SRM UNIVERSITY
(Under section 3 of UGC Act 1956)

M.TECH. (FULL TIME) - POWER SYSTEMS
CURRICULUM & SYLLABUS
2013 – 2014

DEPARTMENT OF
ELECTRICAL AND ELECTRONICS ENGINEERING
FACULTY OF ENGINEERING AND TECHNOLOGY
SRM UNIVERSITY
SRM NAGAR, KATTANKULATHUR – 603 203

Sl. No	**Category**	**Credits**				
		I Semester	**II Semester**	**III Semester**	**IV Semester**	**Category Total**
1	Core courses	12 (3 courses)	12 (3 courses)	---	---	**24**
2	Program Elective courses	18 (in I to III semesters)			---	**18**
3	Interdisciplinary elective courses– mandatory	3 (in I or II or III semester)				**3**
4	Supportive courses – mandatory	3 (in I or II or III semester)			---	**3**
5	Seminar	1	---	---	---	**1**
7	Industrial Training (during summer vacation between II and III semesters)	---	---	1	---	**1**
8	Project work	---	---	06	16	**22**
					Total	**72**

Total credits to be earned for the award of M.Tech degree – 72

PROGRAM CORE COURSES

Course Code	Name of the Course	L	T	P	C
PS2001	Modern Power System Analysis	3	0	2	4
PS2002	Power System Operation and Control	3	0	2	4
PS2003	Power System Protection	4	0	0	4
PS2004	Power System Dynamics	3	0	2	4
PS2005	Flexible AC Transmission Systems	3	0	2	4
PS2006	Deregulation of Power System	4	0	0	4
PS2046	Seminar	0	0	1	1
PS2048	Industrial Training	0	0	1	1
PS2049	Project Work Phase I	0	0	12	6
PS2050	Project Work Phase II	0	0	32	16

PROGRAM ELECTIVE COURSES

Course Code	Name of the course	L	T	P	C
PS2101	High Voltage Direct Current Transmission System	3	0	0	3
PS2102	Power Distribution Systems	3	0	0	3
PS2103	Electrical Transients in Power Systems	3	0	0	3
PS2104	Smart Grid Design and Analysis	3	0	0	3
PS2105	Modern Optimization Techniques in Power Systems	3	0	0	3
PS2106	Power System State Estimation	3	0	0	3
PS2107	Advanced Power System Dynamics	3	0	0	3
PS2108	Wind and Solar Energy Systems	3	0	0	3
PS2109	Power quality	3	0	0	3
PS2110	Industrial Power System Analysis and Design	3	0	0	3
PS2111	Power System Planning and Reliability	3	0	0	3
PS2112	Energy Management and Auditing	3	0	0	3
PS2113	Distributed Generation and Micro Grid	3	0	0	3
PS2114	Design of Controllers in Power Application	3	0	0	3
PS2115	Analysis of Electrical Machines	3	0	0	3
PS2116	Special Machines and their Controllers	3	0	0	3
PS2117	System Theory	3	0	0	3

PS2118	Artificial Neural Networks Applied to Power Systems	3	0	0	3
PS2119	Digital Signal Processing	3	0	0	3
PS2120	Intelligent Controllers	3	0	0	3

PROGRAM SUPPORTIVE COURSES

Course Code	**Name of the course**	**L**	**T**	**P**	**C**
MA2008	Applied Mathematics for Electrical Engineers	3	0	0	3
PS2201	Object Oriented Programming	3	0	0	3
PS2202	Computer Networks	3	0	0	3

CONTACT HOUR/CREDIT:

L: Lecture Hours per weekT: Tutorial Hours per week

P: Practical Hours per week C: Credit

PROGRAM CORE COURSES

		L	T	P	C
PS2001	**MODERN POWER SYSTEM ANALYSIS**	**3**	**0**	**2**	**4**
	Total Contact Hours -75				

PURPOSE

To enable the students to develop the understanding of the steady state analysis of power system.

INSTRUCTIONAL OBJECTIVES

1. To introduce the mathematical representation of power system components and solution techniques.
2. To impart in-depth knowledge on different methods of power flow solutions.
3. To perform symmetrical and unsymmetrical short circuit analysis to understand the effects of different types of faults.
4. To get insight of contingency analysis problem and the solution methods.
5. To gain knowledge on transient stability analysis and the associated solution techniques

UNIT I - PRELIMINARIES FOR POWER SYSTEM PROBLEMS (9 hours)

Per unit quantities - Modeling of generators, transformers, off nominal tap setting and phase shifting transformers, transmission lines and loads. Primitive parameters - Bus admittance matrix - bus impedance matrix - reduction due to zero bus currents and zero bus voltages - Solution through factored matrices - Solution of non-linear algebraic equation and non-linear differential equations.

UNIT II - POWER FLOW ANALYSIS (9 hours)

Formulation of power flow problem - solution through Newton Raphson method - decoupled and fast decoupled power flow solutions - DC power flow solution - Power flow solution using FACTS devices - Optimal power flow solution.

UNIT III - SHORT CIRCUIT ANALYSIS (9 hours)

Sub-transient, transient and steady state reactances of synchronous machine - symmetrical fault analysis using bus impedance matrix - symmetrical components and sequence networks - analysis of unsymmetrical fault at generator terminals - analyzing unsymmetrical faults occurring at any point in a power system.

UNIT IV - CONTINGENCIES ANALYSIS (9 hours)

Importance of contingency analysis - addition / removal of one line - construction of a column of bus impedance matrix from the bus admittance matrix - calculation of new bus voltages due to addition / removal of one line - calculation of new bus voltages due to addition / removal of two lines.

UNIT V - TRANSIENT STABILITY ANALYSIS (9 hours)

Swing equation - equal area criterion - critical clearing angle - critical clearing time - multi-machine transient stability studies by classical representation - step-by-step solution of swing curve and algorithms for multi-machine transient stability studies.

LABORATORY WORK (30 hours)

Computer programs for construction of Y_{bus}, Z_{bus},
Power flow studies,
Short circuit analysis,
contingency analysis and transient stability analysis.
Solving power system problems using simulation software.

REFERENCES

1. G W Stagg and A H El Abiad, "*Computer Methods in Power System Analysis*", McGraw Hill, 1968.
2. J J Grainger and W D Stevension, "Power *System Analysis*", McGraw-Hill, Inc., 1994.
3. D P Kothori and I J Nagrath, "Modern *Power System Analysis*", Tata McGraw Hill Education Private Limited, 2011.
4. Hadi Saadat, "*Power System Analysis*" McGraw-Hill, 2004.
5. M A Pai," *Computer Techniques in Power System Analysis"*, Tata McGraw Publishing Company Limited, 2006.

PS2002	POWER SYSTEM OPERATION AND CONTROL	L	T	P	C
		3	0	2	4
	Total Contact Hours - 75				

PURPOSE	
To enable the students acquire a comprehensive idea on various aspects of power system operation and control.	
INSTRUCTIONAL OBJECTIVES	
1.	To gain knowledge on economic operation of power system and its solution techniques..
2.	To understand hydrothermal scheduling techniques and maintenance scheduling.
3.	To get the insight of load frequency control and its modeling
4.	To study the concept of voltage control using compensation devices
5.	To understand the role of energy control centre, SCADA, EMS functions and power system security states.

UNIT I - ECONOMIC OPERATION OF POWER SYSTEM (9 hours)
Review of economic dispatch problem – Co-ordination equations without and with loss, Solution by direct and Lambda iteration method - Base point and participation factors -Review of Unit commitment problem - constraints - solution by priority list, dynamic programming and Lagrangian Relaxation methods - Formulation of combined active and reactive power dispatch- Security constrained optimal power flow.

UNIT II - HYDROTHERMAL SCHEDULING AND MAINTENANCE SCHEDULING (9 hours)
Hydrothermal scheduling problem formulation- Long and short term problem mathematical model – optimal scheduling of hydrothermal system – solution by dynamic and incremental dynamic programming methods of local variation – pumped hydro storage plants.
Factors considered in maintenance scheduling for generating units, turbines, boilers – Introduction to maintenance scheduling using mathematical programming.

UNIT III - LOAD FREQUENCY CONTROL (9 hours)
Need for frequency and voltage control - Plant and system level control - modeling of LFC of single area system - static and dynamic analysis - LFC of two area system - static and dynamic analysis - Tie line bias control - development of state variable model of single and two area system.

UNIT IV - VOLTAGE CONTROL **(9 hours)**

Production and absorption of reactive power - Modeling of AVR loop - static and dynamic analysis - Methods of Voltage Control – Shunt reactors –Shunt Capacitors – Series Capacitors – Synchronous condensers – Static Var systems –Principles of Transmission system compensation – Modeling of reactive compensating devices – Application of tap changing transformers to transmission systems – Distribution system voltage regulation – Modeling of transformer ULTC control systems.

UNIT V - COMPUTER CONTROL OF POWER SYSTEM **(9 hours)**

Basic concepts – classification of security states – factors affecting power system security – security control – corrective, preventive, emergency, restorative control – single contingency analysis using line outage distribution factors and generation shift factors - contingency ranking – security indices – system under severe upsets and islanding – SCADA system. Data acquisition – Block diagram of a typical microprocessor based data acquisition system – Data transmission & acquisition system – Data transmission & telemetry.

LABORATORY WORK **(30 hours)**

1. Study of Economic dispatch without and with losses using MATLAB coding
2. Study of Economic Dispatch using Mipower Software.
3. Priority order method of unit commitment using MATLAB coding
4. Study of OPF methods using Mipower/Power world simulator softwares
5. Simulation of single area and multi area LFC using MATLAB/SIMULINK.
6. Modeling of AVR using MATLAB/SIMULINK.

REFERENCES

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.
3. Jizhong Zhu, *"Optimization of Power system operation"*, IEEE Press series on Power Engineering, John Wiley and sons Inc Publication, 2009.

4. Mahalanabis.A.K, Kothari.D.P. and Ahson.S.I., *"Computer Aided Power System Analysis and Control"*, Tata McGraw Hill publishing Ltd , 1991.

5. S Sivanagaraju and G Sreenivasan, "*Power System Operation and Control"*, Dorling Kindersley (India) Pvt.Ltd., 2012.

<table>
<tr><td rowspan="3">PS2003</td><td rowspan="2">POWER SYSTEM PROTECTION</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td>Total Contact Hours - 60</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">PURPOSE</td></tr>
<tr><td colspan="6">To impart knowledge on various aspects of protective relaying for power system components</td></tr>
<tr><td colspan="6">INSTRUCTIONAL OBJECTIVES</td></tr>
<tr><td>1.</td><td colspan="5">To illustrate concepts of transformer protection</td></tr>
<tr><td></td><td colspan="5">To describe about the various schemes of Over current protection</td></tr>
<tr><td></td><td colspan="5">To analyze distance and carrier protection</td></tr>
<tr><td></td><td colspan="5">To familiarize the concepts of Busbar protection and Numerical protection</td></tr>
</table>

UNIT I - EQUIPMENT PROTECTION (12 hours)

Types of transformers – Phasor diagram for a three – Phase transformer-Equivalent circuit of transformer – Types of faults in transformers- Over – current protection Percentage Differential Protection of Transformers - Inrush phenomenon-High resistance Ground Faults in Transformers - Inter-turn faults in transformers - Incipient faults in transformers - Phenomenon of over-fluxing in transformers - Transformer protection application chart Electrical circuit of the generator –Various faults and abnormal operating conditions-rotor fault –Abnormal operating conditions; numerical examples for typical transformer and generator protection schemes.

UNIT II - OVER CURRENT PROTECTION (12 hours)

Time – Current characteristics-Current setting – Time setting-Over current protective schemes - Reverse power or directional relay - Protection of parallel feeders - Protection of ring feeders - Earth fault and phase fault protection - Combined Earth fault and phase fault protection scheme - Phase fault protective scheme directional earth fault relay - Static over current relays; numerical example for a radial feeder

UNIT III - DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES (12 hours)

Drawback of over – Current protection – Introduction to distance relay – Simple impedance relay – Reactance relay – mho relays comparison of distance relay – Distance protection of a three – Phase line-reasons for inaccuracy of distance relay reach - Three stepped distance protection - Trip contact configuration for the three - Stepped distance protection - Three-stepped protection of three-phase line against all ten shunt faults - Impedance seen from relay side - Three-stepped protection of double end fed lines-need for carrier – Aided protection – Various options for a carrier –Coupling and trapping the carrier into the desired line section - Unit type carrier aided directional comparison relaying – Carrier aided distance schemes for acceleration of zone II.; numerical example for a typical distance protection scheme for a transmission line.

UNIT IV - BUSBAR PROTECTION (12 hours)

Introduction – Differential protection of busbars-external and internal fault - Actual behaviors of a protective CT - Circuit model of a saturated CT - External fault with one CT saturation :need for high impedance – Minimum internal fault that can be detected by the high – Stability ratio of high impedance busbar differential scheme - Supervisory relay-protection of three – Phase busbars-Numerical examples on design of high impedance busbar differential scheme.

UNIT V - NUMERICAL PROTECTION (12 hours)

Introduction – Block diagram of numerical relay - Sampling theorem- Correlation with a reference wave – Least error squared (LES) technique - Digital filtering-numerical over - Current protection – Numerical transformer differential protection-Numerical distance protection of transmission line.

REFERENCES

Y.G. Paithankar and S.R Bhide, "*Fundamentals of Power System Protection*", Prentice-Hall of India, 2003.

P.Kundur, "*Power System Stability and Control*", McGraw-Hill, 1993.

Badri Ram and D.N. Vishwakarma, "*Power System Protection and Switchgear*", Tata McGraw- Hill Publishing Company, 2002.

PS2004	POWER SYSTEM DYNAMICS	L	T	P	C
		3	0	2	4
	Total Contact Hours - 75				

PURPOSE	
To enable the students to develop understanding of power system components modelling and Small-Signal stability analysis in power system.	
INSTRUCTIONAL OBJECTIVES	
1. .	To impart knowledge on dynamic modelling of a synchronous machine in detail.
2.	To describe the modelling of excitation and speed governing system in detail.
3.	To understand the fundamental concepts of stability of dynamic systems and its classification
4.	To understand and enhance small signal stability problem of power systems.

UNIT I - SYNCHRONOUS MACHINE MODELLING (9 hours)

Schematic Diagram, Physical Description: armature and field structure, machines with multiple pole pairs, MMF waveforms, direct and quadrature axes, Mathematical Description of a Synchronous Machine: Basic equations of a synchronous machine: stator circuit equations, stator self, stator mutual and stator to rotor mutual inductances, dq0 Transformation: flux linkage and voltage equations for stator and rotor in dq0 coordinates, electrical power and torque, physical interpretation of dq0 transformation, Per Unit Representations: L_{ad}-reciprocal per unit system and that from power-invariant form of Park's transformation; Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current and flux-linkage relationships, Phasor representation, Rotor angle, Steady-state equivalent circuit, Computation of steady-state values, Equations of Motion: Swing Equation, calculation of inertia constant, Representation in system studies, Synchronous Machine Representation in Stability Studies: Simplifications for large-scale studies : Neglect of stator $p\Psi$ terms and speed variations, Simplified model with amortisseurs neglected: two-axis model with amortisseur windings neglected, classical model.

UNIT II - MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS (9 hours)

Excitation System Requirements; Elements of an Excitation System; Types of Excitation System; Control and protective functions; IEEE (1992) block diagram for simulation of excitation systems. Turbine and Governing System

Modelling: Functional Block Diagram of Power Generation and Control, Schematic of a hydroelectric plant, classical transfer function of a hydraulic turbine (no derivation), special characteristic of hydraulic turbine, electrical analogue of hydraulic turbine, Governor for Hydraulic Turbine: Requirement for a transient droop, Block diagram of governor with transient droop compensation, Steam turbine modelling: Single reheat tandem compounded type only and IEEE block diagram for dynamic simulation; generic speed-governing system model for normal speed/load control function.

UNIT III - SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS (9 hours)

Classification of Stability, Basic Concepts and Definitions: Rotor angle stability, The Stability Phenomena. Fundamental Concepts of Stability of Dynamic Systems: State-space representation, stability of dynamic system, Linearization. Eigen properties of the state matrix: Eigen values and eigenvectors, modal matrices, eigen value and stability, mode shape and participation factor. Single-Machine Infinite Bus (SMIB) Configuration: Classical Machine Model stability analysis with numerical example, Effects of Field Circuit Dynamics: synchronous machine, network and linearised system equations, block diagram representation with K-constants; expression for K-constants (no derivation), effect of field flux variation on system stability: analysis with numerical example.

UNIT IV - SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS (9 hours)

Effects Of Excitation System: Equations with definitions of appropriate K-constants and simple thyristor excitation system and AVR, block diagram with the excitation system, analysis of effect of AVR on synchronizing and damping components using a numerical example, Power System Stabiliser: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical a example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines, illustration of stability analysis using a numerical example. Principle behind small-signal stability improvement methods: delta-omega and delta P-omega stabilizers.

UNIT V - ENHANCEMENT OF SMALL SIGNAL STABILITY (9 hours)

Power System Stabilizer – Stabilizer based on shaft speed signal (delta omega) – Delta –P-Omega stabilizer-Frequency-based stabilizers – Digital Stabilizer – Excitation control design – Exciter gain – Phase lead compensation – Stabilizing signal washout stabilizer gain – Stabilizer limits.

LABORATORY WORK **(30 hours)**

1. Simulation of IEEE excitation systems.
2. Simulation of turbine and governor modeling.
3. Small-signal stability analysis of single machine-infinite bus system using classical machine model.
4. Small-signal stability analysis of single machine-infinite bus system using classical machine model.
5. Small-signal stability analysis with excitation systems.
6. Small-signal stability enhancement using PSS.

REFERENCES

1. P. Kundur, "*Power System Stability and Control*", McGraw-Hill, 1993.
2. IEEE Committee Report, "*Dynamic Models for Steam and Hydro Turbines in Power System Studies*", IEEE Trans., Vol.PAS-92, pp 1904-1915, November/December,. on Turbine-Governor Model, 1973.
3. P.M Anderson and A.A Fouad, "*Power System Control and Stability*", Iowa State University Press, Ames, Iowa, 1978.
4. R. Ramanujam, "*Power System Dynamics, Analysis and Simulation*", PHI Learning, New Delhi, January 2010.

		L	T	P	C
PS2005	**FLEXIBLE AC TRANSMISSION SYSTEMS**	**3**	**0**	**2**	**4**
	Total Contact Hours - 75				

PURPOSE	
To enable the students gain a fair knowledge on the concepts and technology of flexible AC transmission systems.	
INSTRUCTIONAL OBJECTIVES	
1.	To emphasis the need for FACTS controllers.
2.	To learn the characteristics, applications and modelling of series and shunt FACTS controllers.
3.	To analyze the interaction of different FACTS controller and perform control coordination.

UNIT I - INTRODUCTION (9 hours)

Review of basics of power transmission networks-control of power flow in AC transmission line- Analysis of uncompensated AC Transmission line- Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer- Need for FACTS controllers- types of FACTS controllers.

UNIT II - STATIC VAR COMPENSATOR (SVC) (9 hours)

Configuration of SVC- voltage regulation by SVC- Modelling of SVC for load flow analysis- Modelling of SVC for stability studies-Design of SVC to regulate the mid-point voltage of a SMIB system- Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line.

UNIT III - THYRISTOR AND GTO THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC and GCSC) (9 hours)

Concepts of Controlled Series Compensation – Operation of TCSC and GCSC- Analysis of TCSC-GCSC – Modelling of TCSC and GCSC for load flow studies- modeling TCSC and GCSC for stability studied- Applications of TCSC and GCSC.

UNIT IV - VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS (9 hours)

Static synchronous compensator(STATCOM)- Static synchronous series compensator(SSSC)- Operation of STATCOM and SSSC-Power flow control with STATCOM and SSSC- Modelling of STATCOM and SSSC for power flow and transient stability studies –operation of Unified and Interline power flow controllers(UPFC and IPFC)- Modelling of UPFC and IPFC for load flow and transient stability studies- Applications.

UNIT V - CONTROLLERS AND THEIR CO-ORDINATION (9 hours)

FACTS Controller interactions – SVC–SVC interaction - co-ordination of multiple controllers using linear control techniques – Quantitative treatment of control coordination.

LABORATORY WORK (30 hours)

1. Simulation and Implementation of Voltage Source Inverter and Current source Inverter
2. Load flow studies using TCSC.
3. Load flow analysis with SVC.
4. Modelling and simulation SVC for stability studies.

5. Load flow analysis of two-bus system with SVC and STATCOM.
6. Transient analysis of two-bus system with SVC and STATCOM.
7. Transient stability analysis without FACTS controller.
8. Transient stability analysis with TCSC for damp the power oscillations.
9. Modelling and simulation of UPFC and IPFC for load flow and transient stability studies.

REFERENCES

1. Mohan Mathur, R., Rajiv. K. Varma, "*Thyristor – Based FACTS Controllers for Electrical Transmission Systems*", IEEE press and John Wiley & Sons, Inc, 2002.
2. K.R.Padiyar," *FACTS Controllers in Power Transmission and Distribution*", New Age International (P) Ltd., Publishers, New Delhi, Reprint, 2008.
3. A.T.John, "*Flexible AC Transmission System*", Institution of Electrical and Electronic Engineers (IEEE), 1999.
4. NarainG.Hingorani, Laszio. Gyugyl, "*Understanding FACTS Concepts and Technology of Flexible AC Transmission System*", Standard Publishers, Delhi, 2001.
5. V. K.Sood, "*HVDC and FACTS controllers- Applications of Static Converters in Power System*", Kluwer Academic Publishers, 2004.

		L	T	P	C
PS2006	**DEREGULATION OF POWER SYSTEM**	**4**	**0**	**0**	**4**
	Total Contact Hours - 60				
PURPOSE					
To enable the students to understand the process and operation of restructured power system					
INSTRUCTIONAL OBJECTIVES					
1.	To Introduce the restructuring of power industry and market models.				
	To impart knowledge on fundamental concepts of congestion management.				
	To analyze the concepts of locational marginal pricing and financial transmission rights.				
	To Illustrate about various power sectors in India				

UNIT I - INTRODUCTION TO RESTRUCTURING OF POWER INDUSTRY (12 hours)

Introduction: Deregulation of power industry, Restructuring process, Issues involved in deregulation, Deregulation of various power systems – Fundamentals of Economics: Consumer behavior, Supplier behavior, Market equilibrium, Short and long run costs, Various costs of production – Market models: Market models based on Contractual arrangements, Comparison of various market models, Electricity vis – a – vis other commodities, Market architecture, Case study.

UNIT II - TRANSMISSION CONGESTION MANAGEMENT (12 hours)

Introduction: Definition of Congestion, reasons for transfer capability limitation, Importance of congestion management, Features of congestion management – Classification of congestion management methods – Calculation of ATC - Non – market methods – Market methods – Nodal pricing – Inter zonal and Intra zonal congestion management – Price area congestion management – Capacity alleviation method.

UNIT III - LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS (12 hours)

Mathematical preliminaries: -Locational marginal pricing– Lossless DCOPF model for LMP calculation – Loss compensated DCOPF model for LMP calculation – ACOPF model for LMP calculation – Financial Transmission rights – Risk hedging functionality - Simultaneous feasibility test and revenue adequency – FTR issuance process: FTR auction, FTR allocation – Treatment of revenue shortfall – Secondary trading of FTRs – Flow gate rights – FTR and market power - FTR and merchant transmission investment.

UNIT IV - ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK (12 hours)

Introduction of ancillary services – Types of Ancillary services – Classification of Ancillary services – Load generation balancing related services – Voltage control and reactive power support devices – Black start capability service - ancillary service –Co-optimization of energy and reserve services - International comparison - Transmission pricing – Principles – Classification – Role in transmission pricing methods – Marginal transmission pricing paradigm – Composite pricing paradigm – Merits and demerits of different paradigm.

UNIT V - REFORMS IN INDIAN POWER SECTOR (12 hours)

Introduction – Framework of Indian power sector – Reform initiatives - Availability based tariff – Electricity act 2003 – Open access issues – Power exchange – Reforms in the near future.

REFERENCES

1. Mohammad Shahidehpour, MuwaffaqAlomoush, Marcel Dekker, *"Restructured electrical power systems: operation, trading and volatility"* Pub., 2001.
2. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen, *"Operation of restructured power systems"*, Kluwer Academic Pub., 2001.
3. Sally Hunt, *"Making competition work in electricity"*, John Willey and Sons Inc. 2002.
4. Steven Stoft, *"Power system economics: designing markets for electricity"*, John Wiley & Sons, 2002.

1.

PS2046	**SEMINAR**	**L**	**T**	**P**	**C**
		0	**0**	**1**	**1**
	Total Contact Hours - 30				
PURPOSE					
To expose the communication of the students by conducting seminar					
INSTRUCTIONAL OBJECTIVES					
1.	To motivate the students to attain the confidence and competence.				

- The students are asked to give a seminar on the recent trends in the field of electrical engineering on an individual basis and evaluation will be done by a panel of faculty members. So this course has no credits and no end semester examination. It is only a pass/fail course. However this course is mandatory and the student has to pass the course to become eligible for the award of degree.

PS2048	**INDUSTRIAL TRAINING (Training to be undergone during II semester vacation)**	**L**	**T**	**P**	**C**
		0	**0**	**1**	**1**
PURPOSE					
To provide hands-on experience at industry or a company where Power Engineering projects are carried out.					

INSTRUCTIONAL OBJECTIVES	
1.	Students have to undergo one week practical training in Power Engineering related project at industry or a company so that they become aware of the practical application of theoretical concepts studied in the class rooms.

- Students have to undergo one week practical training in Power Engineering related project at industry or a company of their choice but with the approval of the department. At the end of the training student will submit a report as per the prescribed format to the department.

Assessment process

This is pass (P) / Fail (U) course and no grade point will be awarded. However this course is mandatory and the student has to pass the course to become eligible for the award of degree. The student shall make a presentation before a committee constituted by the department which will assess the student based on the report submitted and the presentation made and award either a P or U. The student with 'U' grade will redo the training.

PS2049	PROJECT WORK PHASE I	L	T	P	C
		0	0	12	6

INSTRUCTIONAL OBJECTIVES	
1.	To impart the practical knowledge to the students and also to make them to carry out the technical procedures in their project work. To provide an exposure to the students to refer, read and review the research articles, journals and conference proceedings relevant to their project work and placing this as their beginning stage for their final presentation.

- Every student has to identify the project supervisor (guide) based on their thrust area of research. He/She has to give the objectives of the project work and the detailed work plan. The project topic will be approved by the project evaluation committee. The committee will assess/review the work done by them by conducting periodical reviews. He/She has to submit a project report at the end of the semester. The grades will be awarded based on their performance in the internal reviews and the viva voce exam conducted at the end of the semester. The topic should be in the recent trends in the field of power system engineering.
-

PS2050	PROJECT WORK PHASE II	L	T	P	C
		0	0	32	16
INSTRUCTIONAL OBJECTIVES					
1.	This enables and strengthens the students to carry out the project on their own and to implement their innovative ideas to forefront the risk issues and to retrieve the hazards by adopting suitable assessment methodologies and stating it to global.				

- Usually the student has to continue the work carried out in Phase I. The student's performance will be evaluated by conducting periodical reviews by the committee members nominated by the head of the department.
- The end semester examination/ viva voce will be conducted by the External/Internal Examiner nominated by the controller of examinations. Due weight age & considerations will be given in the internal marks for the project work presented in conferences/ Journals.

PROGRAM ELECTIVE COURSES

<table>
<tr><td rowspan="3">PS2101</td><td rowspan="2">HIGH VOLTAGE DIRECT CURRENT TRANSMISSION SYSTEM</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>Total Contact Hours - 45</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">PURPOSE</td></tr>
<tr><td colspan="6">To mould the students to acquire knowledge about HVDC Transmission systems.</td></tr>
<tr><td colspan="6">INSTRUCTIONAL OBJECTIVES</td></tr>
<tr><td>1.</td><td colspan="5">This course gives idea about modern trends in HVDC Transmission and its application.</td></tr>
<tr><td>2.</td><td colspan="5">Complete analysis of harmonics and basis of protection for HVDC Systems.</td></tr>
</table>

UNIT I - DC POWER TRANSMISSION TECHNOLOGY (9 hours)

Introduction - Comparison of AC and DC transmission – Application of DC transmission –Classifications of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC. Comparison of Line Commutated Converter (LCC) link and Voltage Source Converter (VSC) link.

UNT II - ANALYSIS OF HVDC CONVERTERS AND HVDC SYSTEM CONTROL (9 hours)

Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters. General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering - power control – Higher level controllers.

UNIT III - MULTITERMINAL DC SYSTEMS AND HARMONICS (9 hours)

Introduction – Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems- parallel operation of AC and DC transmission. Harmonics on AC and DC sides – filters.

UNIT IV - POWER FLOW ANALYSIS IN AC/DC SYSTEMS(9 hours)

Per unit system for DC Quantities - Modeling of DC links - Solution of DC load flow - Solution of AC-DC power flow - Case studies.

1.

UNIT V STABILITY ANALYSIS OF HVDC SYSTEMS (9 hours)

Introduction – System simulation tools – Modeling of HVDC systems for digital dynamic simulation – Dynamic interaction between DC and AC systems.– inclusion of HVDC model in Small Signal Stability (SSS) algorithm – inclusion of HVDC model in transient stability algorithm and voltage stability analysis.

REFERENCES

1. K.R.Padiyar, "*HVDC Power Transmission Systems*", New Age International (P) Ltd., New Delhi, 2002.
2. J.Arrillaga, , "*High Voltage Direct Current Transmission*", Peter Pregrinus, London, 1983.
3. P. Kundur, "*Power System Stability and Control*", McGraw-Hill, 1993.
4. Erich Uhlmann, "Power *Transmission by Direct Current*", BS Publications, 2004.
5. V.K.Sood, "*HVDC and FACTS controllers – Applications of Static Converters in Power System*", Kluwer Academic Publishers, April 2004.
6. Jos Arrillaga, Liu Y.H. and Neville R.Watson, "*Flexible Power Transmission: The HVDC Options*", Wiley Publishers, 2007.

		L	T	P	C
PS2102	**POWER DISTRIBUTION SYSTEMS**	**3**	**0**	**0**	**3**
	Total Contact Hours - 45				

PURPOSE

To enable the student acquire a comprehensive idea on various aspects of power distribution systems.

INSTRUCTIONAL OBJECTIVES

1.	To give an overview of the function of an electrical power distribution in an electric power system.
2.	To derive the tools for distribution analysis.
3.	To have the wider knowledge on planning and design of a distribution infrastructure.

UNIT I - DISTRIBUTION SYSTEM PLANNING AND DESIGN (9 hours)

Distribution system planning Short term planning, Long term planning, dynamic planning, Sub-transmission and substation design. Sub-transmission networks configurations, Substation bus schemes, Distribution substations ratings, Service areas calculations, Substation application curves.

UNIT II - DISTRIBUTED GENERATIONS SYSTEMS (9 hours)

Distributed Generation Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economical impacts of DG Technologies, DG from renewable energy sources, DG from non-renewable energy sources.

UNIT III - DISTRIBUTED GENERATION EVALUATION (9 hours)

Distributed generation applications, Operating Modes, Base load; peaking; peak shaving and emergency power, Isolated, momentary parallel and grid connection.

UNIT IV - DISTRIBUTION SYSTEM RELIABILITY ANALYSIS (9 hours)

Primary and secondary system design considerations Primary circuit configurations, Primary feeder loading, secondary networks design Economic design of secondary's, Unbalance loads and voltage considerations.

UNIT V - DISTRIBUTION SYSTEM AUTOMATION AND CONTROL (9 hours)

Distribution system performance and operation Distribution automation and control, Voltage drop calculation for distribution networks, Power loss Calculation, Application of capacitors to distribution systems, Application of voltage regulators to distribution systems.

REFERENCES

1. Anthony J. Pansini "*Electrical Distribution Engineering*", CRC Press, 2005.
2. H Lee Willis, "*Distributed Power Generation Planning and Evaluation*", CRC Press, 2000.
3. James A Momoh, "*Electric Power Distribution Automation Protection and Control*" CRC Press, 2007.
4. James J. Burke "*Power distribution engineering: fundamentals and applications*", CRC Press, 2004.
5. A. Pabla, *"Electric Power Distribution",* McGraw-Hill, 2005.

PS2103	ELECTRICAL TRANSIENTS IN POWER SYSTEMS	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				

PURPOSE	
To enable the student understand the various types of power system transients and its impact on power system stability.	
INSTRUCTIONAL OBJECTIVES	
1.	To understand the various types of transients and its analysis in power system.
2.	To learn about the various protective devices against transients.

UNIT I - REVIEW OF TRAVELLING WAVE PHENOMENA **(9 hours)**

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion.

UNIT II - LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES **(9 hours)**

Lightning overvoltages: interaction between lightning and power system- ground wire voltage and voltage across insulator; switching overvoltage: Short line or kilometric fault, energizing transients - closing and re-closing of lines, methods of control; temporary overvoltages: line dropping, load rejection; voltage induced by fault; very fast transient overvoltage (VFTO).

UNIT III - PARAMETERS AND MODELLING OF OVERHEAD LINES **(9 hours)**

Review of line parameters for simple configurations: series resistance, inductance and shunt capacitance; bundle conductors : equivalent GMR and equivalent radius; modal propagation in transmission lines: modes on multi-phase transposed transmission lines, α-β-0 transformation and symmetrical components transformation, modal impedances; analysis of modes on untransposed lines; effect of ground return and skin effect; transposition schemes.

UNIT IV - PARAMETERS OF UNDERGROUND CABLES
(9 hours)

Distinguishing features of underground cables: technical features, electrical parameters, overhead lines versus underground cables; cable types; series impedance and shunt admittance of single-core self-contained cables, impedance and admittance matrices for three phase system formed by three single-core self-contained cables; approximate formulas for cable parameters.

UNIT V - COMPUTATION OF POWER SYSTEM TRANSIENTS - EMTP **(9 hours)**

Digital computation of line parameters: why line parameter evaluation programs? salient features of mtline; constructional features of that affect transmission line parameters; elimination of ground wires bundling of conductors; principle of digital computation of transients: features and capabilities of EMTP; steady state and time step solution modules: basic solution methods.

REFERENCES

1. Allan Greenwood, "*Electrical Transients in Power System*", Wiley & Sons Inc. New York, 1991.
2. Rakosh Das Begamudre, "*Extra High Voltage AC Transmission Engineering*", (Second edition) Newage International (P) Ltd., New Delhi, 1990.
3. Naidu M S and Kamaraju V, "*High Voltage Engineering*", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.
4. Hermann W. Dommel, *EMTP Theory Book*, second Edition, Microtran Power System Analysis Corporation, Vancouver, British Columbia, Canada, May 1992, Last Update: April 1999.
5. EMTP Literature from www.microtran.com.

PS2104	SMART GRID DESIGN AND ANALYSIS	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**
PURPOSE					
To enable the students acquire knowledge on smart grid, different options of architectural design and communication technology for various aspects of smart grid , System analysis and stability analysis in smart grid, renewable energy sources and storage integration with smart grid.					
INSTRUCTIONAL OBJECTIVES					
1.	To understand the concepts and design of Smart grid				
2.	To understand the various communication and measurement technologies in smart grid				
3.	To understand the analysis and stability of smart grid.				
4.	To learn the renewable energy resources and storages integrated with smart grid				

UNIT I - SMART GRID ARCHITECTURAL DESIGNS (9 hours)

Introduction – Comparison of Power grid with Smart grid – power system enhancement – communication and standards - General View of the Smart Grid Market Drivers - Stakeholder Roles and Function - Measures - Representative Architecture - Functions of Smart Grid Components-Wholesale energy market in smart grid-smart vehicles in smart grid.

UNITII - SMART GRID COMMUNICATIONS AND EASUREMENT TECHNOLOGY (8 hours)

Communication and Measurement - Monitoring, Phasor Measurement Unit (PMU), Smart Meters, Wide area monitoring systems (WAMS)- Advanced metering infrastructure- GIS and Google Mapping Tools.

UNIT III - PERFORMANCE ANALYSIS TOOLS FOR SMART GRID DESIGN (9 hours)

Introduction to Load Flow Studies - Challenges to Load Flow in Smart Grid and Weaknesses of the Present Load Flow Methods - Load Flow State of the Art: Classical, Extended Formulations, and Algorithms –Load flow for smart grid design-Contingencies studies for smart grid.

UNIT IV - STABILITY ANALYSIS TOOLS FOR SMART GRID (10 hours)

Voltage Stability Analysis Tools-Voltage Stability Assessment Techniques-Voltage Stability Indexing-Application and Implementation Plan of Voltage Stability in smart grid-Angle stability assessment in smart grid-Approach of smart grid to State Estimation-Energy management in smart grid.

UNIT V - RENEWABLE ENERGY AND STORAGE (9 hours)

Renewable Energy Resources-Sustainable Energy Options for the Smart Grid-Penetration and Variability Issues Associated with Sustainable Energy Technology-Demand Response Issues-Electric Vehicles and Plug-in Hybrids-PHEV Technology-Environmental Implications-Storage Technologies-Grid integration issues of renewable energy sources.

REFERENCES

1. James Momoh, "*Smart Grid: Fundamentals of design and analysis*", John Wiley & sons Inc, IEEE press 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "*Smart Grid: Technology and Applications",* John Wiley & sons inc, 2012.
3. Fereidoon P. Sioshansi, *"Smart Grid: Integrating Renewable, Distributed & Efficient Energy",* Academic Press, 2012.
4. Clark W.Gellings, *"The smart grid: Enabling energy efficiency and demand response",* Fairmont Press Inc, 2009.

PS2105	**MODERN OPTIMIZATION TECHNIQUES IN POWER SYSTEMS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
	Total Contact Hours - 45				
PURPOSE					
To learn the concepts and techniques of evolutionary and optimization techniques in power system applications.					
INSTRUCTIONAL OBJECTIVES					
1.	To have knowledge on optimization techniques applied to power systems.				
2.	To understand the different evolutionary computation techniques and multi objective optimization and their applications in power systems.				

UNIT I - FUNDAMENTALS OF OPTIMIZATION (9 hours)

Definition-Classification of optimization problems-Unconstrained and Constrained optimization-Optimality conditions-Classical Optimization techniques (Linear and non linear programming, Quadratic programming, Mixed integer programming)-Intelligent Search methods (Optimization neural network, Evolutionary algorithms, Tabu search, Particle swarm optimization, Application of fuzzy set theory).

UNIT II - EVOLUTIONARY COMPUTATION TECHNIQUES (10 hours)

Evolution in nature-Fundamentals of Evolutionary algorithms-Working Principles of Genetic Algorithm- Evolutionary Strategy and Evolutionary Programming-Genetic Operators-Selection, Crossover and Mutation-Issues in GA implementation- GA based Economic Dispatch solution-Fuzzy Economic Dispatch including losses- Tabu search algorithm for unit commitment problem-GA for unit commitment-GA based Optimal power flow- GA based state estimation.

UNIT III - PARTICLE SWARM OPTIMIZATION (9 hours)

Fundamental principle-Velocity Updating-Advanced operators-Parameter selection- Hybrid approaches (Hybrid of GA and PSO, Hybrid of EP and PSO) -Binary, discrete and combinatorial PSO-Implementation issues-Convergence issues- PSO based OPF problem and unit commitment-PSO for reactive power and voltage control-PSO for power system reliability and security.

UNIT IV - ADVANCED OPTIMIZATION METHODS (8 hours)

Simulated annealing algorithm-Tabu search algorithm-SA and TS for unit commitment-Ant colony optimization- Bacteria Foraging optimization.

UNIT V - MULTI OBJECTIVE OPTIMIZATION (9 hours)

Concept of pareto optimality-Conventional approaches for MOOP-Multi objective GA-Fitness assignment-Sharing function-Economic Emission dispatch using MOGA-Multiobjective PSO (Dynamic neighbourhood PSO, Vector evaluated PSO) –Multiobjective OPF problem.

REFERENCES

1. D.P.Kothari and J.S.Dhillon, "*Power System Optimization*", 2nd Edition, PHI learning private limited, 2010.
2. Kalyanmoy Deb, "*Multi objective optimization using Evolutionary Algorithms*", John Wiley and Sons, 2008.
3. Kalyanmoy Deb, "*Optimization for Engineering Design*",Prentice hall of India first edition,1988.
4. Carlos A.Coello Coello, Gary B.Lamont, David A.Van Veldhuizen, *"Evolutionary Algorithms for solving Multi Objective Problems",* 2nd Edition, Springer, 2007.
5. SolimanAbdel Hady,Abdel Aal Hassan Mantawy, "*Modern optimization techniques with applications in Electric Power Systems*", Springer,2012.

6. Jizhong Zhu,"*Optimization of power system operation*",John Wiley and sons Inc publication,2009.
7. Kwang Y.Lee,Mohammed A.El Sharkawi, "*Modern heuristic optimization techniques*", John Wiley and Sons,2008.

PS2106	**POWER SYSTEM STATE ESTIMATION**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
	Total Contact Hours - 45				
PURPOSE					
To enable the students to impart knowledge on power system state estimation					
INSTRUCTIONAL OBJECTIVES					
1.	To introduce the state estimation on DC network.				
	To impart in-depth knowledge on power system state estimation.				
	To study alternative formulations of WLS state estimation.				
	To get insight of network observability.				
	To gain knowledge on bad data deduction and identification.				

UNIT I - INTRODUCTION TO STATE ESTIMATION (9 hours)
Need for state estimation – Measurements – Noise - Measurement functions - Measurement Jacobian – Weights - Gain matrix - State estimation as applied to DC networks - Comparison of Power flow and State Estimation problems - Energy Management System.

UNIT II - WEIGHTED LEAST SQUARE ESTIMATION (9 hours)
Modeling of transmission lines - Shunt capacitors and reactors - Tap changing and phase shifting transformers - loads and generators - Building network models - Maximum likelihood estimation - Measurement model and assumptions - WLS State Estimation Algorithm - Measurement functions - Measurement Jacobian matrix - Gain matrix - Cholesky decomposition and performing forward and backward substitutions - Decoupled formulation of WLS State estimation - DC State estimation model - Role of Phasor Measurement Units (PMU) in state estimation.

UNIT III - ALTERNATIVE FORMULATION OF WLS STATE ESTIMATION (9 hours)
Weakness of normal equation formulation, Orthogonal factorization, Hybrid method, Method of Peters and Wilkinsons, Equality constraints WLS State estimation, Augmented matrix approach, Blocked formulation and comparison of techniques.

UNIT IV - NETWORK OBSERVABILITY ANALYSIS (9 hours)

Network and graphs, Network matrices, loop equations, Methods Observability analysis, Numerical Method based on Nodal Variable formulation and branch variable formulation, Topological Observability analysis, Determination of critical measurements – Role of PMU in network observability.

UNIT V - BAD DATA DETECTION AND IDENTIFICATION (9 hours)

Properties of measurement residuals - Classification of measurements - Bad data detection and identification using Chi-squares distribution and normalized residuals - Bad data identification - Largest normalized residual test and Hypothesis testing identification. Role of PMU in bad data detection.

REFERENCES

1. Ali Abur and Antonio Gomez Exposito ,"*Power System State Estimation Theory and Implementation*", Marcel Dekker, Inc., New York . Basel, 2004.
2. J J Grainger and W D Stevension, " *Power System Analysis*", McGraw-Hill, Inc., 1994.
3. A Monticelli, "*State Estimation in Electric Power Systems*", Kluwer Academic Publishers, 1999.
4. Mukhtar Ahmad, *"Power System State Estimation"*, Lap Lambert Acad Publishers, 2013.
5. Felix L. Chernousko, " *State Estimation for Dynamic Systems*", CRC Press, 1993.
6. Naim Logic, *"Power System State Estimation"* , LAP Lambert Acad. Publ., 2010.

		L	T	P	C
PS2107	**ADVANCED POWER SYSTEM DYNAMICS**	**3**	**0**	**0**	**3**
	Total Contact Hours - 45				
PURPOSE					
To enable the students to develop understand transient and voltage stability analysis of power system.					
INSTRUCTIONAL OBJECTIVES					
1.	To perform transient stability analysis using unified algorithm.				
2.	To impart knowledge on sub-synchronous resonance and oscillations.				
3.	To analyze voltage stability problem in power system.				
4.	To familiarize the methods of transient stability enhancement.				

UNIT I - TRANSIENT STABILITY ANALYSIS (9 hours)

Review of numerical integration methods: Euler and Fourth Order Runge-Kutta methods, Numerical stability and implicit methods, Simulation of Power System Dynamic response: Structure of Power system Model, Synchronous machine representation: equations of motion, rotor circuit equations, stator voltage equations, Thevenin's and Norton's equivalent circuits, Excitation system representation, Transmission network and load representation, Overall system equations and their solution: Partitioned – Explicit and Simultaneous-implicit approaches, treatment of discontinuities, Simplified Transient Stability Simulation using implicit integration method.

UNIT II - SUBSYNCHRONOUS OSCILLATIONS (9 hours)

Introduction – Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters.

UNIT III - SUBSYSNCHRONOUS RESONANCE (SSR) (9 hours)

Subsysnchronous Resonance (SSR): Characteristics of series –Compensated transmission systems – Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Analytical Methods – Numerical examples illustrating instability of subsynchronous oscillations – Impact of Network-Switching Disturbances: Steady-state switching – Successive network-Switching disturbances – Torsional Interaction Between Closely Coupled Units; time-domain simulation of subsynchronous resonance – EMTP with detailed synchronous machine model.

UNIT IV - TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS (9 hours)

Review of transmission aspects – Generation Aspects: Review of synchronous machine theory – Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage-reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

UNIT V - ENHANCEMENT OF TRANSIENT STABILITY AND COUNTER MEASURES FOR SUB SYNCHRONOUS RESONANCE (9 hours)

Principle behind transient stability enhancement methods: high-speed fault clearing, reduction of transmission system reactance, regulated shunt compensation, dynamic braking, reactor switching, independent pole-operation of circuit-breakers, single-pole switching, fast-valving, high-speed excitation systems; NGH damper scheme.

REFERENCES

1. P. Kundur, "*Power System Stability and Control*", McGraw-Hill, 1993.
2. R. Ramanujam, "*Power System Dynamics, Analysis and Simulation*", PHI Learning, New Delhi, January 2010.
3. T.V. Cutsem and C.Vournas, "*Voltage Stability of Electric Power Systems*", Kluwer publishers, 1998.

PS2108	WIND AND SOLAR ENERGY SYSTEMS	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				
PURPOSE					
To impart knowledge on wind and solar energy in power systems					
INSTRUCTIONAL OBJECTIVES					
1.	To educate the students scientifically the new developments in wind and solar energy systems.				
2.	To emphasize the significant influence of wind and solar energy in power system.				

UNIT I - INTRODUCTION (9 hours)

Recent trends in energy consumption - World energy scenario - Energy sources and their availability - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems - need to develop new energy technologies.

UNIT II - WIND ENERGY CONVERSION SYSTEMS (9 hours)

Basic principle of wind energy conversion - nature of wind - Wind survey in India - Power in the wind - components of a wind energy - conversion system - Performance of induction generators for WECS - classification of WECS - Analysis of different wind power generators - IG - PMSG - DFIG – SEIG.

UNIT III - GRID CONNECTED WIND ENERGY SYSTEMS (9 hours)

Grid Connected WECS: Grid connectors concepts - wind farm and its accessories - Systems for Feeding into the Grid - Induction Generators for Direct Grid Coupling - Asynchronous Generators in Static Cascades - Synchronous Generators Grid related problems - Generator control - Performance improvements - Different schemes - AC voltage controllers - Harmonics and PF improvement.

UNIT IV - SOLAR ENERGY CONVERSION SYSTEMS (9 hours)

Photovoltaic Energy Conversion: Solar radiation and measurement - solar cells and their characteristics -PV arrays - Electrical storage with batteries - Switching devices for solar energy conversion Grid connection Issues - Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing.

PV Applications: Stand alone inverters - Charge controllers - Water pumping, audio visual equipments, street lighting - analysis of PV systems.

UNIT V - OPERATION OF POWER SYSTEM WITH WIND AND SOLAR ENERGY SYSTEMS (9 hours)

Interface requirement – synchronizing with grid – operating limit – energy storage and load scheduling – utility resource planning – electrical performance – voltage, current and power efficiency – component design for maximum efficiency – static bus impedance and voltage regulation – quality of power – renewable capacity limit – Plant economy.

REFERENCES

1. Thomas Ackermann, "*Wind Power in Power Systems*", John Wiley & Sons, Ltd, 2005.
2. Mukund R. Patel, "*Wind and Solar Power Systems*", CRC Press, 1999.
3. Muhammed H. Rashid, "*Power Electronics Handbook*", Academic Press, Second edition,2006.
4. Rao. S. & Parulekar, *"Energy Technology"*, Khanna publishers, Fourth edition, 2005.
5. Rai ,G.D., *"Non- conventional resources of energy"*, Khanna publishers ,Fourth edition , 2010.
6. Bansal N K, Kleeman and Meliss, *"Renewable energy sources and conversion Techniques"*, Tata McGraw hill, 1990.

7. B.H.Khan, *"Non-Conventional Energy Resources"*, Tata McGraw Hills, Second edition, 2009.

PS2109	**POWER QUALITY**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
	Total Contact Hours - 45				
PURPOSE					
To enable the students acquire knowledge on various power quality issues.					
INSTRUCTIONAL OBJECTIVES					
1.	To understand the various power quality characterizations, sources of issues, their mitigation and monitoring.				
2.	To understand the effects of various power quality phenomena in various equipments.				

UNIT I - POWER QUALITY - AN OVERVIEW (9 hours)

Power Quality definition, PQ characterization: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation–Power acceptability curves: CBEMA, ITIC – Sources for Electric Power Quality problem in power system: poor load power factor, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards and Guidelines.

UNIT II - VOLTAGE VARIATIONS (9 hours)

Voltage Sags - Magnitude & duration-Types- Sources of sags - Estimation of Voltage sag performance: Transmission system and Utility distribution system, Effect of sag on AC Motor Drives, Single-Phase Domestic and Office Loads, Monitoring and mitigation of voltage sag. Origin of Long & Short interruption -influence on various equipments-Basic reliability indices related interruption-monitoring and mitigation of interruption.

UNIT III - POWER QUALITY ANALYSIS (9 hours)

Measurements of Voltage, Current, Power, Energy, power factor- Time domain methods and Frequency domain methods: Laplace's, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform. Harmonic Distortion, Voltage versus Current Distortion, Harmonics versus Transients, Harmonic Indexes, Harmonic Sources from Commercial Loads, Harmonic Sources from Industrial Loads.

UNIT IV - POWER QUALITY MONITORING (9 hours)

Monitoring considerations: Power line disturbance analyser, power quality measurement equipment, harmonic / spectrum analyser, flicker meters, disturbance analyser. Analysis of power outages, Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion: On–line extraction of fundamental sequence components from measured samples

UNIT V - POWER QUALITY ENHANCEMENT (9 hours)

Utility-Customer interface –Harmonic filters: passive, Active and hybrid filters –Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC –control strategies: P-Q theory, Synchronous detection method – Custom power park –Status of application of custom power devices.

REFERENCES

1. Math H.J.Bollen, "*Understanding Power Quality Problems-Voltage sag & Interruptions"*, IEEE Press, 2000.
2. Arindam Ghosh "*Power Quality Enhancement Using Custom Power Devices*", Kluwer Academic Publishers, 2002.
3. Roger.C.Dugan, Mark.F.McGranagham, Surya Santoso, H.Wayne Beaty, "*Electrical Power Systems Quality"*, McGraw Hill, 2003.
4. G.T.Heydt, "*Electric Power Quality*", Stars in a Circle Publications, 1994(2nd edition).
5. Jos Arrillaga, Neville R. Watson, " *Power System Harmonics*"- John Wiley & Sons, 2003.

		L	T	P	C
PS2110	**INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN**	**3**	**0**	**0**	**3**
	Total Contact Hours – 45				
PURPOSE					
To gain knowledge on various aspects of power system analysis and design in industries.					
INSTRUCTIONAL OBJECTIVES					
1.	To impart knowledge on Motor Starting Studies.				
2.	To study about Power Factor Correction.				
3.	To analyze Harmonic, Flicker, Ground Grid Analysis problem in power system.				

UNIT I - MOTOR STARTING STUDIES (9 hours)

Introduction-Evaluation Criteria-Starting Methods-System Data-Voltage Drop Calculations-Calculation of Acceleration time-Motor Starting with Limited-Capacity Generators-Computer-Aided Analysis-Conclusions.

UNIT II - POWER FACTOR CORRECTION STUDIES (9 hours)

Introduction-System Description and Modeling-Acceptance Criteria-Frequency Scan Analysis-Voltage Magnification Analysis-Sustained Overvoltages-Switching Surge Analysis-Back-to-Back Switching-Summary and Conclusions.

UNIT III - HARMONIC ANALYSIS (9 hours)

Harmonic Sources-System Response to Harmonics-System Model for Computer-Aided Analysis-Acceptance Criteria-Harmonic Filters-Harmonic Evaluation-Case Study-Summary and Conclusions.

UNIT IV - FLICKER ANALYSIS (9 hours)

Sources of Flicker-Flicker Analysis-Flicker Criteria-Data for Flicker analysis- Case Study-Arc Furnace Load-Minimizing the Flicker Effects-Summary.

UNIT V - GROUND GRID ANALYSIS (9 hours)

Introduction-Acceptance Criteria-Ground Grid Calculations-Computer-Aided Analysis - Improving the Performance of the Grounding Grids-Conclusions.

REFERENCES

1. J. Duncan Glover, Mulukutla S.Sarma, Thomas Overbye, "*Power System Analysis and Design*", 2011.
2. Turan Gonen" *Electrical Power Transmission System Engineering: Analysis and Design*",Mcgraw Hill publishers,1986.
3. Ramasamy Natarajan, "*Computer-Aided Power System Analysis*", Marcel Dekker Inc., 2002.

PS2111	POWER SYSTEM PLANNING AND RELIABILITY	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				

PURPOSE	
To enable the students to acquire a comprehensive idea on the various aspects of planning and reliability on power system.	
INSTRUCTIONAL OBJECTIVES	
1.	To introduce the objectives of Load forecasting.
2.	To study the fundamentals of Generation system, transmission system and Distribution system reliability analysis
3.	To illustrate the basic concepts of Expansion planning

UNIT I - LOAD FORECASTING (9 hours)

Objectives of forecasting - Load growth patterns and their importance in planning - Load forecasting Based on discounted multiple regression technique-Weather sensitive load forecasting-Determination of annual forecasting-Use of AI in load forecasting.

UNIT II - GENERATION SYSTEM RELIABILITY ANALYSI (9 hours)

Probabilistic generation and load models- Determination of LOLP and expected value of demand not served –Determination of reliability of ISO and interconnected generation systems.

UNIT III - TRANSMISSION SYSTEM RELIABILITY ANALYSIS (9 hours)

Deterministic contingency analysis-probabilistic load flow-Fuzzy load flow probabilistic transmission system reliability analysis-Determination of reliability indices like LOLP and expected value of demand not served.

UNIT IV - EXPANSION PLANNING (9 hours)

Basic concepts on expansion planning-procedure followed for integrate transmission system planning, current practice in India-Capacitor placer problem in transmission system and radial distributions system.

UNIT V - DISTRIBUTION SYSTEM PLANNING OVERVIEW (9 hours)

Introduction, sub transmission lines and distribution substations-Design primary and secondary systems-distribution system protection and coordination of protective devices.

REFERENCES

1. Roy Billinton & Ronald N. Allan, "*Reliability Evaluation of Power System*", Springer Publication, 1986.
2. R.L. Sullivan, "*Power System Planning*", Tata McGraw Hill Publishing Company Ltd, 2012.
3. X. Wang & J.R. McDonald, "*Modern Power System Planning*", McGraw Hill Book Company,1994.
4. T. Gonen, "*Electrical Power Distribution Engineering*", McGraw Hill Book Company, 1986.

<table>
<tr><td rowspan="3">PS2112</td><td rowspan="2" colspan="2">ENERGY MANAGEMENT AND AUDITING</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td colspan="2">Total Contact Hours - 45</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">PURPOSE</td></tr>
<tr><td colspan="7">To acquire an in depth knowledge about the energy management and auditing</td></tr>
<tr><td colspan="7">INSTRUCTIONAL OBJECTIVES</td></tr>
<tr><td>1.</td><td colspan="6">To study the concepts behind economic analysis and load management.</td></tr>
<tr><td>2.</td><td colspan="6">To emphasize the energy management on various electrical equipments and metering.</td></tr>
<tr><td>3.</td><td colspan="6">To illustrate the concept of lighting systems and cogeneration.</td></tr>
</table>

UNIT I – INTRODUCTION (9 hours)

Need for energy management – energy basics – designing and starting an energy management program – energy accounting – energy monitoring, targeting and reporting- energy audit process.

UNIT II – ENERGY COST AND LOAD MANAGEMENT(9 hours)

Important concepts in an economic analysis – economic models – time value of money –utility rate structures – cost of electricity – loss evaluation.

Load management: demand control techniques – utility monitoring and control system-HVAC and energy management – economic justification.

UNIT III – ENERGY MANAGEMENT FOR MOTORS, SYSTEMS, AND ELECTRICAL EQUIPMENTS (9 hours)

Systems and equipment – electric motors – transformers and reactors – capacitors and synchronous machines.

UNIT IV – METERING FOR ENERGY MANAGEMENT (9 hours)
Relationships between parameters – Units of measure – typical cost factors – utility meters – timing of meter disc for kilowatt measurement – demand meters – paralleling of current transformers – instrument transformer burdens – multitasking solid-state meters – metering location vs. requirements – metering techniques and practical examples.

UNIT V – LIGHTING SYSTEMS AND COGENERATION (9 hours)
Concept of lighting systems – the task and the working space – light sources – ballasts –luminaries – lighting controls – optimizing lighting energy – power factor and effect of harmonics on power quality – cost analysis techniques – lighting and energy standards.
Cogeneration: forms of cogeneration – feasibility of cogeneration – electrical interconnection.

REFERENCES

1. Eastop T.D and Croft D.R, "*Energy Efficiency for Engineers and Technologists*", Logman Scientific & Technical, 1990.
2. Reay D.A., "*Industrial Energy Conservation*", first edition, Pergamon Press, 1977.
3. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.
4. Amit K. Tyagi, "*Handbook on Energy Audits and Management*", TERI, 2003.
5. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, "*Guide to Energy Management*", Fifth Edition, The Fairmont Press, Inc., 2006.

		L	T	P	C
PS2113	**DISTRIBUTED GENERATION AND MICROGRID**	**3**	**0**	**0**	**3**
	Total Contact Hours – 45				

PURPOSE	
To provide knowledge on the various aspects of distributed generations and micro grids.	
INSTRUCTIONAL OBJECTIVES	
1.	To illustrate the concept of distributed generation
2.	To analyze the impact of grid integration.
3.	To study concept of Microgrid and its configuration

UNIT I – INTRODUCTION (9 hours)

Conventional power generation: advantages and disadvantages, Energy crises, Non-conventional energy (NCE) resources: review of Solar PV, Wind Energy systems, Fuel Cells, micro-turbines, biomass, and tidal sources.

UNIT II – DISTRIBUTED GENERATIONS (DG) (9 hours)

Concept of distributed generations, topologies, selection of sources, regulatory standards/ framework, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. DG installation classes, security issues in DG implementations. Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants.

UNIT III – IMPACT OF GRID INTEGRATION (9 hours)

Requirements for grid interconnection, limits on operational parameters,: voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues.

UNIT IV- MICROGRIDS (10 hours)

Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids, communication infrastructure, modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques.

UNIT V- POWER QUALITY ISSUES IN MICROGRIDS (8 hours)

Power quality issues in microgrids- Modelling and Stability analysis of Microgrid, regulatory standards, Microgrid economics, Introduction to smart microgrids.

REFERENCES

1. AmirnaserYezdani, and Reza Iravani, "*Voltage Source Converters in Power Systems: Modeling, Control and Applications*", IEEE John Wiley Publications,2009.
2. DorinNeacsu, "*Power Switching Converters: Medium and High Power*", CRC Press, Taylor & Francis, 2006.

3. Chetan Singh Solanki, "*Solar Photo Voltaics*", PHI learning Pvt. Ltd., New Delhi,2009.
4. J.F. Manwell, "*Wind Energy Explained, theory design and applications*," J.G. McGowan Wiley publication,2002.
5. D. D. Hall and R. P. Grover, "*Biomass Regenerable Energy*", John Wiley, New York, 1987.
6. John Twidell and Tony Weir, "*Renewable Energy Resources*" Tyalor and Francis Publications, 2005.

		L	T	P	C
PS2114	**DESIGN OF CONTROLLERS IN POWER APPLICATIONS**	**3**	**0**	**0**	**3**
	Total Contact Hours – 45				
PURPOSE					
To provide knowledge on the various types of controllers in power applications.					
INSTRUCTIONAL OBJECTIVES					
1. .	To introduce the mathematical representation of controller components and solution techniques.				
2.	To impart in-depth knowledge on different methods of modern controllers.				
3.	To get insight of contingency analysis problem and the solution methods.				
4.	To gain knowledge on transient stability analysis and the associated solution techniques.				

UNIT I – CLASSICAL CONTROLLER DESIGN (9 hours)

Introduction of Controller design – Proportional (P)-Integral (I)-Derivative (D)-PI-PD - PID Controllers-Characteristics-Design Controller Tuning-Ziegler-Nichol's method and Cohen coon method – Damped oscillation method.

UNIT II – SLIDING MODE CONTROL& VARIABLE STRUCTURE CONTROLLER (9 hours)

Dynamics in the sliding mode – linear system, non-linear system, chattering phenomenon – sliding mode control design – reachability condition, robustness properties –application Sliding Surfaces- Continuous approximations of Switching Control laws-The Modeling/Performance Trade-Variable structure controller-Adaptive Variable structure controller bang-bang control theory-trajectory planning-Case Studies.

UNIT III – CURRENT CONTROLLER DESIGN (9 hours)

Hysteresis current control (HCC) – Design of HCC with PWM schemes-Case Studies
Predictive current controller (PCC) –Model predictive control (MPC)-PWM predictive control (PPC).

UNIT IV – H-INFINITY CONTROL & ROBUST CONTROL THEORY (9 hours)
Instruction of H-infinity methods in control theory-Elements of Robust Control Theory – Design Objectives – Shaping the Loop Gain –Signal Spaces – Computation of H∞ norm- All Pass Systems-- Linear-quadratic-Gaussian control (LQG)- -Case Studies
Robust Control Theory- Robust Controller Design- Robust decision methods-Analytic tools for robust decision making-Case Studies.

UNIT V – CONTROLLER DESIGN (9 hours)
Controller synthesis and tuning, Linear Matrix Inequalities, LMI solvers, control system analysis and design with LMIs using MATLAB/Simulink
Uncertain System Analysis -Statistical and worst-case analysis of stability and performance Analysis.
Survey and Review of different controller's used in power system and power electronics practices.

REFERENCES

1. Jean Pierre Barbot," *Sliding Mode Control In Engineering*" Marcel Bekker, 2002.
2. Green M.,Limebeer DJN and Englewood cliffs NJ "*Linear Robust Control*",: Prentice Hall, 1995.
3. P.C.Chandrasekharan., *"Robust Control of Linear Dynamical Systems" ,* AcademicPress Limited, San Diego.1996.
4. Zinober, Alan S.I., ed.1994 *"Variable Structure and Lyapunov Control"* ,London: Springer-Verlag. doi:10.1007/BFb0033675. ISBN 978-3-540-19869-7.
5. Bryson A.E and Ho. Y., "*Applied Optimal Control: Optimization, Estimation and Control* ", John Wiley and Sons, New York, 1975
6. SomanathMajhi ., *" Advanced Control Theory A relay Feedback Approach",* CengageLearning, 2009.

<table>
<tr><td rowspan="3">PS2115</td><td rowspan="2">ANALYSIS OF ELECTRICAL MACHINES</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>Total Contact Hours - 45</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">PURPOSE</td></tr>
<tr><td colspan="6">To have a fair knowledge on various aspects of Electrical Machines</td></tr>
<tr><td colspan="6">INSTRUCTIONAL OBJECTIVES</td></tr>
<tr><td>1.</td><td colspan="5">To learn about the basic principles of Electromechanical energy conversion</td></tr>
<tr><td>2.</td><td colspan="5">To impart in-depth knowledge on modelling of DC and AC machines</td></tr>
<tr><td>3.</td><td colspan="5">To get insight of steady state and dynamic analysis of Electrical machines</td></tr>
</table>

UNIT I - PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION (9 hours)

General expression of stored magnetic energy, co-energy and force/ torque – example using single and doubly excited system –Calculation of air gap mmf and per phase machine inductance using physical machine data.

UNIT II - REFERENCE FRAME THEORY (9 hours)

Static and rotating reference frames – transformation of variables – reference frames – transformation between reference frames – transformation of a balanced set –balanced steady state phasor and voltage equations – variables observed from several frames of reference.

UNIT III - DC MACHINES (9 hours)

Voltage and torque equations – dynamic characteristics of permanent magnet and shunt DC motors – state equations - solution of dynamic characteristic by Laplace transformation.

UNIT IV - INDUCTION MACHINES (9 hours)

Voltage and toque equations – transformation for rotor circuits – voltage and toque equations in reference frame variables – analysis of steady state operation – free acceleration characteristics – dynamic performance for load and torque variations – dynamic performance for three phase fault – computer simulation in arbitrary reference frame.

UNIT V - SYNCHRONOUS MACHINES (9 hours)

Voltage and Torque Equation – voltage Equation in arbitrary reference frame and rotor reference frame – Park equations - rotor angle and angle between rotor – steady state analysis – dynamic performances for torque variations- dynamic performance for three phase fault – transient stability limit – critical clearing time – computer simulation.

REFERENCES

1. Paul C.Krause, OlegWasyzczuk, Scott S, Sudhoff, "*Analysis of Electric Machinery and Drive Systems*", IEEE Press, Second Edition,2002.
2. R.Krishnan, "*Electric Motor Drives, Modeling, Analysis and Control*" , Prentice Hall of India, 2002.
3. Samuel Seely, "Eletomechanical *Energy Conversion*", Tata McGraw Hill Publishing Company.
4. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, " *Electric Machinery*", Tata McGraw Hill, 5^{th} Edition, 1992.

PS2116	SPECIAL MACHINES AND THEIR CONTROLLERS	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				
PURPOSE					
To have a fair knowledge on various aspects of special machines and their controllers.					
INSTRUCTIONAL OBJECTIVES					
1.	To know about the constructional features, principle of operation and mode of excitation of various special machines.				
2.	To acquire the knowledge of both open loop and closed loop control Torque- Speed Characteristics and Dynamic Characteristics of different Special Machines.				

UNITI - SYNCHRONOUS RELUCTANCE MOTORS (9 hours)
Constructional features – Types – Axial and radial air gap motors – Operating principle – Reluctance – Phasor diagram – Characteristics – Vernier motor.

UNITII - STEPPING MOTORS (9 hours)
Constructional features – Principle of operation – Variable reluctance motor – Hybrid motor – Single and multi stack configurations – Theory of torque predictions – Linear and non-linear analysis – Dynamic Characteristics –

Drive systems and circuit for open loop control &Closed loop control of stepping motor.

UNIT III - SWITCHED RELUCTANCE MOTORS (9 hours)

Constructional features – Principle of operation – Torque prediction – Power controllers, Non-linear analysis, Microprocessor based control – speed – torque Characteristics – Computer control.

UNIT IV - PERMANENT MAGNET BRUSHLESS D.C. MOTOR (9 hours)

Difference between mechanical and electronic Commutators, Hall sensors, Optical sensors, Square - Wave permanent magnet brushless motor drives, torque and EMF equation, torque - speed characteristics of Permanent Magnet Brush less DC Motors - controllers PM DC Motor, applications.

UNIT V - PERMANENT MAGNET SYNCHRONOUS MOTOR (9 hours)

Principle of operation – EMF and torque equations – Reactance – Phasor diagram – Power controllers – Converter – Volt-ampere requirements. – Torque speed characteristics, self control ,Microprocessor based control ,applications.

REFERENCES

1. Miller. T. J. E., "*Brushless Permanent Magnet and Reluctance Motor Drives*", Clarendon Press, Oxford, 1989.
2. Kenjo. T and Nagamori. S, "*Permanent Magnet and Brushless DC Motors*", Clarendon Press, Oxford, 1986.
3. Kenjo. T, "*Stepping Motors and their Microprocessor Control*", Clarendon Press, Oxford, 1989.
4. Krishnan R, "*Switched Reluctance Motor Drives*", Modelling, Simulation, Analysis, Design and applications, CRC press, 2001.
5. P.P. Aearnley, '*Stepping Motors – A Guide to Motor Theory and Practice'*, Peter Perengrinus, London, 1982.

PS2117	SYSTEM THEORY	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				

PURPOSE

To impart students to have a fair knowledge about the use of advanced mathematical techniques in Control Engineering problems.

INSTRUCTIONAL OBJECTIVES

1. To gain knowledge about state variable representation models.
2. To understand reduction techniques and realization of transfer functions.
3. To get exposed to state space design and analysis of non-linear systems.

UNIT I - STATE SPACE ANALYSIS & CONTROLLABILITY, OBSERVABILITY (10 hours)

Introduction to state variable representation models of linear continuous time system solution of state equation by various methods. Diagonalization of matrices. Calculation of generalized eigen vectors. Reduction to canonical and Jordan's canonical form. Gilberts and Kalman's test for controllability and observability

UNIT II - RANSFER FUNCTION AND STATE SPACE DESIGN (8 hours)

Impulse response and transfer function matrices. Properties of transfer functions, reducibility, Realization of transfer functions. State space design. Design by state feedback and pole placements.

UNIT III - NONLINEAR SYSTEMS (9 hours)

Types of non-linear phenomena- singular points- phase plane method- construction of phase trajectories- Derivation of describing functions. Need for model reduction-dominant pole concept-model reduction via partial realization-time moment matching and pade approximation-Hankel norm model reduction.

UNIT IV - STABILITY CONCEPTS (9 hours)

Stability concepts – Equilibrium points –BIBO and asymptotic stability,isoclines equilibrium points stability concepts- Lyaponouv's stability criteria- Stability of non- linear systems by describing function method- jump resonance. Frequency domain stability criteria- Popov's criterion.

UNIT V - OPTIMAL CONTROL & ADAPTIVE CONTROL (9 hours)

Formulation of optimal control problems- solving of optimal control problems – Hamiltonian formulation- linear regulator problem- solution of Richatti equation- Pontryagin's minimum principle- time optimal control. Classification of adaptive control systems-MRAC systems-different configuration- classification- Mathematical description.

REFERENCES

1. Nagrath I.J., and Gopal, M., "*Control Systems Engineering*" New Age International (P) Limited, 2010.
2. Gopal. M., "*Modern control system Theory*", Wiley Eastern Ltd., 2nd Edition Reprint 1995.
3. Graham C., Goodwill, S.Graebe and M.Salgado, "*Control System Design*" Prentice Hall India, New Delhi, 2000.
4. Astrom K.J., and Wittenmark B., "*Adaptive control*", Addison-Wesley Longman Publishing Co, Second Edition,1994.
5. K.Ogata, "*Modern Control Engineering*" Prentice Hall of India, Fifth edition, 2010.
6. Brian D. O. Anderson, John Barratt Moore, "*Optimal Control*" Prentice Hall, 1990.
7. Stefani, Shahian, Savant & Hostetter, "*Design of feedback control systems*," Oxford University Press, 2002.
8. Stanley M. Shinners, "*Modern Control System Theory & Design*," John Wiley & Sons Inc., 1998.

PS2118	ARTIFICIAL NEURAL NETWORKS APPLIED TO POWER SYSTEMS	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				

PURPOSE	
To enable the students to understand the concepts of artificial neural networks and its applications in power engineering.	
INSTRUCTIONAL OBJECTIVES	
1.	To understand the fundamental concepts of ANN and different architectures and its learning methodologies.
2.	To gain knowledge about different network architectures and its

	applications in power systems and power electronics.
3.	To learn the concepts of the various training/learning algorithms and its use.

UNIT I - INTRODUCTION (9 hours)

Artificial neural networks – definition and fundamental concepts –-biological neural networks – Artificial neuron- activation functions – setting of weights – typical architectures – biases and thresholds – learning/ training algorithms & Laws, Self adaptation Equations-Coincidence performance, competitive, filter and spatiotemporal learning.

UNIT II - FEED FORWARD NEURAL NETS (9 hours)

Perceptron – architectures, algorithm and applications – linear separability – ADALINE – feed forward networks – back propagation algorithm– alternate activation functions-number of hidden layers – practical consideration – gradient decent algorithms- radial basis function networks [RBF].

UNIT III - STATISTICAL METHODS BASED NEURAL NETS (9 hours)

Associate memory-Auto associative-hetero associative – bidirectional associative memory-Hopfield neural networks – discrete and continuous net.

UNIT IV - COMPETITIVE NETWORKS (9 hours)

Kohonen's self organizing maps[SOM]-learning vector quantization[LVQ] and its types- Adaptive resonance theory – ART 1, ART2- architecture, algorithms.

UNIT V - APPLICATIONS OF ANN (9 hours)

Applications of ANN in Power systems – load forecasting- unit commitment -load scheduling –Power flow studies- Control applications in FACTS & power quality applications-Fault Analysis and fault classification problems in Power systems.

REFERENCES

1. Simon Haykin, "*Neural Networks and learning machines*" , Prentice Hall,third edition 2009.
2. Laurene fausett, "*Fundamentals of Neural Network Architecture*", algorithms and applications – pearsons education.2008.
3. Yegnanarayana B., "*Artificial Neural Networks*", Prentice Hall of India Private Ltd., New Delhi, 1999.

4. Robert J. Schalkoff, "*Artificial Neural Networks*", McGraw-Hill International Editions, first edition,1997.
5. James a Freeman and David M.Sakapura, "*Neural Network Algorithms applications and programming techniques"* – pearsons education (2004).
6. S.N.Sivanandam,S.N.Deepa, *"Principles of soft computing"*,2nd Edition, Wiley India Pvt Limited, 2011.

<table>
<tr><td rowspan="3">PS2119</td><td rowspan="2">DIGITAL SIGNAL PROCESSING</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>Total contact hours - 45</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">PURPOSE</td></tr>
<tr><td colspan="6">To familiarize the students with the most important application oriented concepts of digital signal processing.</td></tr>
<tr><td colspan="6">INSTRUCTIONAL OBJECTIVES</td></tr>
<tr><td>1.</td><td colspan="5">To understand basic concepts in signals and systems.</td></tr>
<tr><td>2.</td><td colspan="5">To gain knowledge on the related mathematical tools in signal processing.</td></tr>
<tr><td>3.</td><td colspan="5">To design and analyze digital filters for power applications.</td></tr>
</table>

UNIT I - DISCRETE TIME SYSTEMS (9 hours)

Characteristics and classification of signals – Representation and classification of Discrete time systems – Advantages of Digital Signal processing – transfer functions – Z-transform, inverse Z-transform and its applications – convolution.

UNIT II - FOURIER TRANSFORMS (9 hours)

Introduction to analysis of analog and discrete signals – Fourier series, Fourier transform – Discrete Fourier Transform (DFT) properties of DFT – Computation of discrete Fourier transforms – Radix – 2 FFT algorithms.

UNIT III - SAMPLING (9 hours)

Sampling of continuous signals – analog filter design – anti aliasing filters – Sample and hold circuits – Reconstructing fillers – Digital to analog and analog to digital converters.

UNIT IV - FIR & IIR FILTER DESIGN (9 hours)

Realization of FIR and IIR Filters – Impulse invariance and Bilinear transform methods of IIR filter design – Design of FIR filter using windows – Comparison of IIR and FIR Digital filters.

UNIT V - FINITE LENGTH WORD EFFECTS AND QUANITSATION (9 hours)

Introduction – Effects of coefficient on Quantization – Finite register length effects in realizations of Digital filters and discrete Fourier transform computation.

Architecture and features of Texas and Analog Devices DSP processors – Advantages.

REFERENCES

1. Alan V. Oppenheim, Ronald W. Schafer "*Digital Signal Processing*", Prentice Hall of India pvt. Ltd., 2002.
2. John G. Proakis, Dimitris G. Manoiaias, "*Digital Signal Processing*", Prentice Hall of India pvt. Ltd., third edition 2000.
3. Sanjit K. Mitra "Digital *Signal Processing*", Tata McGraw Hill, second edition,2001.
4. Alan V. Oppenheim, Ronald W. Schafer, "*Discrete time Signal processing*", Prentice Hall of India pvt. Ltd., 1998.

PS2120	**INTELLIGENT CONTROLLERS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
	Total contact hours – 45				
PURPOSE					
To enable the students to apply the neural networks, Genetic algorithms & fuzzy logic concepts in power Systems and electronics systems.					
INSTRUCTIONAL OBJECTIVES					
1.	To learn the basic knowledge regarding activation function, learning rules and various neural networks.				
2.	To understand the knowledge of crisp set, fuzzy set and Fuzzy logic controllers				
3.	To apply the Genetic algorithms in the tuning of controllers				
4.	To design controllers using Simulation Software fuzzy logic toolbox & NN tool box.				

UNIT I - NEURAL NETWORKS (9 hours)

Neural Networks – biological neurons – Artificial neurons – activation function – learning rules – feed forward networks – supervised &

Unsupervised learning – perceptron network- linear separability – back propagation networks algorithms-Radial basis function networks.

UNIT II - ASSOCIATIVE MODELS AND CONTROL SCHEMES IN NN (9 hours)

Auto & hetero associative memory – bi-directional associative memory – Self organizing feature maps-Hopfield networks-Neural Networks for non – linear system – Schemes of Neuro control – System identification – forward model and – Inverse model – Case studies.

UNIT III - FUZZY LOGIC AND ITS CONTROLLERS (9 hours)

Fuzzy set - Crisp set – vagueness – uncertainty and imprecision – fuzzy set – fuzzy operation- properties – crisp versus fuzzy relations – fuzzy relations – fuzzy Cartesian product and composition – composition of fuzzy relations-Fuzzy to crisp conversion –structure of fuzzy logic controller – database – rule base – Inference engine.

UNIT IV - GENETIC ALGORITHMS (9 hours)

Genetic Algorithms: Working principles – terminology – Importance of mutation – comparison with traditional methods – constraints and penalty function – GA operators – Real coded GAs.

UNIT V - APPLICATIONS (9 hours)

Applications of Neural network, Fuzzy system & Genetic algorithms for power systems and power electronics systems-Designing of controllers using Simulation Software, NN tool box & Fuzzy Logic Toolbox.

REFERENCES

1. Awrence Fausatt, "*Fundamentals of neural networks*", Prentice Hall of India, New Delhi, 1994.
2. Timothy J. Ross, "*Fuzzy Logic with Engineering Applications*", McGraw Hill International Edition, USA, 1997.
3. Bart kosko, " *Neural Networks and Fuzzy Systems*", Prentice Hall of India, New Delhi, 1994.
4. Jack M.Zurada, "*Introduction to Artificial Neural Systems*", Jaico publishing house 2006.
5. Zimmerman H.J. "*Fuzzy set theory – and its applications*", Kluwer Academic Publishers 1994.
6. Simon Haykin, "*Neural Networks – A comprehensive foundation*", Pearson Education Asia, 2002.

7. Kalyanmoy Deb, “Optimization for Engineering Design”, prentice hall of India first edition, 1988.
8. David E.Goldberg, “*Genetic Algorithms in search,optimization and machine learning*”,pearson edition,2009.

PROGRAM SUPPORTIVE COURSES

<table>
<tr><td rowspan="3">MA2008</td><td rowspan="2">APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>Total Contact Hours - 45</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">PURPOSE</td></tr>
<tr><td colspan="6">To develop analytical capability and to impart knowledge in Advanced Matrix theory, Linear and Non linear programming, Calculus of variations and Random Processes and their applications in Engineering and Technology and to apply these concepts in Engineering problems they would come across.</td></tr>
<tr><td colspan="6">INSTRUCTIONAL OBJECTIVES</td></tr>
<tr><td>1.</td><td colspan="5">To understand mathematical and statistical techniques.</td></tr>
<tr><td>2.</td><td colspan="5">To explain logically the concepts .</td></tr>
<tr><td>3.</td><td colspan="5">To apply the concepts in solving the engineering problems.</td></tr>
</table>

UNIT I - MATRICES (9 hours)

Computation of the greatest and the least eigen values of a matrix by power method - Modal matrix - Spectral - Sylvester's theorem - Power series of matrices - Application of matrices to solution of Differential equations.

UNIT II - LINEAR PROGRAMMING (9 hours)

Linear programming - Graphical Method - Simplex method - Duality Theorems - Dual Simplex method - Integer programming.

UNIT III - BOUNDARY VALUE PROBLEMS (9 hours)

Solution of Initial and boundary value problems - Characteristics - D'Alembert's Solution - Significance of Characteristic curves - Laplace transform solutions for displacement in a long string - a long string under its weight - a bar with prescribed force on one end - free vibration of a string.

UNIT IV - CALCULUS OF VARIATIONS (9 hours)

Calculus of variations - Concepts of functionals - Euler's equation - Brachistochrone problem - Variational problems involving several unknown functions - Functionals involving two or more independent variables - Variational problems with moving boundaries - Isoperimetric problems.

UNIT V - PROBABILITY AND RANDOM PROCESSOR (9 hours)

Probability - Baye's Theorem for conditional probability - Random variables - Distribution function - Density function - Variance and covariance -

Stochastic process - Auto correlation - Auto covariance - Cross correlation and cross covariance - Stationary process - Auto correlation and cross correlation functions - Power spectrum.

REFERENCES

1. Dass H.K., "*Engineering Maths*", S.Chand and Co., 2003.
2. Grewal B.S., "*Higher Engineering Mathematics*", Khanna Publishers.36th Edition.
3. Kanti Swarup, Gupta P.K., Manmohan, "*Operations Research*", Sultan Chand, 11th Edition - 2003.
4. Venkataraman M.K., "*Higher Engineering Mathematics*", National Publishing Co., 4th Edition, July 1992.
5. Veerajan T., "*Probability, Statistics and Random Processes*", Tata Mc Graw Hill, 2004.

PS2201	**OBJECT ORIENTED PROGRAMMING**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
	Total Contact Hours - 45				
PURPOSE					
This course gives a fundamental understanding of the Object Oriented concepts with the help of the programming language C ++.					
INSTRUCTIONAL OBJECTIVES					
1.	To understand the basic concepts of Object Oriented programming.				
2.	To learn the C and C ++ language concepts and programming.				
3.	To study the detailed understanding of OOPS concepts like Inheritance and Polymorphism.				
4.	To learn advanced concepts like Templates and file I/O				

UNIT I - OBJECT ORIENTED CONCEPTS (9 hours)
Traditional Programming Approach – Structured Methodology – Object Oriented Concepts – Objects and Classes – Instance – Messages – Methods – Encapsulation – Inheritance – polymorphism – Dynamic binding – Benefits of Object Oriented Programming – C++ Pointers – Runtime binding - Dynamic Objects – Self referential classes.

UNIT II - C++ CLASSES AND METHODS (9 hours)
C++ Classes and Methods – Members – Message Parsing – Creation and Initialization – Constructor and Destructor functions - Reference variables – Inline functions – Friend functions – Default arguments.

UNIT III - INHERITANCE **(9 hours)**

Inheritance - Benefits – Cost of inheritance – Execution speed - Program size – Message passing overhead - Program complexity – Derived Classes – Abstract classes – Multiple inheritance – Access Control.

UNIT IV - POLYMORPHISM **(9 hours)**

Polymorphism – Overloading – Operator overloading – Function overloading – Overriding – Deferred methods – Virtual functions.

UNIT V - TEMPLATES AND STREAMS **(9 hours)**

Templates – List Templates – Function templates – Template arguments. Streams – Input –Output – Formatting – Files and Streams – Exception handling.

REFERENCES

1. Bjarne Stroustrup , "*The C++ Programming Language*" , 2nd edition , Wesley,1997.
2. Robert Lafore , "*Mastering Turbo C++*" , BPB Publications ,2000.
3. Yashavant Khanitkar , "*Programming in C++*" , 4th edition, BPB Publications,1999.
4. Venugopal K, Rajkumar R, Ravishankar T. , "*Mastering C ++*" , Tata McGraw Hill Publication Company Ltd , 1997.

PS2202	COMPUTER NETWORKS	L	T	P	C
		3	0	0	3
	Total Contact Hours - 45				

PURPOSE

The purpose of this course is to make the students acquire fairly good knowledge on networking computers for reliable and secured operation and also to provide a wide-ranging introduction to modern computer networks and their applications.

INSTRUCTIONAL OBJECTIVES

1.	To learn the functions of different layers. .
2.	To appreciate and understand state-of-the-art in network protocols, topologies and applications
3.	To learn the principles of routing and the semantics and syntax of IP To learn the principles of routing and the semantics and syntax of IP
4.	To study about internetworking, transport and application layer

	protocol.
5.	To learn network security aspects

UNIT I - INTRODUCTION AND PHYSICAL LAYER (8 hours)

Evolution of data networks, Network architecture, ISO Reference model examples of networks, Application of networks, Physical layer, and communication medium characteristics.

UNIT II - DATA LINK LAYERS (10 hours)

Local area networks, conventional channel allocation methods, pure-ALOHA, S-ALOHA, Collision free protocols, Limited contention protocols – IEEE 802 for LAN's - Data link layer design issues – Service primitives – Stop and wait Sliding window protocols – Comparison of stop and wait and sliding window protocols.

UNIT III - NETWORK LAYERS (9 hours)

Network layer design issues -Routing– Types of Routing algorithm- Congestion control algorithms –internetworking- IP protocol.

UNIT IV - TRANSPORT LAYER (8 hours)

Transport layer design issues – User Datagram Protocol (UDP) – Transmission Control Protocol (TCP) –TCP connection management – Quality of services (QOS) – Integrated Services.

UNIT V - APPLICATION LAYER (10 hours)

Abstract syntax notation – Data compression techniques – Remote procedure call - Design Issues – DNS – Electronic mail – Multimedia – introduction to digital audio compression, streaming audio, internet radio, voice over IP.
Network Security: Cryptography – Symmetric key – Public key algorithms – Authentication protocols – Digital signatures – Email security – Social issues.

REFERENCES

1. Andrew .S. Tanenbaum, "*Computer Networks*", Prentice Hall of India publications, 5th edition, 2010.
2. Behrouz A.Forouzan, "*Data Communication and Networking*", fourth Edition, Tata McGraw Hill, 2009
3. Stallings, "*Data and Computer Communications*", Pearson education, 8th edition, 2007.

4. D.Bertsekas and R.Gallager, "*Data networks*", 2nd Edition, Prentice Hall of India, 2003.
5. Achyut S Godbole, "*Data Communications and Networking*", Tata McGraw Hill, 2005.

AMENDMENTS

S. No.	Details of Amendment	Effective from	Approval with date
