NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

RULES AND REGULATIONS
SCHEME OF INSTRUCTION AND SYLLABI
FOR M.TECH POWER SYSTEMS ENGINEERING PROGRAM

Effective from 2016-17

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 centre 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.

GRADUATE ATTRIBUTES

The Graduate Attributes are the knowledge skills and attitudes which the students have at the time of graduation. These attributes are generic and are common to all engineering programs. These Graduate Attributes are identified by National Board of Accreditation.

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. Design/Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. Project management and Finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

DEPARTMENT OF ELECTRICAL ENGINEERING

M.TECH IN POWER SYSTEMS ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES

PEO1.	Design and develop innovative products and services in the field of electrical power systems
PEO2.	keep abreast with the latest technology and toolset.
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

Mapping of Mission statements with program educational objectives

Mission Statement	PEO1	PEO2	PEO3	PEO4
Impart quality education to produce globally competent electrical engineers capable of extending technological services	3	2	3	2
Engage in research & development in cutting edge and sustainable technologies.	1	1	1	1
Nurture scientific temperament, professional ethics and industrial collaboration.	1	2	3	3

Mapping of program educational objectives with graduate attributes

PEO	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11	GA12
PEO1	3	3	3	2	3	2	2	1	2	1	3	3
PEO2	1	1	2	2	3	2	2	1	1			3
PEO3	-	-	-	-	-	1	-	-	3	3	2	2
PEO4	2	3	3	3	3	3	2	1	-	-	-	3

PROGRAM OUTCOMES: At the end of the program the student will be able to:

PO1	Design and develop electric power and energy systems
PO2	Deliver technological solutions in the field of power systems by assimilating advances in allied disciplines
PO3	Simulate and experiment in the field of power systems using modern tools
PO4	Design renewable energy systems to protect environment and ecosystems
PO5	Practice professional ethics with social sensitivity
PO6	Develop innovative and entrepreneurial solutions
PO7	Develop an attitude to learn with self motivation
PO8	Communicate effectively at all levels and demonstrate leadership qualities
PO9	Pursue research to enhance the existing pool of knowledge

Mapping of program outcomes with program educational objectives

PO	PEO1	PEO2	PEO3	PEO4
1	3	2	1	3
2	3	2	1	3
3	3	2	1	3
4	3	2	2	3
5	-	-	2	2
6	3	-	2	3
7	1	3	1	1
8	1	-	3	2
9	3	3	2	3

M.Tech (Power Systems Engineering)
SCHEME OF INSTUCTION AND EVALUATION

I Year I-Semester

S.No.	Course No.	Course Title	L	T	P	Credits
1.	EE5201	Advanced Computational Methods in Power Systems	4	0	0	4
2.	EE5101	Analysis of Power Converters	4	0	0	4
3.	EE5202	Digital Protection of Power Systems	4	0	0	4
4.	EE5203	Power Systems Lab	0	0	3	2
5.	EE5204	Power Systems Computation Lab-I	0	0	3	2
6.		Elective-I	3	0	0	3
7.		Elective –II	3	0	0	3
8.		Elective-III	3	0	0	3
9.	EE5241	Seminar-I	0	0	2	1
		Total	**21**	**0**	**8**	**26**

ELECTIVES (I-Semester):

1. EE5211 AI Techniques in Power Engineering
2. EE5212 Economic Operation of Power systems
3. EE5112 Control &Integration of Renewable Energy Sources
4. EE5213 HVDC Transmission
5. EE5214 Smart Grid Technologies
6. EE5115 Basics of Digital Signal Processors
7. EE5215 Design & Testing of HV Apparatus
8. EE5111 Modern Control Theory
9. EE5216 Microprocessor and Microcontroller Systems

I Year II -Semester

S.No.	Course No.	Course Title	L	T	P	Credits
1.	EE5251	Swarm Intelligence Techniques in Power Systems	4	0	0	4
2.	EE5252	Real-Time Control of Power Systems	4	0	0	4
3.	EE5253	Power System Stability and Control	4	0	0	4
4.	EE5254	Soft Computing Lab	0	0	3	2
5.	EE5255	Power Systems Computation Lab-II	0	0	3	2

6.		Elective-IV	3	0	0	3
7.		Elective -V	3	0	0	3
8.		Elective-VI	3	0	0	3
9.	EE5291	Seminar-II	0	0	2	1
		Total	**21**	**0**	**8**	**26**

ELECTIVES (II-Semester):

1. EE5261 Power System Deregulation
2. EE5262 Distribution System Planning and Automation
3. EE5263 Flexible AC Transmission Systems
4. EE5163 Power Quality Improvement Techniques
5. EE5264 Distributed Generation and Micro Grid
6. EE5265 Energy Auditing and Management
7. EE5266 Power System Reliability and Planning
8. EE5164 Electric Vehicles
9. EE5267 EHVAC Transmission

II - Year I - Semester

S. No.	Course Code	Course Title	L	T	P	Credits
1	EE5142	Comprehensive Viva-voce	0	0	0	2
2	EE 5149	Dissertation-Part-A	0	0	0	6
		Total	-	-	-	**8**

II - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits
1	EE 5199	Dissertation-Part-B	0	0	0	12
		Total				**12**

EE 5201	Advanced Computational Methods in Power Systems	PCC	4– 0 – 0	4 Credits

Course Outcomes:

CO1	Develop proper mathematical models for analysis of a selected problem like load flow study of Power System and Distribution Network or Fault analysis.
CO2	Prepare the practical input data required for load flow or fault calculations.
CO3	Select and identify the most appropriate algorithm for load flow and short circuit studies.
CO4	Develop power system software /implementation algorithm for static power system studies.

Basic power system components – Physical parameters – Significance of per unit representation, Typical single line diagram of a power system. 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) Computer Methods in Power System Analysis, Stagg and El – Abiad, McGraw Hill, ISE, 1986
(2) Power System Analysis, Hadi Sadat, McGraw Hill – International Edition – 1999
(3) Computer Modeling of Electrical Power Systems, J.Arrilaga and NR Watson, John Wiley and Sons.
(4) Computer techniques in Power System Analysis, M A Pai and Dr. Dheeman Chatterjee, McGraw hill, 3e.

EE5101	Analysis of Power Converters		4 – 0 – 0	4 Credits

Course Outcomes:

CO1	Select an appropriate power semiconductor device and design a power converter for the required application
CO2	Determine the power circuit configurations to fulfill the required power conversion with applicable constraints
CO3	Design the control circuit and the power circuit for a given power converter
CO4	Design DC-DC converters, DC-AC inverters and front-end AC-DC converters

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT- MOSFET- IGBT- GTO- GaN Design of driver and snubber circuit, Series and parallel operation of switching devices

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- expression for filter inductor and capacitors, High gain DC-DC converters.

Inverters: Single-phase and three-phase inverters- PWM techniques: single- multiple- and sinusoidal PWM techniques- selective harmonic elimination- space vector modulation- current source inverter- multi-level inverters- Diode-clamped, cascaded, and Flying capacitor types,concept of active Filters

Front-End (AC-DC) Converters: PWM rectifiers-configuration types, three-phase full and semi converters- reactive power- power factor improvements – extinction angle control- symmetrical angle control- PWM control

Text books:

1. M.H. Rashid **:**Power Electronics-circuits, Devices & Applications**,** 3rd ed.,PHI, 2005.
2. N Mohan, T.M. Undeland, WP.Robbins**:** Power Electronics: Converters, Applications**,** 3rd ed.,John Wiley & Sons, 2009.

References:

1. Umanand, L., Power Electronics: Essentials and Applications, chapters 1 to 7, John Wiley, India, 2009.
2. JayantBaliga B, Power Semiconductor Devices, PWS 1996.
3. Current literature

EE 5202	Digital Protection of Power systems	PCC	4– 0 – 0	4 Credits

Course Outcomes:

CO1	Recognize the advantages of digital relays over conventional relays
CO2	Apply the suitable signal processing technique for protection
CO3	Apply correction for measurements due to errors in instrument transformers
CO4	Understand the adaptive criterion for relay decision making
CO5	Identify the new developments in protective relaying and applications.

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

Digital filters – Fundamentals of Infinite Impulse Response Filters, Finite Impulse Response filters, Filters with sine and cosine windows

Correction of errors introduced by Instrument Transformers- PTs and CTs, detection of unsaturated fragment of waveshape, 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. Digital Protection for Power Systems A.T.Johns and S.K.Salman,
2. Digital Signal Processing in Power System Protection and Control – WaldemarRebizant, Springer Publication
3. Computer Relaying for power Systems A.G.Phake, James S.Thorp, John-Wiley and sons

References: Selected papers in the concerned area

EE 5203	Power System Lab	PCC	0 – 0 – 3	2 Credits

Course Outcomes: 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 them with the practical power system.

Detailed syllabus:

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 Analyser
5. Short circuit studies on DC Network Analyser
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. Characteristics of PV Array
10. Grounding grid design for a two layer soil model using AUTOGRID PRO software simulation

EE 5204	Power System Computation Lab - I	PCC	0 – 0 – 3	2 Credits

Course Outcomes:

CO1	Analyze the power system data for load-flow and fault studies.
CO2	Applycomputational methodsfor large scale powersystem studies.
CO3	Develop softwarefor power systemindustry

Detailed syllabus:

1. Solution of simultaneous Algebraic equations by Gauss–Elimination – Crout's method and Cholesky method
2. Solution of Simultaneous differential equations by RK–4 and Modified Euler's method
3. Program to read and print out the power system load flow data of 5 BUS – IEEE 14 Bus and IEEE 30 Bus systems
4. Formation of Ybus using two dimensional arrays by inspection method
5. Formation of Ybus using Sparsity Technique
6. Load flow by Gauss Seidel – Newton Raphson and Fast Decoupled methods using two – dimensional arrays – sparsity techniques and MATLAB
7. Distribution system load flow using backward forward method.

EE 5211	AI Techniques in Power Engineering	EC	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Differentiate between Algorithmic based methods and knowledge based methods
CO2	Use the soft computing techniques for power system problems
CO3	Use appropriate AI framework for solving power system problems
CO4	Apply GA to power system optimization problems

INTRODUCTION: Artificial Neural Networks (ANN) – definition and fundamental concepts – Biological neural networks – Artificial neuron – activation functions – setting of weights – typical architectures – biases and thresholds – learning/training laws and algorithms. Perceptron – architectures, ADALINE and MADLINE – linear separability- XOR function.

ANN PARADIGMS: ADALINE – feed forward networks – Back Propagation algorithm- number of hidden layers – gradient decent algorithm – Radial Basis Function (RBF) network. Kohonen's self organizing map (SOM), Learning Vector Quantization (LVQ) and its types – Functional Link Networks (FLN) – Bidirectional Associative Memory (BAM) – Hopfield Neural Network.

CLASSICAL AND FUZZY SETS: Introduction to classical sets- properties, Operations and relations; Fuzzy sets, Membership, Operations, Properties, Fuzzy relations, Cardinalities, Membership functions.

FUZZY LOGIC CONTROLLER (FLC): Fuzzy logic system components: Fuzzification, Inference engine (development of rule base and decision making system), Defuzzification to crisp sets- Defuzzification methods.

APPLICATIONS OF ANN AND FLC:
Applications of ANN- Load flow, Economic load dispatch, Load forecasting, PWM controllers, selected harmonic elimination- PWM space vector- PWM vector controlled drive- Speed estimation and flux estimation of induction motor.
Applications of FLC- Load frequency control- Single area and two area systems- Speed control of DC motor.

Text Books

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan and pai – PHI Publication.
2. Fuzzy logic with Fuzzy Applications – T.J Ross – Mc Graw Hill Inc, 1997.

References

1. Neural Networks: A comprehensive Foundation – Simon Haykins, Pearson Edition, 2003.
2. Yegnanarayana B, "Artificial Neural Networks", Prentice hall of India Private Ltd., New Delhi, 1999.
3. Zurada, J.M., 'Introduction to Artificial Neural Systems', Jaico publishing house, Bombay, 1992.
4. Zimmermann, H.J., 'Fuzzy set theory and its applications', Allied publishers limited, Madras, 2001.

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

Course Outcomes:

CO1	Analyze Thermal and Hydro generator characteristics and their economic operation.
CO2	Solve the Unit Commitment problem with various constraints using conventional optimization techniques
CO3	Solve ELD, UC and AGC problems using Heuristic techniques.

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.

Text Books

1. Elgerd.O.I, "*Electric Energy System Theory – an Introduction*", - Tata McGraw Hill, New Delhi, 2002.
2. Allen J.Wood and Bruce.F.Wollenberg, "*Power Generation Operation and Control*", 2nd Edition, John Wiley & Sons, New York, 1996.

References

1. Robert H. Miller, James H. Malinowski, 'Power System Operation', Tata McGraw Hill, 2009.
2. Abhijit Chakrabarti and Suita Halder, "Power System Analysis, Operation and Control", PHI, 3rd Edition 2010.

EE 5112	Control and Integration of Renewable Energy Sources	EC	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Knowledge on different renewable energy sources and storage devices
CO2	Recognize, model and simulate different renewable energy sources
CO3	Analyze, model and simulate basic control strategies required for grid connection
CO4	Implement a complete system for standalone/grid connected system

Cahpter-1: Introduction

Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements

Chapter-2: Dynamic Energy Conversion Technologies

Introduction to different conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind based generation technologies, control and integrated operation of different dynamic energy conversion devices

Chapter-3: Static Energy Conversion Technologies

Introduction to different conventional and nonconventional static generation technologies, principle of operation and analysis of fuel cell, photovoltaic based generators, and wind based generation technologies, different storage technologies such as batteries, fly wheels and ultra capacitors, plug-in-hybrid vehicles, control and integrated operation of different static energy conversion devices

Chapter-4: Real and reactive power control

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

Chapter-5: Integration of different Energy Conversion Technologies

Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

Text books:

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

References:

1. Quing-Chang Zhong, “Control of Power Inverters in Renewable Energy and Smart Grid Integration”, Wiley, IEEE Press

2. Bin Wu, Yongqiang Lang, Navid Zargari, “Power Conversion and Control of Wind Energy Systems”, Wiley 2011.
3. Ned Mohan, Tore M. Undeland, William P. Robbins, "Power Electronics: Converters, Applications, and Design", Wiley Publishers
4. Selected scientific and engineering papers, articles from professional magazines, and industry internet sources as reference material.

EE 5213	HVDC TRANSMISSION	EC	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Compare the HVDC Transmission and EHVAC transmission
CO2	Compare the performances between HVDC with Current Source Converters and Voltage Source Converters
CO3	Identify and analyze converter configurations used in HVDC and list the performance metrics
CO4	Understand controllers for controlling the power flow through a dc link Understand the performance of VSC based HVDC under DC fault conditions

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		3– 0 –0	3 Credits

Course Outcomes:

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

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).

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, 2013
2. Gil Masters, Renewable and Efficient Electric Power System, Wiley–IEEE Press, 2004.

Reference Books:

1. A.G. Phadke and J.S. Thorp, “Synchronized Phasor Measurements and their Applications”, Springer Edition, 2010.
2. T. Ackermann, Wind Power in Power Systems, Hoboken, NJ, USA, John Wiley, 2005

EE 5115	**Basics of Digital Signal Processors**	**EC**	**3 – 0 – 0**	**3 Credits**

Course Outcomes:

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

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

Text Books:

1. Hamid A. Tolyat, “DSP Based Electro Mechanical Motion Control”-CRC press, 2004.

Application Notes from the webpage of Texas Instruments.

EE 5215	Design and Testing of High Voltage Apparatus	EC	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Design a compact and economical insulation structure for high voltage equipment.
CO2	Estimate electric field intensity of various electrode configurations for high voltage power equipment.
CO3	Understand the testing methods of High Voltage Equipment
CO4	Understand the methods to diagnose the partial discharge activity in a power equipment

INTRODUCTION: History of high voltage engineering, High voltage power networks, Future of HV Engineering. Electric strength, classification of Electric Fields, control of electric Field intensity, basic equations for potential and field intensity in electrostatic fields, Analysis of electric field intensity in homogenous and multidielectric electric fields, numerical methods for estimation of electric field intensity.

HIGH VOLTAGE OVERHEAD LINES: Towers and supports, conductors, dampers, foundations, Insulator design, electrical discharges, European standards, Testing.
HIGH VOLTAGE CABLES: Components of insulated power cable, design features Testing, diagnostics.
HIGH VOLTAGE BUSHINGS: Types of bushings, Bushing design, Bushing applications, Testing, maintenance and diagnosis.
HIGH VOLTAGE POWER TRANSFORMERS: Insulation design concepts – winding assembly, cooling system insulation, tank and bushings, on load tap changers, dielectric design, electromagnetic design, winding short circuit forces. Testing- specifications and standards, Noise levels, temperature rise, lightning and switching impulses testing and diagnosis

GENERATION OF HIGH VOLTAGES & 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.

TEXT BOOK:

H.M. Ryan: High Voltage Engineering & Testing, IEE Press, 1994.

REFERENCE BOOK:

1. High Voltage Insulation Engineering, Wolfgaug Mosch New Age International Publishers, 1995.

2. E. Kuffel, W.S. Zaengl, J. Kuffel, High voltage Engineering Fundamentals, Newnes Publishers, 2011

EE 5111	Modern Control Theory	EC	3– 0 – 0	3 Credits

Course Outcomes:

CO1	Develop mathematical models of dynamic physical systems.
CO2	Design optimal controllers for physical systems including power electronic and power systems.
CO3	Determine the stability of linear and nonlinear control systems.
CO4	Linearize a given nonlinear system

Detailed syllabus

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. State transition matrix – Properties and methods of valuation – Time response of linear systems – State diagrams – Resolvant matrix – Resolvant algorithm. Definition and concepts – Criteria for controllability and observability – State variable feedback – Pole placement – Luenberg observer design. 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. 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.

Reading:

1. Katsuhiko Ogata: Modern control Engineering, Prentice–Hall of India, 2010
2. M. Gopal: Modern Control Systems Theory, Wiley Eastern Limited, New Delhi, 2005
3. Schultz and Melsa: State functions & linear control systems McGraw Hill Book Co... New York, 1998.
4. Chidambara and Ganapathy: An Introduction to control of dynamic systems, Sehgal Educational consultants and publishers Pvt. Ltd. Faridabad

EE 5216	Microprocessors and Microcontrollers	EC	3– 0 – 0	3 Credits

Course Outcomes:

CO1	Understand the basic architecture of a 8086 microprocessor
CO2	Write the assembly language program for a given application.
CO3	Write interrupt sub routine program for all interrupt types.
CO4	Interface memory and peripheral devices
CO5	Interface external devices including serial…devices with 8051 and PIC microcontrollers

Detailed Syllabus:

8086 Architecture – internal operation – addressing modes – instruction formats – Evolution of Processor architectures – Review of 80386 – 80486 and Pentium architectures – Assembler instruction format – Instruction set–Data transfer – Arithmetic – Branch and Loop instructions – Directives and operators – Byte and string manipulation – Number format conversion – Table translation – Stacks and Subroutines – Macros – Procedures – Procedure calls from high level language programs – Programmed I/O – Interrupt I/O – Structure of interrupts in 8086 – Block transfer and DMA – Structure of computer system – Hardware foundations – Bus standards – Types of Buses – 8–bit ISA and PC Bus standard – Bus timing – access and arbitration – Minimum and maximum mode configurations of 8086 – Memory interfacing – interfacing of memory with wait states – Serial communication interface – 8251A and RS 232 standard – Parallel communication interface – 8255A – A/D and D/A conversion – interfacing examples – Programmable timers and event counters – 8254 – DMA controllers (8257) and Interrupt controller (8259) and Interrupt priority management – 8087 – Interrupt system – interfacing tothe 8086/8086 system – 16–bit Micro controller architecture – simple programs and applications.

Reading:

1. Yu Cheng Liu and Glenn A.Gibson: Microcomputer Systems: The 8086 / 8088 family – Architecture, Programming and Design, PHI–Second Edition, 2009.
2. Douglas V. Hall: Microprocessors and Interfacing, TMH–Revised Second Edition, 2005.
3. Barry B.Brey: The Intel Microprocessors, 8086 to Pentium Pro Processor Architecture, Programming and Interfacing, Pearson publishers, 2010.

EE 5251	Swarm Intelligence Techniques in Power Systems	PCC	4 – 0 – 0	4 Credits

Course Outcomes:

CO1	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimisation problems.
CO2	Examine the importance of exploration and exploitation swarm intelligent system to attain near global optimal solution.
CO3	Distinguish the functioning of various swarm intelligent systems.
CO4	employ various bio-inspired algorithms for Power systems engineering applications.

Course 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.

ANT COLONY OPTIMIZATION and ARTIFICIAL BEE COLONY ALGORITHMS

Biological ant colony system - Artificial ants and assumptions - Stigmergic communications - Pheromone updating- local-global - Pheromone evaporation - ant colony system- ACO models-Touring ant colony system-max min ant system - Concept of elistic ants-Task partitioning in honey bees - Balancing foragers and receivers - Artificial bee colony (ABC) algorithms-binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units.

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, 2015.
2. Kalyanmoy Deb ‘Multi-Objective Optimization using Evolutionary Algorithms’, John Wiley & Sons, 2001.

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

Reference Books:

4. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, ‘Swarm Intelligence-From natural to Artificial Systems’, Oxford university Press, 1999.
5. David Goldberg, ‘Genetic Algorithms in Search, Optimization and Machine Learning’, Pearson Education, 2007.
6. Konstantinos E. Parsopoulos and Michael N. Vrahatis, ‘Particle Swarm Optimization and Intelligence: Advances and Applications’, InformatIon scIence reference, IGI Global, , 2010.
7. N P Padhy, ‘Artificial Intelligence and Intelligent Systems’, Oxford University Press, 2005.

Reference Papers:

1. “Shuffled frog-leaping algorithm: a memetic meta-heuristic for discrete optimization” by Muzaffar eusuff, Kevin lansey and Fayzul pasha, Engineering Optimization, Taylor & Francis, Vol. 38, No. 2, pp.129–154, March 2006.
2. “A New Metaheuristic Bat-Inspired Algorithm” by Xin-She Yang, Nature Inspired Cooperative Strategies for Optimization (NISCO 2010) (Eds. J. R. Gonzalez et al.), Studies in Computational Intelligence, Springer Berlin, 284, Springer, 65-74 (2010).
3. “Firefly Algorithms for Multimodal Optimization” Xin-She Yang, O. Watanabe and T. Zeugmann (Eds.), Springer-Verlag Berlin Heidelberg, pp. 169–178, 2009.

EE 5252	Real-Time Control of Power System	PCC	4– 0 –0	4 Credits

Course Outcomes:

CO1	Develop mathematical models for analysis of linear and non–linear State Estimation, Observability and Contingency analysis of any practical Power System
CO2	Prepare the practical input data required for linear and non–linear State Estimation methods and Contingency studies.
CO3	Identify the strategic locations for measurements to analyses the state of the
CO4	To have complete overview of Real Time operation of Power system(RTPS) and communication & protocols employed in RTPS.

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. Types of SE. Detection and Identification of bad measurements – Network Observability and Pseudo–measurements – observability by Graphical technique and Triangularisation approach – Optimal meter placement – Application of Power System SE. Incorporation of PMU data in WLS-SE.

Security Analysis of Power System:

Concept of security – Security analysis and monitoring – factors affecting Power System Security – Contingency Analysis for Generator and Line Outages by Fast Decoupled Inverse Lemma–based approach – Network Sensitivity factors. Contingency selection.

Real Time Control of Power Systems:

Need for Real Time and Computer Control of Power Systems – Operating states of a Power System

SCADA Functions

Introduction to SCADA: Grid Operation & Control, Difficulties in operating the large power systems manually, need for going to SCADA operation, advantages of SCADA operation. Lay out of substation / Generating Station, Main Equipment in Sub Station/ Generating Station, Instrument Transformers and their importance in measurements and protection, important parameters necessary for Grid operation: Analog Points (MW, MVar, Tap Position, Voltage, Frequency), Status Points (CB Status, Isolator Status, SOE Points), Alarms. Hardware required to get these parameters to RTU: 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 and its use, Operator Dialogs, Mimic Diagram Functions, Printing Facilities.

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 for Electrical Power Systems

Power System Control requirements and 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.

(Ref: www.dnp.org,www.modbus.org, www.kema.nl)

Sub-load Dispatch Center(Sub-LDC)

Various Equipment in Sub LDC: (a) Work Stations: details (b) FEPS: Function of FEPS(Front End Processors). (c) Routers : function of routers, interconnectivity of the equipment by LAN, Functionality and responsibilities 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 and Bruce Woolenberg: Power System Generation, Operation and Control, John Wiley and Sons, 1996.
2. John J. Grainger and William D Stevenson Jr.: Power System Analysis, McGraw Hill ISE, 1994.
3. IEEE Proc. July 1974, Special Issue on Computer Control of Power Systems.
4. Power System control – Technology – by Torsten Cegrell, Prentice –Hall International series in Systems and control Engineering, Prentice Hall International Ltd., 1986.
5. Real – Time Computer Control – by S. Bennett and D.A. Linkens (Editors), IEE Control Engineering series (24), peter Peregrinus Ltd., 1984.

REFERENCE BOOK

Real – Time Systems – by C.M. Krishna and Kangg. Shin, Mc Graw-Hill international companies

EE 5253	Power System Stability and Control	PCC	4– 0 –0	4 Credits

Course Outcomes:

CO1	Develop mathematical models of power system for dynamic studies
CO2	Analyze the performance of single and multi-machine systems under transient, steady state and dynamic conditions.
CO3	Design stabilizers, dynamic resistors and SMES for the power system.

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 Dynamic Stability Criteria:

Normal conditions – Direct and indirect steady state stability criteria of simple and multi– machine systems – practical stability criteria; Dynamic stability of SMIB system & MMP Systems.

Transient Stability Studies:

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

Methods To Improve Stability:

Methods to improve steady state – Dynamic stability /PSSs/transient and voltage stability.

Text Books:

1 P.M. Anderson & A.A. Fouad: Power System Control and Stability, Iowa State University Press.

2 Prabha Kundur: Power Systems stability and Control, McGraw – Hill Inc. New York, 1994

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

EE 5254	Soft Computing Lab	PCC	0– 0 –3	2 Credits

Course Outcomes:

CO1	Analyze and pick the best artificial intelligence technique for a given Power System problem.
CO2	Identify and use modern tools like fuzzy logic, artificial neural networks and ANFIS for power system problems.
CO3	Use ANN, Fuzzy, GA toolboxes of MATLAB.

Detailed Syllabus:

1. Load Flow analysis using Neural Network
2. State Estimations using Neural Network
3. Contingency Analysis using Neural Network
4. Power system Security using Neural Network
5. Fuzzy Logic based AGC – Single area system – Two area system
6. Fuzzy Logic based small signal stability analysis
7. Simulation and verification of fuzzy Logic experiments using fuzzy logic trainer.

EE 5255	**Power System Computation Lab - II**	**PCC**	**0– 0 –3**	**2 Credits**

Course Outcomes:

CO1	Asses the different state estimation techniques.
CO2	Evaluate the economic dispatch of coordinated thermal unit.

Detailed Syllabus:

1. Simulation of Single Area and Two Area Systems using MATLAB Simulink Package.
2. Study of load frequency control problem of (i) uncontrolled and (ii) controlled cases
3. Economic Dispatch of (i) Thermal Units and (ii) Thermal Plants using Conventional and ANN & GA algorithms
4. MVAR Compensation studies on normal and heavily loaded power systems using PSCAD package
5. Contingency evaluation and analysis of power system using POWER WORLD simulator
6. Transient Stability Analysis of Power Systems using MATLAB Simulink Package,
7. State estimation of power systems.

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

Course Outcomes:

CO1	Understand the developments of restructuring worldwide.
CO2	Identify the roles and responsibilities of different entities in power market.
CO3	Explore issues like congestion management, Transmission pricing, Ancillary Services Management.

Detailed Syllabus:

Overview of key issues in electric utilities:
Introduction – Gencos – Discoms–Independent system operator (ISO) – power exchange.
Restructuring models:
Models based on Trading – Models based on transactions – Hybrid model – market operations – market power – standard cost.
Transmission pricing:
Cost Components – Postage Stamp method – Megawatt Mile method – Contract Path Method. Congestion pricing – Preventive and corrective measure – management of inter zonal/intra zonal congestion.
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 – the ISO in pool markets – the ISO in bilateral markets – operational planning activities of a Genco.
Ancillary services management:
Introduction – reactive power as an ancillary service – a review – synchronous generators as ancillary service providers.

Reading:

1. Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder: Operation of Restructured Power Systems, Springer Publishers, 2001.
2. Mohammad Shahidehpour and Muwaffaqalomoush – Restructured Electrical Power Systems, 1st Edition, Marcel Dekker, Inc., 2001.
3. Loi Lei Lai, 'power system restructuring and Deregulation' , John Wiley & Sons Ltd., England

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

Course Outcomes:

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

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. Turan Gonen : Electric Power Distribution Engg., Mc-Graw Hill,1986.
2. James A Momoh: Electric Power Distribution, Automation, Protection and Control, CRC press.
3. A. S. PABLA : Electric Power Distribution, TMH,2000.

EE 5263	**Flexible AC Transmission Systems**	**EC**	**3 – 0 –0**	**3 Credits**

Course Outcomes:

CO1	Understand the need for control of power flow and identify methods for it.
CO2	Analyse the performance of VSCs to control real power, reactive power and harmonic
CO3	Analyse the performance of Series, Shunt and combined controllers
CO4	Improve the performance of power systems with FACTS controllers

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

Current source and Voltage source converters, Harmonics in 3-phase bridge converter, 12 pulse and 24 pulse converters, Pulse width modulation techniques, Elimination of harmonics and voltage control

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, improvement of transient stability, power oscillation damping, Switching converter based Voltage and Phase angle regulator,

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

Text Books:

1. "Understanding FACTS – Concepts and Technology of Flexibile AC Transmission Systems" NarainG.Honorani, Laszlo Gyugyi,
2. "Flexible AC Transmission Systems (FACTS)" Yong Hua Song & Allan T Johns

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

Course Outcomes:

CO1	Assess the severity of power quality problems in distribution system;
CO2	Analyze current and voltage related power quality issues
CO3	Develop control techniques for compensating devices

Introduction to the Power Quality Issues: Definition and 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: 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: Passive power filters: Design, Advantages and disadvantageous; Shunt active power filters: Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire shunt active power filters

Voltage Quality: Sources of Sags, Swell, Unbalance and Harmonics; Voltage quality standards; Effects of sags, Swell, Unbalance and harmonics; 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: Series active power filters: Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire series active power filters

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, Application of multilevel inverters in large rating active power filters

Text books:

1. Electrical Power Systems Quality, Dugan Roger C, Santoso Surya, McGranaghan , Marks F. Beaty and H. Wayre, 3rd edition, McGraw Hill, 2012.
2. Power System Harmonics, J. Arrillaga, N.R. Watson, John Wiley & Sons Ltd, Second Edition, 2003.
3. Instantaneous Power Theory and Applications to Power Conditioning, Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes, Wiley-IEEE Press, 2007.
4. Understanding power quality problems, Math H. Bollen, IEEE Press.

References:

1. Power Quality Enhancement Using Custom Power Devices, Ghosh Arindam, LedwichGerard, Springer, 2009.
2. Power Quality: Problems and Mitigation Techniques, Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Wiley, 2014.
3. IEEE Transactions and Standards.

EE 5264	Distributed Generation and Micro-Grids	EC	3 – 0 –0	3 Credits

Course Outcomes:

CO1	Understand the current scenario of Distributed Generation and the need to implement DG sources.
CO2	Investigate the different types of interfaces for Grid integration of DGs.
CO3	Appraise the technical impacts of DGs upon transmission and distribution systems.
CO4	Evaluate the various control aspects and techniques of different distributed generation sources.
CO5	Associate different types of micro-grids and analyze the transients and protection related issues in micro-grids.

Need for distributed generation - Renewable sources in distributed generation - Current scenario in distributed generation - Planning of DGs – Siting and sizing of DGs – Optimal placement of DG sources in distribution systems.

Grid integration of DGs – Different types of interfaces - Inverter based DGs and rotating machine based interfaces - Aggregation of multiple DG units - Energy storage elements - Batteries, ultra-capacitors, flywheels.

Technical impacts of DGs – Transmission systems, Distribution systems, De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems.

Economic and control aspects of DGs – Market facts, issues and challenges - Limitations of DGs - Voltage control techniques, Reactive power control, Harmonics, Power quality issues - Reliability of DG based systems – Steady state and Dynamic analysis.

Introduction to micro-grids – Types of micro-grids – Autonomous and non-autonomous grids – Sizing of micro-grids - Modeling & analysis - Micro-grids with multiple DGs – Micro-grids with power electronic interfacing units - Transients in micro-grids - Protection of micro-grids – Case studies.

Text Books:

1. H. Lee Willis, Walter G. Scott , ‘Distributed Power Generation – Planning and Evaluation’, Marcel Decker Press, 2000.
2. M.Godoy Simoes, Felix A.Farret, ‘Renewable Energy Systems – Design and Analysis with Induction Generators’, CRC press.
3. Robert Lasseter, Paolo Piagi, ‘ Micro-grid: A Conceptual Solution’, PESC 2004, June 2004.
4. F. Katiraei, M.R. Iravani, ‘Transients of a Micro-Grid System with Multiple Distributed Energy Resources’, International Conference on Power Systems Transients (IPST’05) in Montreal, Canada on June 19-23, 2005.
5. Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson, ‘Facility Microgrids’, General Electric Global Research Center, Niskayuna, New York, Subcontract report, May 2005.

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

Course Outcomes:

CO1	Understand the need and importance of energy audit and management
CO2	Identify the equipment and areas of a system where energy conservation and audit is necessary
CO3	Identify the type and need for instruments used in energy audit
CO4	Design and analyse a process of conducting an energy audit
CO5	Evaluate the benefits of different energy management techniques

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, Evaluation of energy conserving opportunities and environmental management, Preparation and presentation of energy audit reports, case studies 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. 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.

Reference Books

1. D. A. Reay, Industrial Energy Conservation - Pergamon Press, 1980. T.L. Boten,
2. Liptak B.G., (Ed) Instrument Engineers Handbook, Chinton Book Company, 2004.
3. Hodge B.K, Analysis and Design of Energy Systems, Prentice Hall, 2002.

EE 5266	Power System Reliability and Planning	EC	3 – 0 –0	3 Credits

Course Outcomes:

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

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

EE 5164	Electric Vehicles	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Understand the basic concepts of electric vehicles and popular traction systems.
CO2	Analyze the characteristics of train movement other traction mechanics.
CO3	Understand the drive-train topologies and advanced propulsion techniques.
CO4	Analyze the various energy storage methodologies and systems of train lighting

Introduction: Conventional vehicles - basics of vehicle performance - vehicle power source characterization - transmission characteristics - mathematical models to describe vehicle performance - History of electric vehicles - social and environmental importance of electric vehicles - impact of modern drive-trains on energy supplies.

Methods of traction - track electrification - DC system - single phase and three-phase low frequency and high frequency system - composite system - kando system - comparison between AC and DC systems - problems of single phase traction with current unbalance and voltage balance.

Traction mechanics: Mechanics of traction movement - speed-time curves for different services - trapezoidal and quadrilateral speed-time curves - tractive effort requirements and problems - power - specific energy consumption - effect of varying acceleration and braking - Retardation - adhesive weight and braking retardation - coefficient of adhesion.

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

Train lighting: Special requirements of train lighting - methods of obtaining unidirectional polarity constant output-single battery system - Double battery parallel block system - coach wiring - Lighting by making use of 25 KV AC supply.

Electric propulsion unit: Introduction to electric components used in electric vehicles - Configuration and control of DC Motor drives - Configuration and control of Induction Motor drives - Configuration and control of Permanent Magnet Motor drives - Configuration and control of Switch Reluctance Motor drives - Drive system efficiency, Concept of Hybrid Electric Vehicles

Energy storage: Introduction to Energy Storage Requirements in Electric Vehicles - Battery based energy storage and its analysis - Fuel Cell based energy storage and its analysis - Super Capacitor based energy storage and its analysis - Flywheel based energy storage and its analysis - Hybridization of different energy storage devices

Text books:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2014.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

References:

1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. H. Partab: Modern Electric Traction - DhanpatRai& Co, 2007.
4. S. Rao: EHV AC and HVDC Transmission Engineering and Practice, 3rd edition, Khanna Pub, 1997.

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

Course Outcomes:

CO1	Understand issues of concern with EHVAC transmission
CO2	Identify and calculate the various parameters of EHV line for modeling
CO3	Assess the effects of corona and methods to limit the audible noise
CO4	Estimate the over–voltages in EHV AC systems
CO5	Design grounding system for EHVAC systems

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, 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.

Theory of reactive power control
Theory of steady state reactive power control in transmission system, uncompensated transmission lines, fundamental transmission line equation, surge impedance loading, uncompensated line on open circuit / under load. Passive shunt compensation, control of open circuit voltage with shunt reactors, voltage control with switched shunt compensation, Midpoint shunt reactor or capacitor. Series compensation, objectives and limitations symmetrical line with mid-point series capacitance and shunt reactor.

Power System Grounding
Analysis of simple grounding systems, body currents due to touch and step voltages, grounding system safety assessment, Basic design of grounding, Mitigation of touch and step voltages, Design example of a substation grounding.

TEXT BOOKS:

1. Rakesh Das Begamudre : Extra High Voltage Ac Transmission Engineering, PHI (pub) 1991.
2. T.J.E.Miller : Reactive Power Control in Electric Systems, John Wiley & Sons, 1986

REFERENCE BOOKS:

1. Turan Gonen: Electric Power Transmission System Engineering Analysis and Design, McGraw Hill (Pub) 1991
2. A Chakraborti, D.P. Kothari and A.K. Mukhopadyay: Performance, Operation and Control of EHV Power Transmission Systems, T.M.H. (Pub) 1992.
3. AP Sakis Meliopoulos: Power System Grounding and transients