SREE VIDYANIKETHAN ENGINEERING COLLEGE
(Autonomous)
DEPARTMENT OF EEE
COURSE STRUCTURE for M.Tech. (EPS)
I-SEMESTER

Subject Code	Subject	L	T	P	C	Max. Marks		
						Int.	Ext.	Total
14MT10701	Power System Security and State Estimation	4	-	-	4	40	60	100
14MT10702	Static and Digital Protection of Power System	4	-	-	4	40	60	100
14MT10703	Advanced Power System Stability Analysis	4	-	-	4	40	60	100
14MT10704	Power Electronic Converters	4	-	-	4	40	60	100
14MT10705	Advanced Control Systems	4	-	-	4	40	60	100
Elective – I								
14MT10706	Microcontrollers and Applications	4	-	-	4	40	60	100
14MT10707	Reactive Power Compensation and Management							
14MT10708	Solar and Wind Energy Conversion Systems							
14MT10709	Optimization Techniques							
14MT10310	Research methodology	3	-	-	3	40	60	100
Laboratory								
14MT10721	Power Systems and Relays lab	-	-	4	2	25	50	75
	Total	**27**	**-**	**4**	**29**	**305**	**470**	**715**

II-SEMESTER

Subject Code	Subject	L	T	P	C	Max. Marks		
						Int.	Ext.	Total
14MT20701	Operation and Control of Power System	4		-	4	40	60	100
14MT20702	Flexible AC Transmission System	4		-	4	40	60	100
14MT20703	Power Quality	4		-	4	40	60	100
14MT20704	Smart Grid Technology	4		-	4	40	60	100
14MT20705	Intelligent Control	4		-	4	40	60	100
Elective – II								
14MT20706	High Voltage DC Transmission	4	-	-	4	40	60	100
14MT20707	Restructured Power System							
14MT20708	Power System Reliability							
14MT20709	Energy Audit, Conservation and Management							
Laboratory								
14MT20721	Power Systems Simulation lab	-	-	4	2	25	50	75
14MT20722	Seminar	-	-	-	2	-	50	50
	Total	**24**	**-**	**4**	**28**	**265**	**460**	**725**

III-SEMESTER

Subject Code	Course	Periods per Week			C	Int.	Ext.	Total
		L	T	P*				
14MT30721	Project Work Phase-I	-	-	-	4	40	-	40
Total		-	-	-	4	40	-	40

*Fulltime Project Work

IV-SEMESTER

Subject Code	Course	Periods per Week			C	Int.	Ext.	Total
		L	T	P*				
14MT40721	Project Work Phase-II	-	-	-	12	40	120	160
Total		**-**	**-**	**-**	**12**	**40**	**120**	**160**

*Fulltime Project Work

Total Credits: 73 **Total Marks: 1700**

M. Tech. (EPS), I-Semester
(14MT10701) POWER SYSTEM SECURITY AND STATE ESTIMATION

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power system Analysis at UG level

COURSE DESCRIPTION:
Power system network matrices; AC and DC Load flow studies; Balanced and unbalanced Short circuit analysis; Power system security; Methods of Power System State estimation

COURSE OUTCOMES:
On successful completion of the course, student will be able to
1. demonstrate knowledge on:
   - formation of network matrices.
   - developing load flow solutions and fault analysis for different operating conditions.
   - state estimation and security analysis of power systems.
2. analyze the state and security of power system state for operational contingencies.
3. apply the concepts of state estimation in designing operational strategy for secured operation of power system.

DETAILED SYLLABUS:
UNIT-I: POWER SYSTEM NETWORK MATRICES
Formation of bus admittance matrices by direct inspection method - Algorithm for formation of Bus impedance matrix: addition of a branch and addition of a link, removal element in Bus impedance matrix – Simple problems. Π-representation of off-nominal tap transformers.
UNIT-II: POWER FLOW STUDIES
Introduction to load flow analysis. Classification of buses, Load flow solution methods – Gauss-Seidal method, Newton Raphson method, Decoupled and fast decoupled load flow, Comparison of load flow methods, DC power flow method – Simple problems.
UNIT-III: FAULT ANALYSIS
Short circuit studies – introduction, short circuit calculations using Z_{bus}, Z_f^{abc}, Y_f^{abc}, Z_f^{012} and Y_f^{012} matrices for various faults. Analysis of balanced and unbalanced three phase faults – Simple problems.
UNIT-IV: POWER SYSTEM SECURITY
Introduction to power system security, Factors influencing power system security, Contingency analysis: Detection of Network problems, linear

sensitivity factors, AC power flow methods, Contingency selection, concentric relaxation, bounding – simple problems.

UNIT-V: STATE ESTIMATION IN POWER SYSTEM

Power system state estimation, Methods of state estimation – method of least squares, orthogonal decomposition, Treatment of bad data – applications to power system state estimation – simple problems.

TEXT BOOKS:

1. Allen J.Wood and Wollenberg B.F., *Power Generation Operation and control*, John Wiley & Sons, 2nd edition, 2006.
2. Nagrath I.J. and *Kothari D.P., Modern Power System Analysis,* TMH, New Delhi, 2004.

REFERENCES:

1. Grainger J.J. and Stevenson W.D., *Power System Analysis*, Tata McGraw Hill, New Delhi, 2003.
2. Stagg and El Abiad*: Computer methods in power systems analysis*, McGraw Hill ISE, 1986.

M. Tech. (EPS), I-Semester
(14MT10702) STATIC AND DIGITAL PROTECTION OF POWER SYSTEMS

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Switchgear and Protection and Microprocessors and Microcontrollers at UG level.

COURSE DESCRIPTION:
Fundamentals of static and digital relays; Amplitude and Phase Comparators; characteristics of Static over current and differential relays; Static Distance relays; Numerical relays

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge in
   - digital and numerical relays.
   - Operation of static and microprocessor based relays.
2. implement advanced skills in protection of power system components.
3. design and develop different power system protection schemes.
4. select and apply different relays in real time power system protection.

DETAILED SYLLABUS
UNIT-I: **INTRODUCTION TO STATIC AND DIGITAL RELAYS**
Static Relays - basic construction and advantages. Level detectors, Replica impedance, Mixing circuits, Phase and Amplitude Comparators – General equation for two input phase and amplitude comparators, Duality between Phase and Amplitude Comparators
Numerical Relays: Block diagram of typical Numerical Relay – Advantages and Disadvantages.
UNIT-II: **COMPARATORS**
Amplitude comparators: Circulating current type, opposed voltage type rectifier bridge comparators – Direct and Instantaneous comparators.
Phase comparators: Coincidence circuit type - block spike phase comparator, techniques to measure the period of coincidence – Integrating type – Rectifier and vector product type phase comparators.
Multi–Input comparators: Conic section characteristics – Three input amplitude comparator – Hybrid comparator.
UNIT-III: STATIC OVER CURRENTAND DIFFERENTIAL RELAYS
Static over current relays: Introduction, Instantaneous over current relay – Time over current relays. Basic principles – Definite time, Inverse Definite time and Directional over current relays.
Static Differential Relays: Analysis of Static differential relays – static relay schemes – Duo bias transformer differential protection – Harmonic restraint relay.

UNIT-IV: STATIC DISTANCE RELAYS
Static impedance, Reactance, MHO and angle impedance relays – sampling comparator – realization of reactance and MHO relays using a sampling comparator.
Power Swings: Effect of power swings on the performance of distance relays, Power swing analysis, Principle of out-of-step tripping and blocking relays, effect of line length and source impedance on distance relays.
UNIT-V: MICROPROCESSOR BASED PROTECTIVE RELAYS
Microprocessor based over current relays, Impedance relay, Directional relay, Reactance relay. Generalized mathematical expression for distance relays, measurement of resistance and reactance, MHO and offset-MHO relays – Realization of MHO characteristics, realization of offset MHO characteristics – Microprocessor Implementation of Digital Distance Relaying Algorithms.

TEXT BOOKS:

1. T.S. Madhava Rao, *Power system Protection static relay*, 2nd edition, Tata McGraw Hill Publishing Company limited, 2004.
2. Badri Ram and D.N. Vishwakarma, *Power system Protection and Switchgear*, 2nd edition, Tata McGraw Hill Publication Company limited, 2013.

REFERENCE BOOKS:

1. Bhuvanesh A Oza, Nirmal Kumar C Nair et., al., *Power system protection and switchgear*, Tata McGraw Hill Publication Company Limited.

M. Tech. (EPS), I-Semester
(14MT10703) ADVANCED POWER SYSTEM STABILITY ANALYSIS

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power System operation and control, Power system Analysis and Control systems at UG level

COURSE DESCRIPTION:
Introduction to the synchronous machine classical model; state space models of synchronous machine; Methods of Excitation systems and modelling; Effect of excitation on stability; Analysis of Voltage stability

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
    - transient and dynamic stability studies for large power systems.
    - modeling of SMIB, multi-machine systems and excitation systems.
    - voltage control and reactive power management concepts.
2. assess various control schemes for better performance of the interconnected power system with economic considerations.
3. design and develop efficient control techniques for enhancement of voltage stability, rotor-angle stability and reactive power control in large interconnected power systems.

DETAILED SYLLABUS:

UNIT-I: THE ELEMENTARY MATHEMATICAL MODEL

A Classical model of single machine connected to infinite bus – Problems. System Response to small Disturbances: Block diagram of unregulated and regulated synchronous machine, methods of studies – Effect of small changes of speed. Regulated synchronous machine – voltage regulator with one time lag – Governor with one time lag.
Classical model of multi-machine system – modes of oscillation of unregulated Multi-machine system – Problems.

UNIT-II: THE SYNCHRONOUS MACHINE MODEL

Introduction – Clarkes's and Park's Transformation – flux linkage equations, self and mutual inductances of stator and rotor, transformation of inductances – formulations of state space model of one machine system connected to infinite bus, voltage, current equations – effect of excitation on Dynamic stability – examination of dynamic stability by Routh's criterion.

UNIT-III EXCITATION SYSTEMS

Simplified view of excitation control – Control configuration – Excitation system response – Non-continuously regulated systems – continuously regulated systems – Excitation system compensation – state space description of the excitation system - simplified linear model.

Types of Excitation systems: Type-2 system: rotating rectifier system, Type-3 system: Static with terminal potential and current supplies, Type-4 system: non–continuous acting - Block diagram representation – state space representation.

UNIT-IV: EFFECT OF EXCITATION ON STABILITY

Introduction – effect of excitation on generator power limits – Effect of the excitation system on Transient stability. Approximate model of the complete exciter – generator system – Supplementary stabilizing signals – Block diagram of the linear system – Lead compensation – Stability aspect using Eigen value approach.

UNIT-V: VOLTAGE STABILITY ANALYSIS

Voltage stability – factors affecting voltage instability and collapse – Comparison of angle and voltage stability – Analysis of voltage instability collapse – Control of voltage instability.

Review of Lyapunov's stability theorems of non-linear systems using energy concept – Method based on first concept – Method based on first integrals – Quadratic forms – Variable gradient method – Zubov's method – Popov's method, Lyapunov function for single machine connected to infinite bus.

TEXT BOOKS:

1. P.M. Anderson, A.A. Fouad, *Power System Control and Stability*, 2nd edition, IEEE Press, 2003.
2. K.R. Padiyar, *Power System Dynamics (Stability & Control)*, 2nd edition, B.S. Publications, Hyderabad, India, 2008.

REFERENCES:

1. Prabha Kundur, Neal J.Balu, Mark G.Lauby, *Power System Stability and Control*, 2nd edition, McGraw-Hill, 1994.
2. M.A. Pai, *Power System Stability – Analysis by the direct method of Lyapunov*, North Holland Publishing Company, New York, 1981.

M. Tech. (EPS), I-Semester
(14MT10704) POWER ELECTRONIC CONVERTERS

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power Electronics at UG level.

COURSE DESCRIPTION:
Power Semiconductor Devices; Controlled Rectifiers; AC Voltage Controllers, operation and analysis of Cycloconverters; Analysis of DC-DC and Resonant Converters; Multi Level Inverters and PWM techniques

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate in-depth knowledge in advanced Power devices and converters.
2. analyze and design power converter modules for various applications in power industry.
3. extend the concepts of power electronic converters for HVDC and FACTS.

DETAILED SYLLABUS
UNIT-I: MODERN POWER SEMICONDUCTOR DEVICES
Power Diode - Reverse recovery characteristics, types. Steady state characteristics and switching characteristics of Power transistors (power MOSFET, IGBT) and Thyristors(GTO, IGCT). Gate drive circuits for SCR, MOSFET, IGBT and Base drive circuit for Power BJT. Comparison of power devices.
UNIT-II: MULTI-PULSE CONTROLLEDRECTIFIERS
Six pulse SCR rectifiers – semi and full converters, operation with different firing angles-Effect of line inductance - power factor and THD. Power factor improvement – extinction angle control, symmetric angle control, PWM control – single and three phase control. Three phase dual converters. Single phase series converters. Twelve pulse SCR rectifiers – idealized 12 pulse rectifier operation, effect of line and leakage inductance, power factor and THD. 18 and 24 pulse SCR rectifiers, operation.
UNIT-III: AC VOLTAGE CONTROLLERS AND CYCLOCONVERTERS
Single phase AC voltage controllers with R, RL and RLE loads. AC voltage controllers with PWM Control. Effect of source and load inductances. Synchronous tap changers – Applications. Three Phase AC Voltage Controllers – Analysis of controllers with star and delta Connection, applications, numerical problems. Single phase and three phase cycloconverters – analysis with Mid-point and bridge configurations – Limitations – Advantages – Applications – numerical problems
UNIT-IV: ANALYSIS OF DC-DC AND RESONANT CONVERTERS
Voltage commutated chopper. Current commutated chopper. Switch mode regulators – buck, boost, buck-boost and cuk regulators – condition for

continuous inductor current and capacitor voltage - design of LC filter – comparison of regulators. Multi-output boost converters – advantages, applications, Numerical problems Resonant Converters – Concept of ZVS and ZCS, principle of operation, analysis of M-type and L-type Converters

UNIT-V: PWM AND MULTI LEVEL INVERTERS

Voltage control of single phase inverters – single, multiple, sinusoidal, modified sinusoidal pulse width modulation, phase displacement control Advanced PWM techniques – trapezoidal, staircase, stepped, harmonic injection, delta modulations Voltage control of three phase inverter - sinusoidal PWM, 60 degree PWM, third harmonic PWM, space vector modulation. Harmonic reduction Multilevel inverters – Types – diode clamped, flying capacitor, cascaded – operation, features, applications.

TEXT BOOKS:

1. Rashid M.H., *Power Electronics Circuits, Devices and Applications*, 3rd edition, Prentice Hall publications, 2009.
2. Ned Mohan, Undeland and Robbin, *Power Electronics: Converters, Application and Design*, John Wiley and sons Inc., Newyork, 1995.

REFERENCE BOOKS:

1. Bin Wu, *High power converters and AC Drives,* John Wiley and Sons, 2006.
2. P.C Sen, *Modern Power Electronics*, 1st edition, Wheeler publishing Company, 1998.

M. Tech. (EPS), I-Semester
(14MT10705) ADVANCED CONTROL SYSTEMS

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Control Systems at UG level

COURSE DESCRIPTION:
Advanced concepts of controllability, observability; Analysis of non-linear systems; Lyapunov stability and design of controllers and observers; optimal control concepts

COURSE OUTCOMES:
On successful completion of the course, student will be able to
1. demonstrate knowledge in state space analysis, controllability, observability, stability of linear and non-linear control systems.
2. apply describing function, Phase-Plane methods and Lyapunov's stability criterion for non-linear system stability analysis.
3. design controllers and observers using state feedback techniques.

DETAILED SYLLABUS
UNIT–I: CONTROLLABILITY AND OBSERVABILITY
Review of state variable techniques – Concept of controllability and observability, Tests for Controllability and Observability for Continuous Time Systems – Principle of Duality, Controllability and Observability of State Models in Jordan Canonical Form and Other Canonical Forms – Effect of State Feedback on Controllability and Observability.
UNIT–II: ANALYSIS OF NON-LINEAR SYSTEMS
Introduction to Nonlinear Systems, Types of physical Non-linearities, Characteristics of non-linearities, properties of nonlinear systems. Describing Functions, Derivation of Describing Functions for: Dead Zone, Saturation, Backlash, Relay with Dead Zone and Hysteresis. Stability analysis of non-linear systems through describing functions. Phase-Plane Analysis, Singular Points, Isocline method, Delta method.
UNIT-III: STABILITY ANALYSIS
Stability in the Sense of Lyapunov, Lyapunov stability theorems, Definiteness, Sylvester principle, stability analysis by Lyapunov second method, Lyapunov functions, Krasovskii's Method, Variable gradient method
UNIT–IV: CONTROLLERS AND OBSERVERS DESIGN
Design of State Feedback Controller through Pole Placement - Full Order Observer and Reduced Order Observer, state regulator problem
UNIT–V: OPTIMAL CONTROL
Introduction to Optimal Control - Formulation of Optimal Control Problems - Calculus of Variations, Minimization of functional of Single Function, Euler Lagrange Equation, Constrained Minimization, Minimum Principle, Control Variable Inequality Constraints.

TEXT BOOKS:

1. M. Gopal, *Modern Control System Theory*, 2nd edition, New Age International Publishers, 1996.
2. K. Ogata, *Modern Control Engineering,* 3rd edition, Prentice Hall of India, 1998.

REFERENCE BOOKS:

1. I.J. Nagrath and M.Gopal, *Control Systems Engineering*, New Age International (P) Ltd. 2007.
2. M. Gopal, *Digital Control and State Variable Methods,* Tata Mc Graw-Hill Companies, 1997.

M. Tech. (EPS), I-Semester
(14MT10706) MICROCONTROLLERS AND APPLICATIONS
(Elective - I)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Digital logic, Microprocessors and Microcontrollers at UG level

COURSE DESCRIPTION:
8051 Microcontroller: Architecture, Programming and Interfacing; PIC Microcontrollers: Architecture, features, programming and Interfacing

COURSE OUTCOMES:
On successful completion of the course, student will be able to
1. demonstrate knowledge on
   - architecture of 8051 and PIC microcontroller
   - variants of 8051 and PIC
2. critically analyze and develop a suitable interface with an appropriate Microcontroller for the control operations.
3. develop programs for stand-alone systems.

DETAILED SYLLABUS
UNIT–I: 8051 MICROCONTROLLER
Overview of 8051 microcontrollers. 8051/8052 – architecture and features. Memory – internal / external Program, Data memory and their interfacing. Data memory – Register Bank, Bit addressable space, scratch pad area. Special Function Registers (SFRs). Instruction set – Data transfer, Arithmetic, logical, branch control instructions. Addressing modes. Timers – Mode - 0, 1, 2 and 3 operations, TMOD, TCON. Timer applications – wave generation, Device control operations.
UNIT-II: INTERFACING
Basics of serial communication – RS232, MAX232, Baud rate. Serial port programming - SCON, SMOD, SBUF, PCON. Interrupts – IE, TCON, IP. Applications using interrupts of 8051/8052 – wave generation, Device control operations. Interfacing – ADC, DAC, DC motor and PWM
UNNIT-III: PIC MICROCONTROLLERS
CISC Vs RISC. Harvard Vs Von Neumann architectures. PIC16F87XA architecture and features. PIC16 Memory organization – program memory, data memory. PIC Register file – General purpose registers and SFRs.
Introduction to PIC Assembly Programming, PIC Data Format and Directives. PIC programming tools. Instruction set – data transfer, arithmetic, logical, bit manipulation, branch Instructions. I/O Port Programming. Addressing modes – Immediate, Direct, Register Indirect Addressing Modes. Macros and Modules.
UNIT–IV: SERIAL, INTERRUPT, I/O PORTS AND TIMER PROGRAMMING
I/O ports – Port A, TRISA, Port B, TRISB, Port C TRISC. Timer - 0, 1, 2 modules. Compare mode, capture mode. PIC Serial Port programming, PIC

Interrupts, Programming Timer Interrupts, Programming the Serial Communication Interrupts, Port-B - Change Interrupt, Interrupt Priority in the PIC.

UNIT–V: PIC INTERFACING

ADC Characteristics, ADC Programming in the PIC, DAC Interfacing, Sensor Interfacing and Signal Conditioning, Standard and Enhanced CCP Modules, Compare Mode Programming, Capture Mode Programming, PWM Programming, ECCP Programming, Relays and Opto-isolators, Stepper Motor Interfacing, DC Motor Interfacing and PWM, PWM Motor Control with CCP, DC Motor Control with ECCP.

TEXT BOOKS:

1. Muhammad Ali Mazidi, Jancie Gillispie Mazidi, Rolin McKinlay, *The 8051 Microcontroller and Embedded Sytems using Assembly and C*, 2^{nd} edition, Pearson Education.
2. John B. Peatman, *Design with PIC Microcontrollers*, Pearson Education, 2007.

REFERENCE BOOKS:

1. PIC16F87XA manual.
2. Muhammad Ali Mazidi, Rolin D. McKinlay, Danny Causey, *PIC Microcontroller and Embedded Systems using assembly and C for PIC 18,* Pearson Education, 1999.
3. John B. Peatman, *Embedded design with the PIC18F452 Microcontroller*, Printice Hall, 2003.

M. Tech. (EPS), I-Semester
(14MT10707)REACTIVE POWER COMPENSATION AND MANAGEMENT
(Elective - I)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power Systems at UG level

COURSE DESCRIPTION:
Reactive Power Compensation: Line and Load compensation; compensating devices; Reactive power coordination: Power Quality; Reactive power management in Domestic and Industrial Sectors

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
   - different methods of reactive power compensation.
   - types of load patterns and loss reduction methods in distribution lines.
   - quality of power supply and reactive power coordination
2. analyze different types of compensations.
3. apply skills in designing a compensator for an industrial application.

DETAILED SYLLABUS

UNIT-I: REACTIVE POWER COMPENSATION

Need for Reactive Power compensation – reactive power characteristics. Ideal compensator, Practical compensation – power factor correction and voltage regulation. Load compensator as a voltage regulator, phase balancing and power factor correction of unsymmetrical loads– examples.

UNIT-II: REACTIVE POWER COMPENSATION IN TRANSMISSION SYSTEMS

Steady state Reactive power compensation – Uncompensated line. Types of compensation, Passive shunt, series and dynamic shunt compensation – examples.

Transient state Reactive power compensation – Characteristic time periods. Passive shunt compensation. Static compensations – series capacitor compensation, compensation using synchronous condensers - examples.

UNIT-III: REACTIVE POWER COORDINATION

Reactive power coordination: Objective, Mathematical modeling, Operation planning, transmission benefits. Basic concepts of quality of power supply: Disturbances, steady – state variations, effects of under voltages, frequency, Harmonics, radio frequency and electromagnetic interferences.

UNIT-IV: REACTIVE POWER MANAGEMENT

Demand side management: Load patterns, basic methods of load shaping, power tariffs, KVAR based tariffs penalties for voltage flickers and Harmonic voltage levels.

Distribution side Management: System losses, loss reduction methods, examples, Reactive power planning: Objectives, Economic Planning, capacitor placement and retrofitting of capacitor banks.

UNIT-V: REACTIVE POWER MANAGEMENT IN DOMESTIC AND INDUSTRIAL SECTORS

KVAR requirements for domestic appliances: Purpose of using capacitors, selection of capacitors, deciding factors. Types of available capacitor – characteristics and Limitations. Typical layout of traction systems–reactive power control requirements. Distribution transformers, Electric arc furnaces, textile and plastic industries, furnace transformer, filter requirements, remedial measures, and power factor of an arc furnace.

TEXT BOOKS:

1. T.J.E.Miller, *Reactive power control in Electric power systems*, John Wiley and Sons, 1982
2. D.M. Tagare, *Reactive power Management*, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.

REFERENCES:

1. Wolfgang Hofmann, Jurgen Schlabbach, Wolfgang Just, *Reactive Power Compensation: A Practical Guide*, Wiley, April, 2012

M. Tech. (EPS), I-Semester
(14MT10708) SOLAR AND WIND ENERGY CONVERSION SYSTEMS
(Elective - I)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PREREQUISITES:
Power Electronics and Non-Conventional Energy Resources at UG level.

COURSE DESCRIPTION:
Non-Conventional energy resources; Wind and Solar energy systems: design and operation; Power Conditioning Schemes for Solar and Wind Energy systems; Impact of power quality problems

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on role of power electronics for renewable energy.
2. analyze the power conditioning schemes for grid connected systems.
3. apply skills in designing wind, solar systems and their integration.

DETAILED SYLLABUS

UNIT-I: INTRODUCTION TO RENEWABLE ENERGY SYSTEMS
Renewable Energy systems, Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass and Fuel cell.

UNIT-II: DESIGN AND OPERATION OF WIND POWER SYSTEM
Wind Power System: Components, Turbine Rating, Electrical Load Matching, Variable-Speed operation, system design features, Maximum Power Operation, System Control Requirements, Speed Control, Rate Control and Environmental Aspects. Wind Energy Conversion Systems and their Classification.

UNIT-III: DESIGN AND OPERATION OF PV SYSTEM
Solar Photovoltaic Power System: The PV Cell, Module and Array, Equivalent Electrical Circuit, Open Circuit Voltage and Short Circuit Current, I-V and P-V Curves, Array Design, Peak Power Point Operation, PV System Components.
Solar Thermal System: Energy Collection, Synchronous Generator, Equivalent Electrical circuit, Excitation Methods, Electrical Power Output, Transient Stability Limit, Commercial Power Plants.

UNIT-IV: POWER CONDITIONING SCHEMES FOR SOLAR AND WIND ENERGY SYSTEMS
Switching devices for solar energy conversion: DC power conditioning converters, maximum power point tracking algorithms, AC Power conditioners, Line commutated inverters, synchronized operation with grid supply, Harmonic reduction.

Wind energy Conversion system (WECS): Performance of Induction generators for WECS, Self excited induction generator (SEIG) for isolated power generators. Controllable DC power from SEIGs, system performance, Grid related problems, generator control, AC voltage controllers, Harmonic reduction and Power factor improvement.

UNIT-V: POWER QUALITY ISSUES IN INTEGRATION OF RENEWABLE ENERGY RESOURCES

Stand alone and Grid connected systems, Power Quality issues, Impact of power quality problems on DG, Mitigation of power quality problems, Role of custom power devices in Distributed Generation.

TEXT BOOKS:

1. Mukund. R. Patel, *Wind and Solar Power Systems*, CRC Press, 1999.
2. G.D. Rai, *Non - Conventional Energy Resources*, Khanna Publishers, 2002.

REFERENCES:

1. Daniel, Hunt. V, *Wind Power – A Hand Book of WECS*, Van Nostrend Co., New York, 1998.
2. Arindam Ghosh, Gerard Ledwich, *Power Quality Enhancement Using Custom Power Devices,* Springer, 2002.
3. Roger C. Dugan, Mark E. Mc. Granaghan, Surya Santosoh and H. Wayne Beaty, *Electrical Power Systems Quality*, 2nd edition, TATA McGraw Hill, 2010.

M. Tech. (EPS), I-Semester
(14MT10709) OPTIMIZATION TECHNIQUES
(Elective - I)

Int. Marks	Ext. Marks	Total Marks		L	T	P	C
40	60	100		4	--	--	4

PRE-REQUISITES:
Probability and Statistics and Mathematical Methods at UG level.

COURSE DESCRIPTION:
Linear and Nonlinear programming; one dimensional and multi-dimensional search methods; Dynamic programming

COURSE OUTCOMES:
On successful completion of the course, student will be able to
1. demonstrate knowledge on:
   - Linear programming.
   - Non-linear programming
   - Dynamic Programming Assessment.
   - Univariate Estimation.
2. analyze problems on queuing models and develop convincing solutions.
3. apply problem solving skills in dynamic and static system.

DETAILED SYLLABUS
UNIT-I: **LINEAR PROGRAMMING**
Formulation of LPP, Graphical Method, Basic Definitions, Simplex method, Duality theory, Fundamental theorem, Dual Simplex Method, Primal Dual method, Sensitivity analysis. Transportation and Assignment problems: Shortest path problem, Max-flow problem and Mini - cost Flow Problem.
UNIT-II: NON-LINEAR PROGRAMMING
Convex sets and functions, constrained optimization methods: Introduction, Kuhn-Tucker conditions, convex optimization, Lagrange multipliers, One-dimensional minimization method, search method, unconstrained and constrained optimization.
UNIT- III: ONE DIMENSIONAL SEARCH METHODS
Unimodal functions, simultaneous uniform search method, Sequential search method, Fibonacci search method, Golden section search method.
UNIT-IV: MULTI-DIMENSIONAL SEARCH METHODS
Multi-dimensional Search Methods: Univariate search method, Method of steepest descent, Conjugate gradient method, Fletcher Reeves method,
Constrained Multi-dimensional Search Methods: Rosen's Gradient projection method, Penalty function method.
UNIT-V: DYNAMIC PROGRAMMING
Dynamic programming: Multistage decision problems, computation procedure and case studies. Fundamentals of queuing system, Poisson process, the birth and death process, special queuing methods.

TEXT BOOKS:

1. S.S Rao, *Optimization: Theory and Practices*, New Age Int. (P) Ltd. Publishers, New Delhi.
2. S. D. Sharma, *Operations Research*, S Chand Publications, New Delhi, 2008.

REFERENCE BOOKS:

1. TahaH.A., *Operations Research; An Introduction*, 7th edition, Mac Millan Publishing Co., 2003.
2. Pant J.C., *Introduction to Optimization techniques (Operations Research)*, 6th edition, Jain Brothers, New Delhi, 2005.
3. S. Hira and P.K.Gupta., *Problems in Operations Research*, S Chand Publications, New Delhi, 2007.

M. Tech. I-Semester
(14MT10310) RESEARCH METHODOLOGY
(Common to all M. Tech. Programmes)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	3	--	--	3

PRE-REQUISITES: --

COURSE DESCRIPTION:
Fundamentals of research work - research problem and design; Data collection, Analysis and hypothesis; Statistics in Research; Interpretation and Report Writing.

COURSE OUTCOMES:
On successful completion of course, the student will be able to

1. Demonstrate knowledge on research approaches, research process and data collection.
2. Identify and analyze research problem.
3. Solve the research problems using statistical methods.
4. Carryout literature survey and apply good research methodologies for the development of scientific / technological knowledge in one or more domains of engineering.
5. Learn, select and apply modern engineering tools to complex engineering activities.
6. Write effective research reports.

DETAILED SYLLABUS:
UNIT-I: INTRODUCTION TO RESEARCH METHODOLOGY
Objectives and Motivation of Research, Types of Research, Research Approaches, Research Process, Criteria of good Research.
UNIT-II: RESEARCH PROBLEM AND DESIGN
Defining and Formulating the Research Problem, Problem Selection, Necessity of Defining the Problem, Techniques involved in Defining a Problem. Features of Good Design, Research Design Concepts, Different Research Designs.
UNIT-III: DATA COLLECTION, ANALYSIS AND HYPOTHESIS
Different Methods of Data Collection, Processing Operations, Types of Analysis, Basic Concepts of Testing of Hypothesis, Hypothesis Testing Procedure.

UNIT-IV: STATISTICS IN RESEARCH

Review of Statistical Techniques - Mean, Median, Mode, Geometric and Harmonic Mean, Standard Deviation, Measure of Asymmetry. Normal Distribution, Chi-Square Test as a Test of Goodness of Fit.

UNIT-V: INTERPRETATION AND REPORT WRITING

Interpretation – Techniques and Precautions. Report Writing – Significance, Stages, Layout. Types of reports, Precautions in Writing Reports.

TEXT BOOK:

1. C.R. Kothari, *Research Methodology: Methods and Techniques*, New Age International Publishers, New Delhi, 2nd Revised edition, 2004.

REFERENCE BOOKS:

1. Ranjit Kumar, *Research Methodology: A step-by-step guide for beginners*, Sage South Asia, 3rd edition, 2011.
2. R. Panneerselvam, Research Methodology, PHI learning Pvt. Ltd., 2009.

M. Tech. (EPS), II-Semester
(14MT10721)POWER SYSTEMS AND RELAYS LAB

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
25	50	75	--	--	4	2

PRE-REQUISITES:
Electrical Machines and Power Systems at UG Level

COURSE DESCRIPTION:
Relay testing, fault analysis, determination of sequence reactances of power system components, dielectric strength of transformer oil and synchronous machine power angle characteristic.

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate in-depth knowledge in power system protection and testing of relays.
2. analyze and apply protective schemes and testing methods in the field of power systems.
3. apply skills in identifying, selecting and developing suitable protection schemes for reliable operation of power system.
4. execute real time projects in the field of power system operation and control.

List of experiments:
Conduct any Twelve experiments from the following:

1. Determination of Sub-transient reactances of Salient Pole Synchronous Machine.
2. Determination of Sequence Impedances of Cylindrical Rotor Synchronous Machine.
3. Fault Analysis
   i) LG and LL Faults
   ii) LLG and LLLG Faults
4. Measurement of Dielectric Strength of Transformer Oil Using Variable Electrodes.
5. Reactive power compensation using Tap changing transformer.
6. Power Angle Characteristic of Three-Phase Salient Pole Synchronous Machine.
7. Long Transmission line analysis.
8. Determination of Sequence Components of Salient Pole Synchronous Machine.
9. Scott Connection of Transformers.
10. Characteristics of Over Current Relay.
11. Characteristics of Over Voltage Relay.
12. Characteristics of Percentage Biased Differential Relay.
13. Testing of Frequency Relay.
14. Testing of Reverse Power Relay.

M. Tech. (EPS), II-Semester
(14MT20701) OPERATION AND CONTROL OF POWER SYSTEMS

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	3

PRE-REQUISITES:
Power Systems operation and control, Control Systems at UG level
Power System security and state estimation at PG level

COURSE DESCRIPTION:
Economic dispatch problem with and without Transmission losses; Optimal power flow problem; Unit commitment; Hydro-thermal scheduling; Automatic generation control in an interconnected power systems.

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
   - economic operations of various power plants and their scheduling methods.
   - coordination of hydro thermal power plant for optimal and secured operation.
   - automatic generation control importance and their control strategies for reliable operation of interconnected power systems.
2. apply skills to envisage and solve problems to obtain optimal solution in power system operation and control for the needs of industry and society.
3. apply various optimization algorithms for:
   - optimal generation scheduling of thermal power plants.
   - scheduling and coordination of hydro thermal power plants.
   - regulation of load frequency control problems.

DETAILED SYLLABUS:
UNIT-I: ECONOMIC DISPATCH OF GENERATING PLANTS
Economic operation importance – generator unit characteristics – Economic dispatch problem without transmission losses. Solution methods of economic dispatch: Gradient method, Reduced Gradient method, Newton's method, Base point and participation factor method – simple problems.
UNIT-II: TRANSMISSION SYSTEM EFFECTS AND OPTIMAL POWER FLOW PROBLEM
Economic dispatch problem with transmission losses. Expression for transmission loss - Simple problems. Optimal power flow problem – Optimal power flow with inequality constraints – problem formulation, steepest descent method. Optimal power flow with equality constraints on control variables and dependent variables.

UNIT-III: UNIT COMMITMENT

Characteristics of thermal units – Input-Output characteristics, Heat Rate and Incremental Heat Rate characteristics, Fuel cost and Incremental Fuel cost characteristics, Incremental production cost, start-up and shut-down costs. Unit commitment – unit commitment Vs economic dispatch, constraints in unit commitment. Unit commitment solution methods: Priority-List method, Dynamic Programming method – simple problems.

UNIT-IV: HYDROTHERMAL CO-ORDINATION

Long-term and short-term hydro-scheduling problem. Short-term hydrothermal scheduling – condition for optimal operation and maximum efficiency, gradient approach. Hydro units in series. Pumped-storage hydro-scheduling – λ-γ iteration method, gradient method–hydrothermal scheduling using dynamic programming and linear programming. Security constrained unit commitment.

UNIT-V: AUTOMATIC GENERATION CONTROL IN INTERCONNECTED POWER SYSTEMS

Load frequency control Vs Economic dispatch control. Review of single area load frequency control. Two area LFC – Flat frequency regulation, Parallel frequency regulation, Flat tie-line loading control, Tie-line load bias control. AGC features – AGC Implementation– static response of uncontrolled and controlled two-area system – Optimal LFC control for two area AGC. Power exchange in interconnected utilities: utility energy evaluation – Power pools – Transmission effects and Issues: Limitations –Wheeling.

TEXT BOOK:

1. Allen J. Wood & B.F. Woolenberg, *Power Generation, Operation and Control*, John Wiley & Sons, New York, 2006.
2. Nagrath, I.J. and Kothari D.P., *Modern Power System Analysis*, 3rd edition,Tata McGraw-Hill, New Delhi.

REFERENCES:

1. D.P. Kothari & J.S. Dhillon, *Power System Optimization*, Printice Hall of India, 2004.

M. Tech. (EPS), II-Semester
(14MT20702) FLEXIBLE AC TRANSMISSION SYSTEM

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
1. Power Electronics and Power Systems at UG level
2. Power Electronic Converters and Microcontrollers and Applications at I-Sem. of M.Tech. EPS

COURSE DESCRIPTION:
Need for Flexible AC transmission systems; objectives of shunt and series compensation, phase angle regulators; FACTS controllers: shunt, series and combined; Coordination of various FACTS controllers.

COURSE OUTCOMES:
On successful completion of the course, student will be able to
1. demonstrate knowledge on:
   - compensation schemes for real and reactive power control.
   - Static Shunt, Series and Shunt-Series compensation.
   - FACTS devices
2. critically analyze and adopt a suitable FACTS device for the appropriate control operation.
3. apply skills in coordination of multiple FACTS controllers in an interconnected power systems.

DETAILED SYLLABUS
UNIT-I: INTRODUCTION TO AC TRANSMISSION SYSTEMS
Overview of interconnected power system. Power flow in AC systems – Expression for real and reactive power flow between two nodes of a power system, controllable parameters. Power flow in parallel and meshed system. Overview of uncompensated transmission lines – open circuit, short circuit. Overview of compensated transmission lines – shunt and series compensation. Conventional controllers for real and reactive power flows – merits and demerits. FACTS – benefits, types of FACTS controllers.
UNIT-II: STATIC SHUNT COMPENSATION
Objectives of shunt compensation, Expression for real and reactive power flow with mid-point voltage regulation. Variable impedance type static VAR generators - V-I characteristics and control schemes of TCR, TSR, TSC. Q_D-Q_O characteristic and control scheme of TSC-TCR. Switching converter type VAR generators – V-I characteristics and control schemes of STATCOM. Hybrid VAR generators – V-I characteristics of SVC and STATCOM. Regulation slope of SVC and STATCOM through V-I characteristics. Applications of static shunt compensators – Voltage regulation, improvement in transient stability, prevention of voltage instability, power oscillation damping. Comparison of static shunt compensators.

UNIT-III: STATIC SERIES COMPENSATION
Objectives of series compensation, Expression for real and reactive power flow with series line compensation. Variable impedance type series compensators: V-I characteristics and control schemes of GCSC, TSSC, TCSC - modes of operation. Sub-synchronous resonance. Switching converter type series compensator – V-I characteristics, internal and external control schemes of SSSC. Applications of static series compensators – improvement in transient stability, power oscillation damping. Comparison of static series compensators.

UNIT-IV: STATIC PHASE ANGLE REGULATORS AND COMBINED COMPENSATOR
Power flow control by phase angle regulators - Concept of voltage and phase angle regulation. Operation and control of TCVR and TCPAR. Switching converter type phase angle regulators. Objectives of TCPAR - improvement of transient stability, power oscillation damping. UPFC – Principle, expression for real and reactive power between two nodes of UPFC, independent real and reactive power flow control using UPFC, control schemes of UPFC - operating principle and characteristics of IPFC.

UNIT-V: CO-ORDINATION OF FACTS CONTROLLERS
FACTS controller interactions – interaction between multiple SVC's – interaction between multiple TCSC's – SVC-TCSC interaction – coordination of multiple controllers using linear control techniques. Comparative evaluation of different FACTS controllers: performance comparison and cost comparison

TEXT BOOKS:

1. Narain G. Hingorani, Laszi Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems,* Wiley-IEEE Press, 1999.
2. R. Mohan Mathur and Rajiv k. Varma, *Thyristor based FACTS controllers for Electrical Transmission Systems,* Wiley-IEEE Press, 2002.

REFERENCE BOOKS:

1. Xiao-Ping, Rehtanz, Christian, Pal, Bikash, *Flexible AC Transmission Systems: Modeling and Control*, Springer Power Systems Series, 2006.
2. T.J.E. Miller, *Reactive Power control in electric systems*, Wiley, 1982.

M. Tech. (EPS), II-Semester
(14MT20703) POWER QUALITY

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	3

PRE-REQUISITES:
Distribution of Electric Power and Power Electronics at UG level

COURSE DESCRIPTION:
Power Quality concepts; harmonics and voltage regulation using conventional methods; power quality enhancement using custom power devices; power quality issues in distributed generation

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
   - various power quality issues and mitigation.
   - power quality issues and operating conflicts in distributed generation.
2. analyze the harmonic distortion due to commercial and industrial loads.
3. apply skills in design of various custom power devices.
4. apply the principles of interfacing distributed generation with utilities.

DETAILED SYLLABUS

UNIT-I: FUNDAMENTALS OF POWER QUALITY
Definition of Power Quality, Classification of Power Quality Issues, Power Quality Standards, Categories and Characteristics of Electromagnetic Phenomena in Power Systems: Impulsive and Oscillatory Transients, Interruption, Sag, Swell, Sustained Interruption, Under Voltage, Over Voltage and Outage. Sources and causes of different Power Quality Disturbances.

UNIT-II: HARMONICS AND APPLIED HARMONICS
Harmonic Distortion, Voltage Vs Current Distortion, Harmonics Vs Transients, Power System Qualities under Non-Sinusoidal Conditions, Harmonic Indices, Harmonic Sources from Commercial Loads, Harmonic Sources from Industrial Loads.
Applied Harmonics**:** Effects of Harmonics, harmonic distortion evaluations, principles of controlling harmonics and devices for controlling harmonic distortion.

UNIT-III: VOLTAGE REGULATION USING CONVENTIONAL METHODS
Principles of regulating the voltage, Devices for voltage regulation: utility step-voltage regulators, ferro-resonant transformers, magnetic synthesizers, on-line UPS systems, motor-generator sets, static VAR compensators, shunt capacitors and series capacitors.

UNIT-IV: POWER QUALITY ENHANCEMENT USING CUSTOM POWER DEVICES Introduction to Custom Power Devices - Network Reconfiguring Type: Solid State Current Limiter (SSCL) - Solid State Breaker (SSB) - Solid State Transfer Switch (SSTS).

Compensating Type: Dynamic Voltage Restorer, Distribution STATCOM and Unified Power Quality Conditioner – operation, realization and control of DVR, DSTATCOM and UPQC – load compensation. Power quality monitoring - Power quality monitoring standards.

UNIT-V: POWER QUALITYISSUES IN DISTRIBUTED GENERATION

DG Technologies, Perspectives on DG benefits - Interface to the Utility System - power quality issues affected by DG - Operating Conflicts: Utility fault-clearing, Reclosing, Interference with relaying, Voltage regulation issues, Islanding - siting DG.

TEXT BOOKS:

1. Roger C. Dugan, Mark E. Mc. Granaghan, Surya Santosoh and H. Wayne Beaty, *Electrical Power Systems Quality*, 2nd edition, TATA McGraw Hill, 2010.
2. Arindam Ghosh, Gerard Ledwich, *Power Quality Enhancement Using Custom Power Devices,* Springer, 2002.

REFERENCE BOOKS:

1. Math H J Bollen, *Understanding Power Quality Problems*, IEEE Press, 1998.
2. C.Sankaran, *Power Quality*, CRC press, 2000.

M. Tech. (EPS), II-Semester
(14MT20704) SMART GRID TECHNOLOGY

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power systems at UG level

COURSE DESCRIPTION:
Concept of smart grid; various information and communication technologies for Smart Grid; Smart metering; Demand side integration; Energy management systems

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge in:
   - Smart grid initiatives and technologies
   - Information and communication technologies for the smart grid.
   - Sensing, measurement, control and automation.
2. apply skills in fault calculation and state estimation.
3. apply various information security tools in the smart grid technology.

DETAILED SYLLABUS
UNIT–I: SMART GRID
Introduction, Ageing assets and lack of circuit capacity, thermal constraints, operational constraints, security of supply, national initiatives, early smart grid initiatives, active distribution networks, virtual power plant, other initiatives and demonstrations, overview of the technologies required for the smart grid.
UNIT–II: COMMUNICATION TECHNOLOGIES FOR THE SMART GRID
Data Communications: Introduction, Dedicated and Shared Communication Channels, Switching Techniques, Circuit Switching, Message Switching, Packet Switching, Communication Channels, Wired Communication, Optical Fiber, Radio Communication, Cellular Mobile Communication, Layered Architecture and Protocols, the ISO/OSI Model, TCP/IP
Communication Technologies: IEEE 802 Series, Mobile Communications, Multi Protocol Label Switching, Power line Communication, Standards for Information Exchange, Standards For Smart Metering, Modbus, DNP3, IEC61850
UNIT–III: INFORMATION SECURITY FOR THE SMART GRID
Introduction, Encryption and Decryption, Symmetric Key Encryption, Public Key Encryption, Authentication, Authentication Based on Shared Secret Key, Authentication Based on Key Distribution Center, Digital Signatures, Secret Key Signature, Public Key Signature, Message Digest, Cyber Security Standards, IEEE 1686: IEEE Standard for Substation Intelligent Electronic Devices(IEDs) Cyber Security Capabilities, IEC 62351: Power Systems Management and Association Information Exchange – Data and Communication Security.

UNIT–IV: SMART METERING AND DEMAND SIDE INTEGRATION

Introduction, smart metering – evolution of electricity metering, key components of smart metering, smart meters: an overview of the hardware used – signal acquisition, signal conditioning, analogue to digital conversion, computation, input/output and communication.

Communication infrastructure and protocols for smart metering - Home area network, Neighborhood Area Network, Data Concentrator, meter data management system, Protocols for communication. Demand Side Integration-Services Provided by DSI, Implementation of DSI, Hardware Support, Flexibility Delivered by Prosumers from the Demand Side, System Support from DSI.

UNIT–V: TRANSMISSION AND DISTRIBUTION MANAGEMENT SYSTEMS

Data Sources, Energy Management System, Wide Area Applications, Visualization Techniques, Data Sources and Associated External Systems, SCADA, Customer Information System, Modelling and Analysis Tools, Distribution System Modelling, Topology Analysis, Load Forecasting, Power Flow Analysis, Fault Calculations, State Estimation, Applications, System Monitoring, Operation, Management, Outage Management System, Energy Storage Technologies, Batteries, Flow Battery, Fuel Cell and Hydrogen Electrolyser, Flywheels, Super conducting Magnetic Energy Storage Systems, Super capacitors.

TEXT BOOKS:

1. Janaka Ekanayake, Liyanage, Wu, Akihiko Yokoyama, Jenkins, *Smart Grid*, Wiley Publications, 2012.
2. James Momoh, *Smart Grid: Fundamentals of Design and Analysis*, Wiley, IEEE Press, 2012.

REFERENCE BOOKS:

1. Raj Samani, *Applied Cyber Security and the Smart Grid*, Syngress Publishers, 2012.

M. Tech. (EPS), II-Semester
(14MT20705) INTELLIGENT CONTROL

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Engineering Mathematics, Power Systems, Power Electronic Drives and Electrical machines at UG level

COURSE DESCRIPTION:
Neural Networks; Fuzzy Logic Systems; Genetic Algorithms; Hybrid Intelligent Systems; Applications

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge to identify and describe soft computing techniques and their roles in building intelligent systems.
2. design and analyze intelligent control systems for electrical engineering problems.
3. identify and apply suitable soft computing techniques for engineering problems.

DETAILED SYLLABUS

UNIT-I: NEURAL NETWORKS
Neural network Architectures, Perceptron model, Learning strategies – Supervised Learning – Radial basis function network, Back propagation Network–Unsupervised Learning – Kohonen's SOM, Full counter propagation Network – Reinforced learning.

UNIT-II: FUZZY LOGIC SYSTEMS
Fuzzy sets– Relations & Operations, Membership functions, Fuzzification, Rule base, Inference Mechanism, Defuzzification and design of Fuzzy control system.

UNIT-III: GENETIC ALGORITHMS
Introduction to evolutionary computation, History of genetics, Genetic algorithms(GA) – main components of GA – selection, crossover, mutation, survival of the fittest, population size, Evaluation of the fitness function and benefits of genetic algorithms.

UNIT-IV: HYBRID INTELLIGENT SYSTEMS
Introduction to hybrid intelligent systems – Adaptive Neuro-Fuzzy Inference Systems – Architecture and Learning. Fuzzy GA systems – rules generation. ANN Learning Using GA – Optimization of weights.

UNIT-V: APPLICATIONS
Speed control of separately excited DC motor using neural networks and fuzzy logic, Load forecasting problem using GA and Neuro-fuzzy approach, Load frequency control using fuzzy logic.

TEXT BOOKS:

1. Fakhreddine O. karray, Clarence De Silva, *Soft computing & intelligent systems design, Theory, tools and applications,* Pearson Education Limited, 2009.
2. S.N.Sivanandam, S.N.Deepa, *Principles of soft computing*, Wiley–India Edition, 2008

REFERENCE BOOKS:

1. Devendra K. Chaturvedi, *Soft Computing: Techniques and Its Applications in Electrical Engineering*, Springer.
2. J.S.R.Jang, C.T.Sun, E.Mizutani, *Neuro-Fuzzy & Soft computing*, Pearson Education Limited, 2004.

M. Tech. (EPS), II-Semester
(14MT20706) High Voltage DC TRANSMISSION
(Elective-II)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power Electronics and Power Systems at UG level
Power Electronic converters at PG level

COURSE DESCRIPTION:
HVDC Transmission: capabilities, applications, planning, faults and Protection; Analysis and Control of Power Converter; Harmonics and Filters; Types of Multi-Terminal DC systems and control

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
   - HVDC transmission systems.
   - operation of static converters and analysis.
   - different types of faults and protection schemes in HVDC systems.
2. analyze various static converters in HVDC systems, filters and MTDC systems.
3. design, control and analyze HVDC systems.

DETAILED SYLLABUS
UNIT-I: INTRODUCTION TO HVDC TRANSMISSION
H.V.D.C Transmission – Comparison of HVAC and HVDC transmission, Power Handling Capabilities of HVDC lines, Applications of HVDC Transmission, Planning for HVDC Transmission, Modern trends in DC Transmission.
UNIT-II: STATIC POWER CONVERTER ANALYSIS AND CONTROL
Static Power Converters – 6 pulse & 12 pulse converters, converter station and terminal equipment. Converter Bridge characteristics, equivalent circuit for converter
Control of HVDC converter: Principle of DC link control – constant current, constant extinction angle and constant ignition angle control. Individual phase control and equidistant firing angle control.
UNIT-III: HARMONICS AND FILTERS
Generation of Harmonics in HVDC systems, methods of harmonics elimination, harmonic instability problems, Causes for instability, remedies for instability problems. Design of AC & DC filters
UNIT-IV: MULTI-TERMINAL DC LINK AND SYSTEMS
Introduction – Potential applications of MTDC systems – Types of MTDC systems – series, parallel and series-parallel systems, their principle of operation and control - Protection of MTDC systems.

UNIT-V: FAULTS AND PROTECTION

Over voltages due to disturbance on DC side, over voltages due to DC and AC side line faults – Converter faults, over current protection – Valve group and DC line protection. Over voltage protection of converters – surge arresters.

TEXT BOOKS:

1. K.R. Padiyar, *High Voltage Direct current Transmission*, New Age International (P) Ltd. Publishers, 2004.
2. S. Rao, *EHV-AC, HVDC Transmission & Distribution Engineering*, Khanna Publishers, 2006.

REFERENCES:

1. E.Uhlman, *Power Transmission by Direct Current*, Springer Verlag, Berlin, 2000.
2. E. W. Kimbark, *Direct current Transmission*, John Wiely & sons, New York.
3. J. Arillaga, *H.V.D.C. Tranmission*, peter peregrilnus Ltd., London UK, 1983.

M. Tech. (EPS), II-Semester
(14MT20707) RESTRUCTURED POWER SYSTEM
(Elective-II)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Power Systems at UG level

COURSE DESCRIPTION:
Features of Restructured Power systems; Market models; Information and transmission services; Electricity pricing and forecasting; Ancillary services management

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
   - Operation of deregulated electricity market systems.
   - Key issues of electricity market models and their functionalities in different scenarios.
   - Electricity pricing methods and ancillary service management in competitive market.
2. demonstrate analytical skills to envisage market models to provide power exchange among various entities of deregulated power system.
3. implement forecasting methods for minimizing energy price and regulate congestion in interconnected deregulated power system.

DETAILED SYLLABUS:
UNIT-I: OVERVIEW OF KEY ISSUES IN ELECTRIC UTILITIES
Introduction – Deregulation, need for deregulation, Advantages of deregulation in power system. Restructuring Models: POOLCo Model, Bilateral Model, Hybrid Model – independent system operator (ISO) – Role of ISO – power exchange – market operations – market power – standard cost – transmission pricing – congestion pricing – management of congestion.
UNIT-II: MARKET MODELS IN RESTRUCTURED POWER SYSTEMS
Introduction - Market models based on contractual arrangements: Monopoly model, Single buyer model, Whole sale competition model, Retail competition model. Comparison of various market models. Market architecture: Day-ahead and Hour-Ahead Markets, Block forwards Market, Transmission Congestion Contracts (TCCs), Ancillary service market.

UNIT-III: OASIS: OPEN ACCESS SAME-TIME INFORMATION SYSTEM
Structure of OASIS: Functionality and Architecture of OASIS – Information requirement of OASIS - Transfer Capability on OASIS: Definitions, Transfer Capability Issues, ATC Calculation, TTC Calculation, TRM Calculation, CBM Calculation – Transmission Services – Methodologies to Calculate ATC.

UNIT-IV: ELECTRICITY PRICING - VOLATILITY, RISK AND FORECASTING

Electricity pricing – introduction – electricity price volatility, electricity price indexes – Challenges to Electricity Pricing: Pricing Models, Reliable Forward Curves – Construction of Forward Price Curves: Time frame for Price Curves, Types of Forward Price Curves – Short-term Price Forecasting: Factors Impacting Electricity Price, Forecasting Methods, Analyzing Forecasting Errors.

UNIT-V: ANCILLARY SERVICES MANAGEMENT

Introduction – Types of ancillary services, Classification of ancillary services– Load - generation balancing related services: Frequency regulation, Load following, Spinning reserve services – Voltage control and reactive power support services: Generators, Synchronous condensers, Capacitors and inductors, SVCs, STATCOMs – Black start capability service

TEXT BOOKS:

1. Kankar Bhattacharya, Math H.J. Bollen, Jaap E. Daalder, *Operation of Restructured Power System*, Klumer Academic Publisher, 2001.
2. Mohammad Shahidehpour, and Muwaffaqalomoush, - *Restructured electrical Power systems,* Marcel Dekker, Inc. 2001.

REFERENCES:

1. Loi Lei Lai, *Power system Restructuring and Deregulation*, Jhon Wiley & Sons Ltd., England.

M. Tech. (EPS), II-Semester
(14MT20708) POWER SYSTEM RELIABILITY
(ELECTIVE-II)

Int. Marks	Ext. Marks	Total Marks		L	T	P	C
40	60	100		4	--	--	4

PRE-REQUISITES:
Probability and Statistics at UG level

COURSE DESCRIPTION:
Fundamentals of Reliability Engineering; Evaluation of Power system operating capacity reserve; Evaluation of Frequency and Duration Techniques; Reliability Analysis of Interconnected Systems; Power Distribution System Reliability Analysis

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on
   i. conceptual algorithms for planning and operation of secured power system
   ii. system risks during normal and adverse weather conditions.
2. evaluate complex network configurations using reliability indices.
3. design and develop efficient algorithms for analyzing power system network reliability in real time.

DETAILED SYLLABUS
UNIT–I: **FUNDAMENTALS OF RELIABILITY ENGINEERING**
Probability Concept, Random variables, Probability Density and Distribution functions– Probability Distributions: time dependent and independent, mean, SD, Variance. Reliability function, hazard rate, types of failures, bath tub curve and reliability cost and worth.
Network and Markov Modeling: redundant and non-redundant configuration – complex systems – conditional probability approach, Decomposition Method, cut-set, tie-set approaches – Standby redundant systems – Event trees. Markov chain – Markov Process, STPM, LSP – one, two and three component repairable models
UNIT–II: **EVALUATION OF GENERATING CAPACITY RESERVE**
Introduction – Generation system model – determination of capacity outage probability table – identical units, non-identical units – Determination of transitional rates – deterministic and probabilistic criteria – Sequential addition method– Recursive relation for unit addition, unit removal - LOLP, LOLE and EIR.
UNIT–III: EVALUATION OF FREQUENCY AND DURATION TECHNIQUES
Frequency and duration concepts – Two component repairable model (with & without identical components) – Evaluation of cumulative probability and cumulative frequency by using recursive relation – Equivalent transition rates – non-equivalent transition rates.

System risk indices: Daily load model – Two level representation of daily load modeling– evaluation of probabilities, transitional rates.

UNIT–IV: RELIABILITY ANALYSIS OF INTERCONNECTED SYSTEMS

Introduction – probability array method in two interconnected systems – evaluation techniques – equivalent assisting approach – factors affecting interconnections, effect of tie capacities, tie lines.

Weather effects on transmission lines – common mode failures – circuit breaker model – Preventive maintenance

UNIT–V: DISTRIBUTION SYSTEM RELIABILITY ANALYSIS

Distribution system reliability analysis – Basic indices – Customer oriented indices – Load and energy indices – active and passive failures – open circuit & short circuit failures – simple problems on above indices.

TEXTBOOKS:

1. Roy Billinton and Ronald NAllen, *Reliability Evaluation of Power Systems*, 2nd edition, Springer, New York, 1996.
2. J. Endrenyi, *Reliability Modelling in Electric Power Systems*, 1st edition, John Willey and Sons, US, 1978.

REFERENCES:

1. Roy Billinton and Ronald NAllen, *Reliability Evaluation of Engineering Systems*, 2nd edition, Springer, NewYork, 2013.
2. Charles Eebeling, *An Introduction to Reliability and Maintainability Engineering*, Tata McGraw Hill, India, 2004.

M. Tech. (EPS), II-Semester
(14MT20709) ENERGY AUDITING, CONSERVATION & MANAGEMENT
(ELECTIVE-II)

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
40	60	100	4	--	--	4

PRE-REQUISITES:
Managerial Economics and Financial Analysis and Generation of Electric Power at UG level

COURSE DESCRIPTION:
Energy Audit; Energy Management; Energy Efficient Motors and Lighting; Energy Instruments; Computation of Economic Aspects and Analysis

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge on:
    - Energy management, Energy conservation management.
    - Computation of economic aspects and analysis.
    - Energy efficient motors and lighting system.
    - Energy audit instruments.
2. analyze life cycle estimation and cost analysis methods for various components**.**
3. design energy efficient motors and lighting schemes.
4. apply Energy instruments in analysis of economic aspects.

DETAILED SYLLABUS

UNIT-I: BASIC PRINCIPLES OF ENERGY AUDIT
Energy audit – definitions, concept, types of audit, energy index, cost index, pie charts, Sankey diagrams, load profiles, Energy conservation schemes – Energy audit of industries – energy saving potential, energy audit of process industry, thermal power station, building energy audit.

UNIT-II: ENERGY MANAGEMENT
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manger, Qualities and functions, language, Questionnaire – check list for top management.

UNIT-III: ENERGY EFFICIENT MOTORS AND LIGHTING
Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics – variable speed, variable duty cycle systems, RMS hp- voltage variation– voltage unbalance – over motoring – motor energy audit. Good lighting system design and practice, lighting control, lighting energy audit

UNIT-IV: ENERGY INSTRUMENTS
Energy Instruments: watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers, application of PLC's.

UNIT-V: COMPUTATION OF ECONOMIC ASPECTS AND ANALYSIS

Economic Analysis – Depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, life cycle costing analysis - Energy efficient motors, calculation of simple payback method, net present worth method - Power factor correction, lighting - Applications of life cycle costing analysis, return on investment.

TEXT BOOKS:

1. W.R. Murphy & G. Mckay Butterworth, *Energy Management*, Heinemann publications.
2. Paul O' Callaghan, *Energy Management*, 1st edition, McGraw Hill Book company.

REFERENCE BOOKS:

1. John C. Andreas, *Energy Efficient Electric Motors*, 2nd edition, Marcel Dekker Inc. Ltd.,
2. W.C. Turner, *Energy management Hand Book*, John Wiley and sons.

M. Tech. (EPS), II-Semester
(14MT20721) POWER SYSTEMS SIMULATION LABORATORY

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
25	50	75	--	--	4	2

PRE-REQUISITES:
Power system, Power electronics, Control Systems and Electrical Machines at UG level
Economic operation and control of power system at PG level

COURSE DESCRIPTION:
Modelling, simulation and analysis of multi area power system, load flows, load frequency control, power system stability, power quality problems and power electronic converters

COURSE OUTCOMES:
On successful completion of the course, student will be able to
1. demonstrate knowledge in analyzing the power system behavior using simulation / programming tools.
2. design and perform experiments, as well as analyze and interpret results for better understanding of power system operation.
3. design various power system networks through programming and simulation for better functionality.
4. select and apply modern software tools for solving real time problems in the existing power system.

DETAILED SYLLABUS
Conduct any Twelve experiments from the following:
1. Formation of bus admittance matrix with and without off-nominal ratios of transformer of a power system network using MATLAB
2. Formation of Bus Impedance matrix with and without mutual coupling of a power system network using MATLAB
3. Load flow studies using
   (a) Gauss Seidal Method
   (b) Newton Rahpason Method
   (c) Fast Decoupled Method
4. Transient stability analysis
5. Economic Dispatch using MATLAB
6. Modeling of standard test system with generator excitation and governor action using SIMULINK
7. Modeling and analysis of automatic load frequency control of multi-area power system using SIMULINK
8. Simulation of power quality problems (like Sag/Swell, interruption, transients, harmonics, flickers etc.) using SIMULINK

9. Single phase half-controlled converter using R- and RL- loads using MATLAB/ SIMULINK.
10. Single phase full-controlled converter using R- and RL- loads using MATLAB/ SIMULINK
11. Analysis of Transmission line parameters using PSCAD
12. Simulation of Capacitor switching transient using PSCAD
13. Transformer inrush currents measurement using PSCAD
14. Analysis of Short circuit studies with and with fault impedance using PSCAD
15. Simulation of FACTS controllers using PSCAD

M. Tech. (EPS), II-Semester
(14MT20722) SEMINAR

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
--	50	50	--	--	--	2

PRE-REQUISITES: --

COURSE DESCRIPTION:
Identification of seminar topic; Literature survey; Preparation of technical report and Presentation.

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate in-depth knowledge in core and allied areas of interest.
2. analyze and synthesize information related to the areas.
3. conceptualize and construct research problems.
4. extract information pertinent to a specific area through literature survey to conduct research.
5. identify the applicability of modern software and tools.
6. contribute positively to multidisciplinary groups in emerging areas with objectivity and rational analysis.
7. plan, organize, prepare and present effective written and oral technical reports.
8. engage in lifelong learning to improve competence.
9. acquire awareness on professional code of conduct in the chosen area.
10. develop independent and reflective learning.

M. Tech. (EPS), III & IV Semesters
(14MT30721 & 14MT40721) PROJECT WORK

Int. Marks	Ext. Marks	Total Marks	L	T	P	C
80	120	200	--	--	--	16

PRE-REQUISITES: --

COURSE DESCRIPTION:
Identification of topic for the project work; Literature survey; Collection of preliminary data; Identification of implementation tools and methodologies; Performing critical study and analysis of the topic identified; Time and cost analysis; Implementation of the project work; Writing of thesis and presentation.

COURSE OUTCOMES:
On successful completion of the course, student will be able to

1. demonstrate knowledge in the areas of interest.
2. analyze critically chosen project topic for conducting research.
3. apply knowledge gained through Programme, self learning and experience for solution of a given problem efficiently.
4. undertake research confidently in the project domain.
5. use the techniques, skills and modern engineering tools necessary for project work.
6. perform harmonically in multi-disciplinary, multi-cultural groups, and develop a high level of interpersonal skills.
7. manage projects in respective disciplines and multidisciplinary environments with due consideration to cost and time efficiency.
8. communicate effectively in both oral and written forms for preparing and presenting reports.
9. engage in lifelong learning to improve knowledge and competence continuously.
10. perceive professional and ethical responsibility for sustainable development of society.
11. develop independent and reflective learning.