text Books:

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

References Books:

1. Research publications.

EE 5115	Digital Signal Processors	DEC	3 – 0 – 0	3 Credits

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

CO1	Write Assembly Language Programs for the Digital Signal Processors
CO2	Configure and use Digital Input / Output lines and ADCs
CO3	Configure and use Interrupts for real-time control applications
CO4	Configure and use Event Managers for PWM generation

CO-PO Mapping:

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

Detailed Syllabus:
Introduction to the TMS320LF2407 DSP Controller:
Basic architectural features, Physical Memory, Software Tools

C2xx DSP CPU and Instruction Set:
Introduction & code Generation, Components of the C2xx DSP core, Mapping External Devices to the C2xx core, peripheral interface, system configuration registers, Memory, Memory Addressing Modes, Assembly Programming Using the C2xx DSP Instruction set

General Purpose Input/Output (GPIO) Functionality:
Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing, General Purpose I/O control registers, Using the General Purpose I/O Ports

Interrupts on the TMS320LF2407:
Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software

The Analog-to-Digital Converter (ADC):
ADC Overview, Operation of the ADC and programming modes

The Event Managers (EVA - EVB):
Overview of the Event Manager, Event Manager Interrupts, General Purpose Timers, Compare Units, Capture Units and Quadrature Encoded Pulse (QEP), General Event Manager Information, PWM signal Generation with Event Manager

Introduction to TMS320F28335 DSP Controller, Architecture, Peripherals and Interrupts.

Text Books:
1. Hamid A. Tolyat**:** DSP based Electromechanical Motion Control**,** CRC press, 1^{st} ed., 2003.
2. George Terzakis: Introduction to C Programming With the TMS320LF2407A DSP Controller, Createspace Independent Pub, 2011.

Reference books:
1. Application Notes from Texas Instruments.

EE5167	Distributed Power Generation and Grid Integration	PCC	3 – 0– 0	3 Credits

Course Outcomes:

At the end of the course student will be able to

CO1	Understand different renewable energy sources, micro-grid 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

CO-PO mapping:

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

Introduction: Electric grid, Distributed generation, features and operations, advantages and disadvantages of DG, Comparison among the DG Technologies, Importance & Effects of Renewable Energy penetration into the grid.

Micro-Grid: Concept of micro-grids – Types of micro-grids – Autonomous and non-autonomous grids – Sizing of micro-grids - Modeling & analysis - Micro-grids with multiple DGs.

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 and Islanding Operations, stability and protection issues, load sharing, Hybrid energy systems, IEEE & IEC standards for renewable energy grid integrations, Case studies.

Text books:

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

References:

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

EE 5252	Real-Time Control of Power System	PCC	3– 0 –0	3 Credits

Course Outcomes:

After completion 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.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	2	3
CO2	3	2	2	2
CO3	3	2	2	3
CO4	3	2	1	3

Detailed Syllabus:

State Estimation of Power Systems:

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 Equipments in Sub Station, Instrument Transformers, 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 ~~the~~ IEC (International Electrotechnical Commission) communication Standards.

Sub-load Dispatch Center(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 Center (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 Centers (SRLDC) and National Load Dispatch Centrer (NLDC**)-** Functions & Responsibilities of SRLDC, Operations carried at SRLDC, Overview of SCADA, Real Time operation in detail Operations carried out NLDC

Text Books:

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

Reference Books:

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

EE 5253	Power System Stability and Control	PCC	3– 0 –0	3 Credits

Course Outcomes:
After completion 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

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	3	2
CO2	3	2	3	3
CO3	3	2	2	2
CO4	3	2	2	3

Detailed 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.

Text Books:

1.P.M. Anderson & A.A. Fouad: Power System Control and Stability, Willey IEEE Press, 2003.

2.Prabha Kundur: Power Systems stability and Control, McGraw – Hill Inc. Indian edition, 2006.

Reference Books:

1. K R Padiyar: Power System Dynamics Stability and Control, BS Publications, Hyderabad, 2008.

2. M. A. Pai and Peter W. Sauer-“ Power system stability”, , Pearson Education, 2006.

EE 5254	Soft Computing Lab	PCC	0– 1 –2	2 Credits

Course Outcomes:
After completion of the course the student will be able to:

CO1	Analyze and select artificial intelligence techniques for Power Systems.
CO2	Employ fuzzy logic, artificial neural networks and ANFIS for power system problems.
CO3	Apply Evolutionary Techniques in Power Systems.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	2	1
CO2	3	2	3	1
CO3	1	2	3	3

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. Economic Load Dispatch using Differential Evolution.
8. Economic Load Dispatch using Genetic Algorithm
9. Economic Load Dispatch using Particle Swarm Optimization
10. Multiobjective Optimization: Minimization of Fuel Cost and Emission in a Power System

EE 5255	Power System Computation Lab - II	PCC	0– 1 –2	2 Credits

Course Outcomes:

After completion 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	Analyze the power system under fault conditions.

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	3	2
CO-2	2	2	3	1
CO-3	3	2	3	1

List of Experiments:

1. Study of load frequency control problem of Single Area and Two Area Systems with (i) uncontrolled and (ii) controlled cases using simulation software.

2. Economic Load Dispatch of (i) Thermal Units and (ii) Thermal Plants using Conventional method.

3. MVAR Compensation studies on normal and heavily loaded power systems using simulation package

4. Transient Stability Analysis of Power Systems using simulation software.

5. State estimation of power system using DC load flow based WLS-SE.

6. State estimation of power system using NR WLS-SE.

7. Contingency evaluation and analysis of power system using simulation package.

8. Fault studies using Zbus matrix.

EE 5261	Power System Deregulation	DEC	3 – 0 –0	3 Credits

Course Outcomes:
After completion of the course the student will be able to:

CO1	Understand the developments of power system deregulation and restructuring.
CO2	Identify the roles and responsibilities of different entities in power market.
CO3	Explore congestion management, Transmission pricing and Ancillary Services Management.
CO4	Evaluate pricing, transfer capabilities, forecasting through different methods.

CO-PO mapping:

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

Detailed Syllabus:

Overview of key issues in electric utilities:

Introduction, Gencos, Discoms, Independent system operator (ISO), power exchange, market operations, market power, standard cost, transmission pricing, congestion pricing, management of inter zonal/intra zonal congestion.

Restructuring models:
Models based on Trading, Models based on transactions, Hybrid model.

Transmission pricing:
Cost Components, Postage Stamp method, Megawatt Mile method, Contract Path Method.

OASIS (Open Access Same–time Information System)
Structure of oasis, pooling of information, transfer capability on OASIS, Definitions transfer capability issues: ATC, TTC, TRM, CBM calculations, methodologies to calculate ATC.

Electricity Pricing:
Introduction, electricity price volatility, electricity price indexes, challenges to electricity pricing, construction of forward price curves, short–time price forecasting, ANN based price forecasting.

Power system operation in competitive environment:
Introduction, operational planning activities of ISO, ISO in pool markets, ISO in bilateral markets, operational planning activities of a Genco.

Ancillary services management:
Introduction, reactive power as an ancillary service, a review of synchronous generators as ancillary service providers.

Text Books:
1.Loi Lei Lai: Power System Restructuring and Deregulation, 1st Edition, John Wiley & Sons Ltd.,2012,
2.Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder: Operation of Restructured Power Systems, Springer Publishers, 2001.

Reference Books:

1.Ashikur Bhuiya: Power System Deregulation: Loss Sharing in Bilateral Contracts and Generator Profit Maximization, Publisher VDM Verlag, 2008.

2.Mohammad Shahidehpour and Muwaffaqalomoush: Restructured Electrical Power Systems, 1st Edition, Marcel Dekker, Inc., 2001.

EE 5262	Distribution System Planning and Automation	DEC	3 – 0 –0	3 Credits

Course Outcomes:

After completion of the course, the student will be able to

CO 1	Understand and distinguish characteristics of distribution systems from transmission systems
CO 2	To design, analyze and evaluate distribution system design based on forecasted data
CO 3	Identify and select appropriate sub–station location
CO 4	Design and evaluate a distribution system for a given geographical service area from alternate design alternatives

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	1	2	1	1
CO2	3	2	2	2
CO3	3	2	3	2
CO4	3	2	3	2

Detailed 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.

Text books:

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

Reference Books:

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

EE 5263	Flexible AC Transmission Systems	DEC	3 – 0 –0	3 Credits

Course Outcomes: After completion 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	Analyze the performance of Series, Shunt and combined FACTS controllers
CO4	Evaluate the performance and stability of power systems with FACTS controllers

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	3	2
CO2	3	2	2	2
CO3	3	2	3	3
CO4	3	2	3	3

Detailed 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.

Text Books:

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

Reference:

1. K.R. Padiyar, "Facts Controllers in Power Transmission and Distribution", New Age International Publishers, 2016.
2. R. Mohan Mathur and Rajiv K. Varma, "Thyristor- Based FACTS controllers for electrical transmission systems", IEEE Press, 2002.

EE 5265	Energy Auditing And Management	DEC	3 – 0 –0	3 Credits

Course Outcomes: After completion 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, analyze and evaluate an energy audit and the benefits of different energy management techniques

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	2	1	2	3
CO2	1	3	2	2
CO3	2	2	3	3
CO4	1	3	3	3

Detailed 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,

Text books :

1. Amlan Chakrabarti- Energy Engineering and management, PHI, 2018
2. Rajiv Shanker- Energy auditing in Electrical utilities, Viva books Pvt.Ltd., 2015

Reference Books:

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

EE 5266	Power System Reliability And Planning	DEC	3 – 0 –0	3 Credits

Course Outcomes:
After completion 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.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	1	2	2	2
CO2	2	2	3	3
CO3	1	2	3	2
CO4	1	2	3	2

Detailed 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

Text Books:

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

Reference Books:

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

EE 5267	EHV AC Transmission	DEC	3 – 0 –0	3 Credits

Course Outcomes:
After completion of the course, the student will be able to

CO1	Evaluate parameters of EHV line modeling
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.

CO-PO mapping:

	PO1	PO2	PO3	PO4
CO1	3	2	3	2
CO2	3	2	3	3
CO3	3	2	3	3
CO4	3	2	2	2

Detailed 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.

Text Books:

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

Reference Books:

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

2. Md. Abdus Salam, Quazi M. Rahman "Power Systems Grounding" Springer publishers, 2016
3. A Chakraborti, D.P. Kothari and A.K. Mukhopadyay: Performance, Operation and Control of EHV Power Transmission Systems, T.M.H. (Pub) 1992.

EE 5268	Evolutionary Algorithms application in Power Engineering	DEC	3 – 0 – 0	3 Credits

Course Outcomes:
After completion 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 systems engineering applications.

CO-PO mapping:

	PO-1	PO-2	PO-3	PO-4
CO-1	3	2	3	2
CO-2	2	2	2	2
CO-3	1	2	2	3
CO-4	2	2	2	3

Detailed 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- memeplex 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 to power systems.

Text Books:

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

Reference Books:

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

EE 5163	Power Quality Improvement Techniques	DEC	3 – 0 – 0	3 Credits

Course Outcomes:
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 system
CO4	Suggest compensating devices to improve power quality in distribution system

CO-PO Mapping:

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

Detailed 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

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; Interharmonics.

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

Text Books:

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

References Books:

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

EE5164	**Electric Vehicles**	**DE C**	**3 – 0 – 0**	**3 Credits**

Course Outcomes:
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

CO-PO Mapping:

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

Detailed 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, SuperCapacitor 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 and super conducting magnetic storage systems.

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

Text Books:

1. Ali Emadi,Advanced Electric Drive Vehicles, CRC Press, Taylor & Francis Group 2015.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, Second Edition 2003.

References Books:

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

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