Proposed Structure of M.Tech Electrical Engineering (Power Systems)
CBCS Pattern (2015-16)

STRUCTURE & EXAMINATION PATTERN

Semester I									**Total Duration: 20 hrs/week** **Total Marks :500** **Total Credits: 18**		
Subjects	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme (Marks)**						**Examination Scheme (Credits)**		**Total Credits**
	L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/assignments**	**TW**	**Pract/ Oral**	**TH**	**TW/PR /OR**	
Research Methodology	04	--	60	20	10	10	-	--	04	-	04
FACTS and HVDC	04	--	60	20	10	10	-	--	04	-	04
Advanced Microcontroller & Its Applications	04	02	60	20	10	10	25	25	04	01	05
Power System Modeling	04	02	60	20	10	10	25	25	04	01	05
Total	**16**	**04**	**240**	**80**	**40**	**40**	**50**	**50**	**16**	**02**	**18**

Semester II									**Total Duration: 20 hrs/week** **Total Marks :500** **Total Credits: 18**		
Subjects	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme (Marks)**						**Examination Scheme (Credits)**		**Total Credits**
	L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/ assignments**	**TW**	**Pract/ Oral**	**TH**	**TW/PR/ OR**	
Power Systems Dynamics	04	--	60	20	10	10	--	--	04	-	04
Digital Protection of Power System	04	02	60	20	10	10	25	25	04	01	05
PLC & SCADA	04	02	60	20	10	10	25	25	04	01	05
Elective - I	04	--	60	20	10	10	--	--	04	--	04
Total	**16**	**04**	**240**	**80**	**40**	**40**	**50**	**50**	**16**	**02**	**18**

Semester III									**Total Duration: 28 hrs/week** **Total Marks : 500** **Total Credits: 40**		
Subject	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme**						**Examination Scheme (Credits)**		**Total Credits**
	L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/ assignments**	**TW**	**Pract/ Oral**	**TH**	**TW/PR /OR**	
Power Quality Issues	04	02	60	20	10	10	25	25	04	01	05
Elective –II	04	02	60	20	10	10	25	25	04	01	05
Self-Study Paper-I	04	--	60	20	10	10	-	-	04	-	04
Dissertation Stage –I	-	07	-	-	---	--	25	25		21	21
Seminar	-	05	-	-	**--**	**--**	25	25	-	05	05
Total	**12**	**16**	**180**	**60**	**30**	**30**	**100**	**100**	**12**	**28**	**40**

Elective – I	**Elective - II**
a) Power Sector Restructuring & Deregulation b) Power system planning & reliability	a) Advanced Control system b) Advanced Power Electronics & Drives

Semester IV									**Total Duration: 14 hrs/week** **Total Marks : 325** **Total Credits: 34**		
Subject	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme**						**Examination Scheme (Credits)**		**Total Credits**
	L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial /assignments**	**TW**	**Pract/ Oral**	**TH**	**TW/PR/OR**	
Self-Study Paper-II	04	--	60	20	10	10	-	-	**04**	**-**	**04**
Dissertation Stage –II	-	10	-	-	--	-	150	75		30	30
Total	**04**	**10**	**60**	**20**	**10**	**10**	**150**	**75**	**04**	**30**	**34**

List of Self Study paper I & II

Self Study Paper I	**Self Study Paper II**
Condition Monitoring of Electrical Equipments	Electrical Power Capacitors
Energy Storage Devices	Nano technology & its applications in Electrical Engineering
Digital Measurement Techniques	High voltage insulation system & design
Energy Conservation & Audit	Use of synchronized measurement techniques in power system
Solar PV & Wind energy systems	Distributed Generation
Demand response & demand side management	Smart Grid - Automation System for State Transmission Utility
Digital Signal Processing Applications in Power Systems	Substation design

RESEARCH METHODOLOGY			
TEACHING SCHEME:		**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week		End Semester Examination: 60 Marks	04 Credits
		Continuous Assessment: 40 Marks	

UNIT - I	**Fundamentals**	**(08 Hours)**
	Definition, Research Characteristics, Research Need, Objectives and types of research, Motivation and objectives – Research methods vs Methodology, Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical	
UNIT - II	**Formulation of research problem**	**(08 Hours)**
	Research Formulation – Defining and formulating the research problem - Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem – Literature review – Primary and secondary sources – reviews, treatise, monographs-patents – web as a source – searching the web - Critical literature review – Identifying gap areas from literature review - Development of working hypothesis. Summarizing a Technical Paper -summary template , Online tools - Google, CiteSeer, ACM Digital Library, IEEE, The on-line Computer Science bibliography, Searching patents	
UNIT - III	**Research design methods**	**(08Hours)**
	Research design, sampling design and scaling techniques – Research design – Basic Principles- Need of research design — Features of good design – Important concepts relating to research design, basic principles of experimental designs, implications of sample design, steps in sample design, criteria of selecting sampling procedure, characteristics of good sampling design, different types of sample design. Scaling techniques: measurement scales, sources of error, technique of developing measurement tool, important scaling techniques, scale construction techniques.	
UNIT - IV	**Statistical analysis**	**(08 Hours)**
	Data Collection and analysis:- Observation and Collection of primary and secondary data - Methods of data collection, processing operations, types of analysis, statistics in research, measures of central tendency, measures of dispersion, measures of asymmetry, measures of relationships, simple regression analysis, multiple correlation and regression, partial correlation.	
UNIT - V	**Research Paper & Thesis writing**	**(08 Hours)**
	Reporting and thesis writing – Structure and components of scientific reports - Types of report – Technical reports and thesis – Significance – Different steps in the preparation – Layout, structure and Language of typical reports – Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation – Planning – Preparation –Practice – Making presentation –	

	Use of visual aids - Importance of effective communication - Documentation and presentation tools: LATEX. Types of technical papers - Journal papers, Conference papers, Survey papers, Poster papers, Review papers Comparison, Structure of a survey, conference and journal paper, Organization and flow of thesis/ Project report, Research proposal: preparation, budgeting, presentation, funding agencies for engineering research,	
UNIT - VI	**Research ethics, IPR and publishing**	**(08 Hours)**
	Ethics: ethical issues. IPR: intellectual property rights and patent law, techniques of writing a Patent, filing procedure, technology transfer, copy right, royalty, trade related aspects of intellectual property rights Publishing: design of research paper, citation and acknowledgement, plagiarism tools, reproducibility and accountability.	

Text Books:

1. Kothari, C.R., Research Methodology: Methods and Techniques. New Age International
2. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., An introduction to Research Methodology, RBSA Publishers
3. Suresh Sinha, Anil K Dhiman,Research Methodology, ESS Publications,Volumes 2
4. Day R.A., How to Write and Publish a Scientific Paper, Cambridge University Press
5. Wadehra, B.L. Law relating to patents, Trade Marks, copyright designs and geographical indications. Universal Law Publishing

Reference Books:

1. Louis Cohen, Lawrence Manion and Keith Morrison, Research Methods in Education, 7th Edition, Cambridge University Press, ISBN – 978-0415-58336-7
2. Anthony, M., Graziano, A.M. and Raulin, M.L., Research Methods: A Process of Inquiry, Allyn and Bacon
3. Ranjit Kumar, Research Methodology: A Step by Step Guide for Beginners, 2nd Edition, APH Publishing Corporation
4. Leedy, P.D. and Ormrod, J.E., Practical Research: Planning and Design, Prentice Hall
5. Fink, A., Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications
6. Leslie Lamport, ' Latex: A document preparation system' Addison Wesley, Reading, Massachusetts, second

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT - III
Unit Test -2	UNIT – IV, UNIT – V, UNIT - VI

FACTS & HVDC

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	

UNIT - I	**FACTS:**	**(08 Hours)**
	Conventional methods to increase transmission capacity, Series, Shunt reactors, Phase shifting transformers, Synchronous condensers, Flexible AC transmission controllers Basics, Challenges and needs, Static Power converter structures, AC controller based structures, DC link converter topologies, Converter output and harmonic control, Power converter control issues	
UNIT - II	**Shunt and Series Compensation:**	**(08 Hours)**
	Operation and control of thyristor controlled reactor, Thyristor switched Capacitor, SVC, STATCOM configuration and control, Applications of SVC, Power oscillation damping, Mitigation of sub-synchronous resonance, TCSC operation, Layout and protection, Applications of TCSC, Static Synchronous Series Compensator (SSSC)	
UNIT - III	**Unified Power Flow Controller:**	[08 Hrs]
	UPFC configuration, Independent real and reactive power flow control, Control scheme for UPFC, Basic control system for P and Q control, Dynamic performance, Operational constraints of UPFC, Power flow studies in UPFC embedded systems	
UNIT - IV	**General Background of HVDC Transmission:**	**(08 Hours)**
	EHV AC versus HVDC Transmission, Different configurations of HVDC link - Monopolar, Bipolar, Back to Back, Power flow through HVDC link, Equation for HVDC power flow, Connections of three phase six pulse and twelve pulse converter bridges, Voltage and current waveforms. Effect of delay angle, Extinction angle, Overlap angle, Control of DC voltage	
UNIT - V	**Multi Terminal HVDC:**	**(08 Hours)**
	Bipolar HVDC terminal, Converter transformer connections, Switching arrangements in DC yard for earth return to metallic return, HVDC switching system, Switching arrangements in a bipolar HVDC terminal, Sequence of switching operations, HVDC circuit breakers, DC current interruption, Commutation principle, Probable types and applications of HVDC circuit breakers, Multi-terminal HVDC systems, Parallel tapping, Reversal of power, Configurations and types of multi-terminal HVDC systems, Commercial multi terminal systems	
UNIT - VI	**Protection and Control:**	**(08 Hours)**
	Faults and abnormal condition in bipolar, Two terminal HVDC system, Pole-wise segregation, Protective zones, Clearing of DC line faults and reenergizing, Protection of converters, Transformer, Converter valves, DC yards, Integration of protection and controls, Hierarchical levels of control, Block diagram, Schematic diagram, Current control, Power	

	control, DC voltage control, Commutation channel, Master control, Station control, Lead station, Trail station, Pole control, Equidistant firing control, Synchronous HVDC link, Asynchronous HVDC Link	

Text Books:

1. E.Acha, V.A.Agelidis, O.Anaya-lara and TJE MillerNewnes, Power Electronic control in Electrical Systems Oxford.
2. N.G. Hingorani and L.Gyugi, Understanding FACTS- IEEE Press, New York.
3. J. Arrilaga, Y.H.Liu and N.R.Watson, Flexible Power Transmission- The HVDC Options, John Wiley and sons Ltd., New York.

Reference Books:

1. T J E Miller, "Reactive Power Control in Electric Systems", John Wiley
2. Padiyar K R "FACTS Controllers in Power Transmission & Distribution", New Age.
3. R. Mohan and R.K.Varma, "Thyristor-Based FACTS Controllersfor Electrical Transmission Systems", IEEE Press.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT – III
Unit Test -2	UNIT – IV, UNIT – V, UNIT – VI

Advance Micro controllers and applications

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	
	TW&OR : 50 Marks	01 Credits

UNIT - I	Introduction to PIC 16F8XX family and development tools. CPU architecture and instruction set. Harvard architecture and pipelining, program memory considerations, register file structure and addressing modes, CPU registers.	(08 Hours)
UNIT - II	PIC peripherals I/O ports, external interrupts and timers, timer operation, ADC, short overview of synchronous serial port, serial peripheral interface I2C bus.	(08 Hours)
UNIT - III	Learning MPLAB (V 5.0 or above) Integrated development environment from Microchip (Assembler and simulator),Study of applications like motor control, temperature control, lamp dimmer, 4X4 matrix keyboard and LCD interfacing etc.	(08 Hours)
UNIT - IV	ARM & AVR Processors : RISC, ARM design philosophy, ARM fundamentals, instruction set, thumb instruction set, exception & interrupt handling, efficient C programming, optimizing ARM assembly code, AVR architecture, instruction set, hardware interfacing, communication links and design issues.	(08 Hours)
UNIT - V	Interfacing considerations: Intel process communication, synchronization of processes, tasks, threads, devices & buses for networks, hardware-software co-design embedded programming in C/RT Linux	(08 Hours)
UNIT - VI	Real time operating systems: Survey of software architectures- round robin, with interrupts, function queue scheduling, RTOS architecture, selecting an architecture, task states, task and data semaphores and shared data, message queues, mailboxes ,pipes, timer functions, events, memory management, interrupt routines in an RTOS environment, basic design using RTOS, embedded software development tools, Micro C/OS- II, VX works.	(08 Hours)

Reference Books:

1. Microchip PIC family Microcontroller handbook
2. Design with PIC microcontrollers –John Peatman, Pearson Education Asia ,LPE
3. Rajkamal,''Embedded system –architecture, programming and design",TMH Publication, edition 2003
4. David Simon," An embedded software Primer", Pearson education , Asia
5. Jonathan W. Valvano, Brooks, Cole" Embedded Microcomputer systems-Real time interfacing" Thomson Learning

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT – III
Unit Test -2	UNIT – IV, UNIT – V, UNIT – VI

Power System Modeling

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Theory: 04Hours / Week	End Semester Examination: 60 Marks	04Credits
	Continuous Assessment: 40 Marks	
	PR & OR : 50 Marks	01 Credits

UNIT – I	**Modeling of Non-Electrical Parameters:**	**(08 Hours)**
	Different areas of power system analysis, Need for mathematical modeling of power system, Simplified models of non-electrical components such as boiler, steam & hydro turbine, governor system	
UNIT – II	**Modeling of Transformers:**	**(08 Hours)**
	Transformer modeling for two winding transformer, tap-changer, phase shifting transformer, three winding transformer and auto-transformer	
UNIT – III	**Modeling of Transmission Line:**	**(08 Hours)**
	Modeling of transmission network, Transformation to Alpha-Beta components using D-Q components, Steady state equations	
UNIT – IV	**Synchronous Machine Modeling:**	**(08 Hours)**
	Introduction, Park's Transformation, Flux Linkage Equation, Voltage Equations, Formulation of State-Space Equation, Current Formulation, Per Unit Conversion, Normalizing Voltage equations, Normalizing Torque Equations, Torque & Power Equivalent Circuit of Synchronous Machine	
UNIT – V	**Excitation System Modeling :**	
	Types of excitation systems, Control and protective systems, Modeling of excitation systems (excitation system components and entire excitation system, Voltage Response Ratio, Exciter voltage ratings	**(08 Hours)**
UNIT – VI	**Load Modeling:**	
	Basic Load Modeling concepts, Static load representation, Dynamic load representation, Induction motor (as load) modeling, synchronous motor (as load) modeling, acquisition of load model parameters	**(08 Hours)**

Text Books:

1. K. R. Padiyar", Power System Dynamics", B.S. Publications
2. John J. Granier & W.D. Stevenson Jr., "Power System Analysis ", 4th Edition, McGraw Hill International Student Edition
3. Olle Elegard, "Electrical Energy System Theory - An Introduction", TMH Publishing Company, 2nd Edition
4. Kundur, "Power System Dynamics & Control", IEEE Press, New York

Reference Books:

1. Anderson & Foud, "Power System Control & Stability", Vol-I, IEEE Press, New York
2. P.S.R Murthy, " Power System Operation & Control"

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II
Unit Test -2	UNIT – III, UNIT – IV
Unit Test-3	UNIT –V, UNIT-VI

Power System Dynamics		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	

UNIT - I	**Classical Methods of Power System Dynamic Studies**	**(08 Hours)**
	Equality and inequality constraints in power system operation, state transition diagram, concept of system security and stability, classical model of system of one machine connected to infinite bus, Clark diagram for two machines series reactance system, extension of Clark diagram to cover any reactance network, elementary model of overall power system	
UNIT - II	**Small Signal Stability:**	**(08 Hours)**
	Small signal analysis, analysis of synchronizing & damping torque, state equation for small signal model, Simplified synchronous machine model, calculation of initial conditions, system simulation, improved model of synchronous machine, small signal stability of multi machine system	
UNIT - III	**Large Signal Analysis:**	**(08 Hours)**
	Elementary view of transient stability, Large signal analysis, Analysis using numerical integration methods (Modified Euler's, Runge-Kutta), Simulation of power system dynamic response, Analysis of unbalanced faults, Case study of a large system	
UNIT - IV	**Power System Stabilizers:**	**(08 Hours)**
	Basic concepts of control signals in power system stabilizers (PSS), Structure and tuning, Field implementation, PSS design and application, Future trends	
UNIT - V	**Multi-machine system:**	**(08 Hours)**
	Simplified model, Improved model of the system for linear load, Inclusion of load and SVC, Introduction to analysis of large power system	
UNIT - VI	**Voltage stability:**	**(08 Hours)**
	Definition, Factors affecting voltage stability & collapse, Analysis & comparison of angle & voltage stability and voltage instability & collapse, Control of voltage instability, islanding - necessity, methods, advantages and disadvantages, implication on power system dynamic performance	

Text Books:

1. Anderson &Foud, "Power system Control & Stability", IEEE press, New York
2. OlleElgerd, "Electrical Energy System Theory - An Introduction", TMH

Reference Books:

1. K R Padiyar, "Power System Dynamics", B S Publications
2. PrabhaKundur, "Power system Stability & control", TMH
3. C.W.Taylor, "Power System Voltage Stability", TMH
4. R. A. Walling, " Distributed Generation Islanding", N.W. Miller

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT – III
Unit Test -2	UNIT – IV, UNIT – V, UNIT – VI

Digital Protection of Power System

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Theory: 04Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	
	TW & OR : 50 Marks	01 Credit

UNIT – I	**Introduction:**	**(08 Hours)**
	Need for Power system protection, Digital Protection: State of Art, Merits of Microprocessor relaying scheme, Power System Components, Basic Philosophy of Protection Scheme, Section of Protection Scheme, Circuit Breakers and Relays, Types and Applications. Architecture of Modern Digital Relay	
UNIT - II	**Static Relays:**	**(08 Hours)**
	Introduction to Static Relay, Overcurrent Relay, Distance Relay, Protection Schemes of transmission lines, Switched distance relay, Poly-phase relay, Relay as Comparator - Dual input Comparator, Relay characteristics by comparison of constants, Multi-input comparator, Pilot Relaying Scheme	
UNIT - III	**Elements of Digital Protection:**	**(08 Hours)**
	Basic components of a digital relay, Signal conditioning subsystem: Transducers, Surge protection circuits, Analog filtering and analog multiplexers, Conversion subsystems, Sampling Theorem, Digital filter signal aliasing error, Sample and hold circuit, Digital multiplexing, Digital to analog conversion, Analog to digital conversion, Digital relay subsystem, Digital relay as unit	
UNIT – IV	**Digital Protection of Transmission Line:**	**(08 Hours)**
	Protection scheme of transmission line, Distance Relay, Travelling wave relays. Digital protection scheme based on fundamental signal: hardware design, software design, Digital protection of EHV/UHV transmission line based on travelling wave phenomena, New relaying scheme using amplitude comparison	
UNIT – V	**Digital Protection of Transformer and Synchronous Generator:**	**(08 Hours)**
	Faults in Transformer, Schemes used for Transformer Protection, Digital Protection of Transformer Faults in Synchronous generator, Protection schemes for Synchronous generator, Digital Protection of Synchronous Generator	
UNIT – VI	**Artificial Intelligence in Power System Protection:**	**(08 Hours)**
	Introduction, An Expert System (ES) for Protective Relay Settings: Introduction, Problem Description, ES Approach, Typical Application, Fuzzy Logic (FL) for Power system Protection: Introduction, Problem Description, FL Approach, Artificial Neutral Network (ANN) in Phase Selection: Introduction, Problem Description, Measurement of fault generated in high frequency components, ANN Approach	

Text Books:

1. "Digital Protection – Protective Relaying from Electro-Mechanical to Microprocessor" By L.P. Singh. 2nd Edition, Reprint-2004, New Age International Publisher, New-Dehli.
2. "Digital Power System Protection" By S.R. Bhide. PHI Learning Private Limited, New Delhi.
3. "Artificial Intelligence Techniques in Power Systems", By Kevin Warwick, Auther Ekwue & Raj Aggarwal, Publication : Institution of Electrical Engineers, London, UK.
4. "Digital Protection for Power system" by A.T Johns and S.K. Salman. Peter Peregrinus Ltd. Of The Institute of Electrical Engineers, London, United Kindom.
5. "Soft Computing Techniques and its Applications in Electrical Engineering" By Dr. Devendra Chaturvadi,

Publication: Springer – Verlag Berlin Heidelburg.	
Reference Books:	
1. "Power System Protection 4: Digital Protection and Signalling" edited by ETA Electricity Training Association. Published by Institute of Engineers, London, UK.	
2. "Digital Signal Processing in Power System Protection and Control" By Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski.	
Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT - III
Unit Test -2	UNIT – IV, UNIT – V, UNIT - VI

PLC and SCADA		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	
	Term Work: 50 Marks	01 Credits

UNIT – I	**Introduction to PLC**	**(08 Hours)**
	Definition & History of PLC, Overall PLC system, PLC Input and Output modules, CPU, Interfaces, Power supplies, PLC advantages and disadvantages, Selection criteria for PLC, Architecture of Industrial Automation Systems, Process Control, PID Control, Predictive Control, Introduction to Sequence Control, PLCs and Relay Ladder Logic, Hardware environment	
UNIT – II	**PLC Programming**	**(08 Hours)**
	Programming equipments, Construction of PLC ladder diagram, Basic components and symbols in ladder diagram, Ladder logic, Functional block, Structural text, Instruction, trouble shooting, features, programming ON/OFF Inputs to produce ON/OFF outputs, Networking of Sensors, Actuators and Controllers: The Fieldbus, The Fieldbus Communication Protocol	
UNIT – III	**PLC Applications**	**(08 Hours)**
	Analog PLC operation, PID control of continuous processes, simple closed loop systems, closed loop system using Proportional, Integral & Derivative (PID), PLC interface, Motors Controls: AC Motor starter, AC motor overload protection, DC motor controller, Variable speed (Variable Frequency) AC motor Drive	
UNIT – IV	**SCADA**	**(08 Hours)**
	Need of SCADA system, Features, SCADA architecture – First generation, Second generation, Third generation, HMI, MTU, RTU, IED's, 7 Layers of OSI, Communication requirements for SCADA (communication protocols – DNP, IEC, Ethernet, TCP/IP, Modbus, UDP), Client – Server based communication concept, SCADA Benefits	
UNIT – V	**SCADA in Power System**	**(08 Hours)**
	Operation and control of interconnected power system, Automatic substation control, SCADA configuration, Energy Management System (EMS), system security, State estimation, SCADA system security issues overview	
UNIT – VI	**Supervisory Management**	**(08 Hours)**
	Networked SCADA environment with implementation examples, Substation Automation and Equipment condition monitoring using SCADA, Distribution system design mapping, trouble call management, Customer level intelligent automation system, computer level monitoring and control of equipments	

Text Books:

1. Terson, "Power System Control Technology", Prentice Hall
2. Green, J. N, Wilson, R, "Control and Automation of Electric Power Distribution Systems", Taylor and Francis, 2007
3. Turner, W. C, " Energy Management Handbook", 5th Edition, 2004
4. Gary Dunning, "Introduction to Programmable Logic Controllers", Thomson, 2nd Edition
5. John W. Webb, Ronald A. Reis, "Programmable Logic Controllers: Principles and Application", 5th Edition
6. Stuart A Boyer, "SCADA supervisory control and data acquisition"

Reference Books:	
1. Handschin, E. “Energy Management Systems”, Springer Verlag, 1990	
2. Gordan Clark, Deem Reynders, “Practical Modem SCADA Protocols”	
Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT - III
Unit Test -2	UNIT – IV, UNIT – V, UNIT - VI

(Elective – I) Power Sector Restructuring & Deregulation		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	

UNIT - I	**Power Sector in India** Introduction to various institutions in an Indian Power sector such as CEA, Planning Commissions, PGCIL, PFC, Ministry of Power, State and Central governments, REC, Load Dispatch Centers ,Utilities and their roles. Critical issues / challenges before the Indian power sector, Electricity act 2003-Provision in the Generation, Transmission& Distribution Sector, Various national policies and guidelines under this act.	**(08 Hours)**
UNIT - II	**Fundamentals of Economics& Power Sector Regulation** Fundamentals of economics applicable to Power Sector, Consumerbehavior, Supplier behavior, Market Equilibrium, Short- run & Long- run costs, Various costs of production-Total cost (TC), Average fixed cost (AFC), Average variable cost (AVC), Average cost (AC) and Marginal cost (MC),Relationship between short-run and long-run average costs, Perfectly competitive market, Concept of life cycle cost , Annual rate of return , methods of calculations of Internal Rate of Return(IRR) and Net Present Value(NPV) of project, Role of regulation and evolution of regulatory commission in India, Types and methods of economic regulation, Regulatory process in India.	**(08 Hours)**
UNIT - III	**Power Tariff** Different tariff principles (marginal cost, cost to serve, average cost), Consumer tariff structures and considerations, different consumer categories, telescopic tariff, fixed and variable charges, time of day, interruptible tariff, and different tariff based penalties and incentives etc., Subsidy and cross subsidy, life line tariff, Comparison of different tariff structures for different load patterns. Government policies in force from time to time. Effect of renewable energy and captive power generation on tariff,Availability based tariff, Latest reformsand amendments	**(08 Hours)**
UNIT - IV	**Power sector restructuring and market reform** Introduction to power sector restructuring,Reasons for restructuring / deregulation of power industry, Understanding the restructuring process-Entities involved, The levels of competition, The market place mechanisms and Sector-wise major changes required , Different industry structures and ownership models, Market models based on contractual arrangements-Monopoly Model, Single buyer Model, Wholesale competition model and Retail competition model, Marketarchitecture, Timeline for various energy markets, Bilateral / forward contracts, The spot market, Models for trading arrangements, ISO or TSO model,Reasons and objectives of deregulation of various power systems acrossthe world-The US, The UK, The Nordic Pool and The developing countries.Congestion Management, Ancillary Services	**(08 Hours)**
UNIT - V	**Electricity Markets Pricing and Non-price issues** Electricity price basics, Market Clearing price (MCP), Zonal and locational MCPs, Dynamic, spot pricing and real time pricing, Dispatch based pricing, Power flows and prices. Optimal power flow Spot prices for real and reactive power. Unconstrained real spot prices, constrains and real spot prices.Non price issues in electricity restructuring (quality of supply and service, environmental and social considerations),Global experience with	**(08 Hours)**

	electricity reforms in different countries.	
UNIT - VI	**Transmission Planning and Pricing** Transmission planning& operation in open access power systems, Introduction & Principles of transmission pricing, Differenttransmission pricingmethods, Transmission cost allocation methods, Marginal & Composite pricing Paradigms & their comparison, Introduction to transmission loss allocation & various methods of loss allocation, Debated issues in transmission pricing, Congestion issues and management,Ancillary Service Management, Forward ancillary service auction. Power purchase agreements.	**(08 Hours)**

ReferenceBooks:

1. Loi Lei Lai, 'Power System Restructuring &Deregulation, John Wiley & Sons Ltd.
2. "Know Your Power", A citizens Primer On the Electricity Sector, Prayas Energy Group, Pune
3. Sally Hunt, "Making Competition Work in Electricity", 2002, John Wiley Inc
4. Electric Utility Planning and Regulation, Edward Kahn, American Council for Energy Efficient Economy
5. D. S. Kirschen& G. Strbac,'Fundamentals of Power System Economics', John Wiley & Sons Ltd.
6. Steven Stoft,'Power System Economic Designing markets for Electricity, Wiley-Inter Science.
7. M Shahidepour, Hatim Yamin, Zuyi Li,'Market Operations in Electrical Power Systems, Forecasting, Scheduling and Risk Management', Wiley Inter Science.

References:

1. Regulation in infrastructure Services: Progress and the way forward - TERI, 2001
2. Maharashtra Electricity Regulatory Commission Regulations and Orders - www.mercindia.com
3. Various publications, reports and presentations by Prayas, Energy Group, Pune www.prayaspune.org
4. Central Electricity Regulatory Commission, Regulations and Orders - www.cercind.org
5. Electricity Act 2003 and National Policies – www.powermin.nic.in
6. Market Operations in Electric Power Systems Forecasting, Scheduling and Risk Management –Mohammad Shadepur, HatimYatim, Zuyi Li.
7. BhanuBhushan, "ABC of ABT - A primer on Availability Tariff" - www.cercind.org

Website: NPTEL-Phase II-

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT – III
Unit Test -2	UNIT – IV, UNIT – V, UNIT – VI

(Elective – I)POWER SYSTEM PLANNING AND RELIABILITY		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	03 Credits
Practical: 02 Hours / Week	Continuous Assessment: 40 Marks	
	Term Work: 25 Marks	01 Credit

UNIT - I	**Unit 1: Load Forecasting :**	**(06 Hours)**
	Introduction, Factors affecting Load Forecasting, Load Research, Load Growth Characteristics, Classification of Load and Its Characteristics, Load Forecasting Methods -(i) Extrapolation (ii) Co-Relation Techniques, Energy Forecasting, Peak Load Forecasting, Reactive Load Forecasting, Non-Weather sensitive load Forecasting, Weather sensitive load Forecasting, Annual Forecasting, Monthly Forecasting, Total Forecasting, Objectives & Factors affecting to System Planning , Short Term Planning, Medium Term Planning, Long Term Planning. [10 hrs]	
UNIT - II	**Unit 2: Probability theory**	**(06 Hours)**
	Introduction to probability, Probability distributions : Random variables, density and distribution functions. Mathematical expectation. Binominal distribution, Poisson distribution, normal distribution, exponential distribution, Weibull distribution. Normal Gaussian, Gamma and Beta distribution. Correlation and regression	
UNIT - III	**Unit 3: Reliability**	**(06 Hours)**
	Reliability, Failure, Concepts of Probability, Evaluation Techniques (i) Markov Process (ii) Recursive Technique, Stochastic Prediction of Frequency and Duration of Long & Short Interruption, Adequacy of Reliability, Reliability Cost.	
UNIT - IV	**Unit 4: Generation Planning and Reliability :**	
	Objectives & Factors affecting Generation Planning, Generation Sources, Integrated Resource Planning, Generation System Model, Loss of Load (Calculation and Approaches), Outage Rate, Capacity Expansion, Scheduled Outage, Loss of Energy, Evaluation Methods. Interconnected System, Factors affecting interconnection under Emergency Assistance.	
UNIT - V	**Unit 5: Transmission Planning and Reliability**	**(06 Hours)**
	Transmission Planning and Reliability: Introduction, Objectives of Transmission Planning, Network Reconfiguration, System and Load Point Indices, Data required for Composite System Reliability.	
UNIT - VI	**Unit 6: Distribution Planning and Reliability**	**(06 Hours)**
	Radial Networks – Introduction, Network Reconfiguration, Evaluation Techniques, Interruption Indices, Effects of Lateral Distribution Protection, Effects of Disconnects, Effects of Protection Failure, Effects of Transferring Loads, Distribution Reliability Indices. Parallel & Meshed Networks -Introduction, Basic Evaluation Techniques, Bus Bar Failure, Scheduled Maintenance, Temporary and Transient Failure, Weather Effects, Breaker Failure.	

Text Books:	
1. Roy Billinton& Ronald N. Allan, Reliability Evaluation of Power System - Springer Publication.	
2. R.L. SullivanPower System Planning -, Tata McGraw Hill Publishing Company Ltd.	
3. Miler& Freund's, Probability and Statistic for Engineers, Pearson Education, Richard Johnson.	
Reference Books:	
1. X. Wang & J.R. McDonald, Modern Power System Planning –, McGraw Hill Book Company	
2. T. Gönen, Electrical Power Distribution Engineering - McGraw Hill Book Company	
3. B.R. Gupta Generation of Electrical Energy –, S. Chand Publications	
4. A.S. Pabla, Electrical Power Distribution Tata McGraw Hill Publishing Company Ltd.	
5. T.W.Berrie, Electricity Economics & Planning –, Peter Peregrinus Ltd., London	
Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT - III
Unit Test -2	UNIT – IV, UNIT – V, UNIT - VI

Power Quality Issues		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	04 Credits
	Continuous Assessment: 40 Marks	

UNIT - I	**Voltage sag; swells and interruptions** Introduction; importance of power quality; terms and definitions of power quality as per IEEE std. 1159. Sources & Effects of Power Quality Problems; Sources of sag; swell and interruptions; Estimation of voltage sag performance; Fundamental principles of protection; solutions at end user level; utility systems and fault clearing issues; motor starting sags; evaluation of the economics of different alternatives.	**[8Hrs]**
UNIT - II	**Transient Over- Voltages** Sources of transient over voltages; capacitor switching; lightening; Ferro resonances and other switching transients; Principles of over voltage protections; devices of over voltage protections; Utility capacitor switching transients; Utility system lightening protection; managing Ferro resonance; switching transients problems with loads; computer tools for transient analysis.	**[8Hrs]**
UNIT - III	**Fundamentals of Harmonics and its Analysis** Introduction; the Mechanism of Harmonic Generation; Definitions and Standards: Factors Influencing the Development of Standards, Existing Harmonic Standards, General Harmonic Indices. Introduction to Harmonic Analysis; Fourier Series and Coefficients; Simplifications Resulting from Waveform Symmetry; Complex Form of the Fourier Series; Convolution of Harmonic Phasors; The Fourier Transform; Sampled Time Functions; Discrete Fourier Transform (DFT); The Nyquist Frequency and Aliasing; Fast Fourier Transform (FFT); Window Functions; Efficiency of FFT Algorithms; Alternative Transforms.	**[8Hrs]**
UNIT - IV	**Harmonic Sources and Distortions** Harmonic Sources : Introduction; Transformer Magnetization Nonlinearities; Rotating Machine Harmonics; Distortion Caused by Arcing Devices; Single-Phase Rectification; Three-Phase Current-Source Conversion; Three-Phase Voltage-Source Conversion; Thyristors-Controlled Reactors. Harmonic Distortion : Introduction; Resonances; Effects of Harmonics on Rotating Machines; Effect of Harmonics on Static Power Plant; Harmonic Interference with Power System Protection; Effect of Harmonics on Consumer Equipment; Interference with Communications.	**[8Hrs]**
UNIT - V	**Computation, Assessment and Harmonic Elimination** Harmonic Computation : Introduction; Direct Harmonic Analysis; Derivation of Network Harmonic Impedances from Field Tests; Transmission Line Models; Underground and Submarine Cables; Load Models; Computer Implementation; Examples of Application of the Models; Harmonic Elimination : Introduction; Filter Design Criteria; Network Impedance for Performance Calculations; Tuned Filters; Damped Filters; Conventional Filter	**[8Hrs]**

	Configurations; Band-Pass Filtering for Twelve-Pulse Converters; Distribution System Filter Planning; Filter Component Properties; D.C. Side Filters; Active Filter	
UNIT - VI	**Power quality monitoring; Assessment & Mitigation** Need and approaches followed in power quality monitoring; objectives and requirements; Initial site survey; Power quality Instrumentation; Selection of power quality monitors; monitoring location and period; Selection of transducers; Harmonic monitoring; Transient monitoring; event recording and flicker monitoring. Power Quality assessment; Power quality indices and standards for assessment; waveform distortion; voltage and current unbalances; Power assessment under waveform distortion conditions. Power quality state estimation; State variable model; observability analysis; capabilities of harmonic state estimation; Test systems; Mitigation techniques at different environments.	**[8Hrs]**

References:

1. Understanding power quality problems; voltage sag and interruptions - M. H. J. Bollen IEEE press; 2000; series on power engineering.
2. "POWER SYSTEM HARMONICS", Second Edition By Jos Arrillaga and Neville R. Watson; John Wiley and Publication, 2003 ISBN: 0-470-85129-5.
3. Electrical power system quality - Pogei C. Dugan; Mark F. McGranghan; Surya santoso; H. Wayne Beaty; second edition; McGraw Hill Pub.
4. Power system quality assessment - J. Arrillaga; M.R. Watson; S. Chan; John Wiley and sons.
5. Electric power quality - G. J. Heydt.
6. Power system harmonics: Computer modeling and analysis- Enriques Acha; Manuel Madrigal; John wiley and sons ltd.
7. Power System Harmonics – J. Arrillaga & N. Watson
8. IEEE std 519-1992/ IEEE std 1159 IEEE recommended practices and requirements for harmonics control in electrical power system.
9. ECBC Code 2007 (Edition 2008) published by Bureau of Energy Efficiency; New Delhi Bureau of Energy Efficiency Publications Rating System; TERI PUBLICATIONS GRIHA Rating System; LEEDS Publications

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT – III
Unit Test -2	UNIT – IV, UNIT – V, UNIT – VI

(Elective – II) **Advanced Control System**		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week	End Semester Examination: 60 Marks	03 Credits
	Continuous Assessment: 40 Marks	

UNIT - I	**PID Control:**	**(08 Hours)**
	Review of classical and modern control concepts: PID control and tuning approaches, Selection of Variables for Control, PID Controller Tuning for Dynamic Performance - Determining Tuning Constants for Good Control Performance, Ziegler-Nichols method, Correlations for Tuning Constants, Fine-Tuning the Controller Tuning Constants, Controller tuning based on stability – Dead beat and self tuning, Rate feedback	
UNIT - II	**State Variable Analysis:**	**(08 Hours)**
	Control System Analysis Using State Variable Methods, Conversion of transfer function to phase variable and canonical variable model, Eigen value and eigen vector, Kalman's test and Gilbert's Test for controllability and observability analysis and design of control system in state space, Pole placement, State observer, Design of control system with Luenberger observer	
UNIT - III	**Nonlinear and Robust Control:**	**(08 Hours)**
	Nonlinear Systems and Equilibrium Points, Concepts of Stability, Describing function analysis, Phase plane analysis, Linearization, Feedback Linearization, Input-output linearization, Input-State Linearization Concept of robust control, Description and categorization of system uncertainties, System and signal norms, Small gain theorem, Robust stability, Design of robust control, Introduction to H-∞ control.	
UNIT - IV	**Digital Control:**	**(08 Hours)**
	Structure of the Digital Control System, ADC, DAC, Effects of Sampling of continuous time signals, Quantization, Sample and hold, Reconstruction of signal, Sampling Theorem**, A**liasing, Elementary discrete-time signals, Impulse response, Linear convolution and its properties, Z transform: Basics, Properties, Inverse Z transform using power series and partial fraction difference equation, Stability analysis in z- plane with Jury's stability criteria	
UNIT - V	**Frequency Analysis:**	**(08 Hours)**

	Frequency response of first order and second order systems, Polar plot, Bode plot, Bode plot from Sweep Frequency Response Analysis (SFRA) of transformer and its conclusion, Phase and group delays, Ideal filters and their pole zero locations, Zero phase and linear phase transfer functions Exponential representation of Fourier series and Fourier transform of continuous time signals, The Fourier series for discrete-Time periodic signals (only concept), The Fourier transform of discrete-time a periodic signals (only concept), Discrete Fourier Transform, Properties: Periodicity, Linearity, Symmetry properties, Circular convolution, Linear convolution using circular convolution, Fast Fourier Transform: Radix 2 DIT and DIF algorithms	
UNIT - VI	**Optimal Control:**	**(08 hours)**
	Parameter optimization and optimal control problems, Hamiltonian formulation of optimal control problem, Hamilton-Jacoby equation, Linear regulator problem, Quadratic performance criterion, Numerical solution of Matrix Riccati equation, Pontryagin's minimum principle, Application to optimal control of discrete and continuous systems (quadratic performance index, analysis and design of finite and infinite time), Linear Quadratic Regulators, Introduction to Linear Quadratic Gaussian approach	

Text Books:

1. 'Modern Control Engineering'- Katsuhiko Ogata, Prentice Hall India, 5th edition 2010.
2. 'Non-linear Systems', by Hassan Khalil, Prentice Hall.
3. Digital Control – Ogata , Prentice Hall India

Reference Books:

1. Digtal Control- B.C.Kuo
2. 'Digital Control and State Variable Methods' by M. Gopal, Tata-McGraw-Hill Publishing Company Limited
3. Optimal Control: Linear Quadratic Methods' Brian D. O. Anderson, John Barratt Moore, Dover Publications, 2007

Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT – III
Unit Test -2	UNIT – IV, UNIT – V, UNIT – VI

(Elective – II) ADVANCED POWER ELECTRONICS AND DRIVES			
TEACHING SCHEME:		**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Theory: 04 Hours / Week		End Semester Examination: 60 Marks	04 Credits
Practical: 02 Hours / Week		Continuous Assessment: 40 Marks	
		Term Work: 25 Marks	01 Credit
UNIT - I	**Converters:**		**(08 Hours)**
	Voltage Source Converters Review of 3-ph-full wave bridge converter, operation and harmonics, 3 level voltage source converters. PWM converter. Generalized technique of harmonic elimination and voltage control. Advanced modulation techniques (space vector modulation, 3rd harmonic PWM) Comparison of PWM techniques. Converter rating **Current source converters** (i) Matrix Converter: 3×3 matrix converter, principle of working, mathematical treatment, comparison of matrix converter with multipulse converter (ii) Self and Line commutated current source converter: Basic concepts of CSC, converters with self commutating devices		
UNIT - II	**Multilevel Inverters:**		**(08 Hours)**
	Multilevel concept, Types of multilevel Inverters, diode clamped multilevel inverter, flying-capacitors multilevel inverters, cascaded multilevel inverter, switching device currents, D.C. link capacitor voltage balancing, features of multilevel inverters, comparison of multilevel inverters. Applications of multilevel Inverter: Reactive power compensation Back to back intertie system		
UNIT - III	**DC Drives:**		**(08 Hours)**
	Single phase and 3 phase converter drives. Four quadrant Chopper drives, closed loop control of DC motor, Permanent magnet DC motor drives, DC Servo drives, applications		
UNIT - IV	**Induction Motor Drives:**		**(08 Hours)**
	3 phase induction motor control, stator voltage control/rotor voltage control, voltage and frequency control, current control, closed loop control of 3-phase induction motor. Soft starters, comparison of variable frequency drives, Speed control by static slip power recovery, induction motor servo drives, applications.		
UNIT - V	**Synchronous Motor Drives:**		**(08 Hours)**
	Voltage and frequency control, closed loop control of synchronous motors. Synchronous motor servo drive with sinusoidal waveform, synchronous motor servodrive with trapezoidal waveform. Load commutated invertor drives, speed control of synchronous motors by cyclo-convertors, applications		
UNIT - VI	**Akagi's p-q theory**		**(08 Hours)**
	Conventional concepts of active and reactive power in single phase and three phase circuits-Equation of power with sinusoidal voltage source and non-linear loads -αβo transformation of three phase four wire system-Akagi's instantaneous power (pq) theory-relationship between Akagi's components and conventional active and reactive power application of pq theory to reactive and harmonic power compensation in simple circuits.		

Text Books:	
1. Bimal K Bose, Modern power electronics and AC drives, Pearson education asia	
2. G. K. Dubey, Fundamentals of Electrical Drives CRC press 2002	
3. VedamSubrahmanyam Electric Drives: Concepts &Appl Tata McGraw-Hill	
4. Power electronics convertors, applications and design, Ned Mohan, Tore M Undeland, William P Robbins, Wiley India Pvt. Ltd., 2009	
5 E. Acha, Miller & Others, Power Electronic Control in Electrical Systems (Newnes, Oxford publication) – first Edition	
6 M. H. Rashid Power Electronics, Prentice Hall of India Pvt. Ltd. New Delhi, (3rd Edition)	
7. R Krishnan, Electric motor drives, modeling, analysis and control, PHI learning Pvt. ltd. 2001	
8. S.K. Pillai, A first course in electrical drives, Newage international publishers. 2010	
Reference Books and Papers:	
1. E. H. Watanube, R.M. Stephen and Maurico Ardes "New Concepts of instantaneous active and reactive powers in Electrical systems with Generic loads" (IEEE transaction on Power Delivery Vol.8, no.2 April 1993, PP-697-703	
2. L. Benchaita, S. Sadaate and A. Salemnia – "A comparison of voltage source and current source shunt Active filter by simulation and Experimentation" (IEEE Transaction on Power Systems, Vol 14, No.2, May 99, PP 642-647	
3. H. Akagi, E.H. Watanabe and M. Aredes "Instantaneous Power Theory and Applications to Power Conditioning, IEEE Press, New York	
Syllabus for Unit Test:	
Unit Test -1	UNIT – I, UNIT – II, UNIT - III
Unit Test -2	UNIT – IV, UNIT – V, UNIT - VI