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UNIVERSITY OF MUMBAI

Revised Syllabus for the

M.E. Electrical Engineering
(Power System Engineering)

(As per Credit Based Semester and Grading System with effect from the academic year 2012–2013)

University of Mumbai
Program Structure for
M.E. Electrical Engineering (Power System Engineering)
(With Effect from 2012-2013)

Semester I

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
PSC101	Advanced Engineering Mathematics*	04	--	--	04	--	--	04
PSC102	Advanced Power System Protection	04	--	--	04	--	--	04
PSC103	Advanced Power System Analysis	04	--	--	04	--	--	04
PSE101X	Elective I	04	--	--	04	--	--	04
PSE102X	Elective II	04	--	--	04	--	--	04
PSL101	Lab Practice-I	--	02	--	--	01	--	01
PSL102	Lab Practice-II	--	02	--	--	01	--	01
Total		**20**	**04**	**--**	**20**	**02**	**--**	**22**

Subject Code	Subject Name	Examination Scheme							
		Theory					Term Work	Pract. /oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test1	Test 2	Avg.					
PSC101	Advanced Engineering Mathematics*	20	20	20	80	03	--	--	100
PSC102	Advanced Power System Protection	20	20	20	80	03	--	--	100
PSC103	Advanced Power System Analysis	20	20	20	80	03	--	--	100
PSE101X	Elective I	20	20	20	80	03	--	--	100
PSE102X	Elective II	20	20	20	80	03	--	--	100
PSL101	Lab Practice I	--	--	--	--	--	25	25	50
PSL102	Lab Practice II	--	--	--	--	--	25	25	50
Total		**100**	**100**	**100**	**400**	**--**	50	**50**	**600**

*** Common for M.E. Electrical Engineering in Power System Engineering and Power Electronics & Drives**

Semester II

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
PSC201	Power System Modeling	04	--	--	04	--	--	04
PSC202	Electrical Power Quality**	04	--	--	04	--	--	04
PSC203	Power System Stability & Control	04	--	--	04	--	--	04
PSE203X	Elective III	04	--	--	04	--	--	04
PSE204X	Elective IV	04	--	--	04	--	--	04
PSL201	Lab Practice III	--	02	--	--	01	--	01
PSL202	Lab Practice IV	--	02	--	--	01	--	01
Total		**20**	**04**	**--**	**20**	**02**	**--**	**22**

Subject Code	Subject Name	Examination Scheme							
		Theory					Term Work	Pract. /oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test1	Test 2	Avg.					
PSC201	Power System Modeling	20	20	20	80	03	--	--	100
PSC202	Electrical Power Quality**	20	20	20	80	03	--	--	100
PSC203	Power System Stability & Control	20	20	20	80	03	--	--	100
PSE203X	Elective III	20	20	20	80	03	--	--	100
PSE204X	Elective IV	20	20	20	80	03	--	--	100
PSL201	Lab Practice III	--	--	--	--	--	25	25	50
PSL202	Lab Practice IV	--	--	--	--	--	25	25	50
Total		**100**	**100**	**100**	**400**	**--**	**50**	**50**	**600**

**** Common for M.E. Electrical Engineering in Power System Engineering and Power Electronics & Drives**

Semester III

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
PSS301	Seminar	--	06	--	--	03	--	03
PSD301	Dissertation I	--	24	--	--	12	--	12
Total		--	30	--	--	15	--	15

Subject Code	Subject Name	Examination Scheme						
		Theory				Term Work	Pract. / Oral	Total
		Internal Assessment			End Sem. Exam.			
		Test1	Test 2	Avg.				
PSS301	Seminar	--	--	--	--	50	50	100
PSD301	Dissertation I	--	--	--	--	100	--	100
Total		--	--	--	--	**150**	**50**	**200**

Semester IV

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
PSD401	Dissertation II	--	30	--	--	15	--	15
Total		--	30	--	--	15	--	15

Subject Code	Subject Name	Examination Scheme						
		Theory				Term Work	Pract. / Oral	Total
		Internal Assessment			End Sem. Exam.			
		Test1	Test 2	Avg.				
PSD401	Dissertation II	--	--	--	--	100	100	200
Total		--	--	--	--	**100**	**100**	**200**

Note:

- In case of Seminar, 01 Hour / week / student should be considered for the calculation of load of a teacher
- In case of Dissertation I, 02 Hour / week / student should be considered for the calculation of load of a teacher
- In case of Dissertation II, 02 Hour / week / student should be considered for the calculation of load of a teacher
- **End Semester Examination:** In all six questions to be set, each of 20 marks, out of these any four questions to be attempted by students. Each question will comprise of mixed questions from different units of the subjects.

Subject Code	Elective I	Subject Code	Elective II
PSE1011	Application of Power Electronics in Power System #	PSE1021	Artificial Intelligence & its Application in Power System #
PSE1012	Restructured Power System	PSE1022	Non Conventional Energy sources and systems #
PSE1013	Modern Control System #	PSE1023	Evaluation of Power System Reliability
PSE1014	Advanced Power Electronic Converters.	PSE1024	Distributed Generation & Micro grid #

 # Common for M.E. Electrical Engineering in Power System Engineering and Power Electronics & Drives

Subject Code	Elective III	Subject Code	Elective IV
PSE2031	DSP and its Application in Power System ##	PSE2041	Industrial Drives & Control
PSE2032	Smart Grid ##	PSE2042	Extra High Voltage Transmission ##
PSE2033	Energy Management and Auditing ##	PSE2043	High Voltage Insulation System Design.
PSE2034	Optimization Techniques and its Application in Power System	PSE2044	Entrepreneurship Development ##

Common for M.E. Electrical Engineering in Power System Engineering and Power Electronics & Drives

Subject Code	Subject Name	Credits
PSC101	**Applied Engineering Mathematics**	**04**

Module	Contents	Hours
1	Vector space, subspace of vector space , span, linear independence, basis, dimension, linear functions and transformations, kernel(or null) and image (or range)subspaces, change of basis and similarity, invariant subspaces .	10
2	Matrices, norms, sensitivity, and condition number.	4
3	Solution of linear systems: LU and Cholesky factorizations. Effect of round off errors.	10
4	Linear least-squares problems: Normal equations, orthogonal transformations, QR factorization, singular value decomposition (SVD), conditioning.	14
5	Eigenvalues: reduction to canonical form, inverse iteration, QR algorithm, computing the SVD. Large sparse linear systems. Introduction to iterative methods.	10

Assessments:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Demmel, Applied Numerical Linear Algebra, SIAM. Ist edition.
2. Golub& Van Loan, Matrix Computation, John Hopkins University Press.
3. Strang, Applied Linear Algebra, Wellesly Cambridge Press.
4. Watkins, Fundamentals of Matrix Computations, Wiley series of Tech.

Reference Books:

1. Trefethen and Bau, .Numerical Linear Algebra,

Subject Code	Subject Name	Credits
PSC102	**Advanced Power System Protection**	**04**

Module	Contents	Hours
1	**Introduction** Power system Protection, Prevention and control of system failure, Protective system design consideration, Definitions used in System Protection, System disturbances	4
2	**Protection Measurements and Controls:** Graphic symbols and device connections, Typical relay connections, Circuit Breaker Control Circuits, Instrument Transformers-Selection, Types and Connections, Relay control configurations, Optical Communications	6
3	**Protective Device Characteristics:** Relay characteristics, Power circuit breakers, Automatic circuit reclosers and line sectionalizes, Circuit switches and digital fault recorders	6
4	**Relay Logic:** Analog relay logic, Digital relay logic, Hybrid relay logic, Relays as comparators	5
5	**System Characteristics:** Computation of available fault current, System equivalent for protection studies, Compensation theorem, Compensation application in fault studies	5
6	**Protection against Abnormal frequency:** Abnormal frequency operation, Effects of frequency on generator, Frequency effects on the turbine, A system frequency response module, Off normal frequency protection, under frequency protection	6
7	**Protective schemes for stability enhancement:** Review of stability fundamentals, System transient behavior, Automatic reclosing, Loss of synchronism protection, Special protection schemes	6
8	**HVDC Protection:** A general working principle of line, Philosophy of HVDC protection, AC side protection, DC side protection, Special HVDC protection	5
9	**SSR(Sub synchronous resonance) Protection:** SSR overview, SSR system counter measures, SSR unit counter measures	5

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by

students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Anderson PM, “Power system protection,” McGraw-hill, 1999.
2. Singh LP, “Digital protection”

Reference Books:

1. Badriram &Vishwakarma, “Power system protection and SWG,” Mcgraw Hill
2. Madhava Rao TS, “Power system protection with static relays and Microprocessor application,” McGraw hill
3. 4. Mason CR, “The art and science of protective relaying,” John Wiley & sons
5. Chapman & Hall, “Electrical Power System Protection”
6. J.Lewis Blackburn & T.J. Domin, “Protective Relaying Principles & Applications”

Subject Code	Subject Name	Credits
PSC103	**Advanced Power System Analysis**	**04**

Module	**Contents**	Hours
1	Y bus formulation, Modifications in Ybus to account for change in networks. Power Flow Problem and Its Solution: The Power Flow Problem on a DC Network, Gauss-Seidel Method, Newton-Raphson Method, Decoupled Power Flow, DC Power Flow.	8
2	**Optimal dispatch of generation**: Nonlinear function optimization, equality and inequality constraints. Economic dispatch neglecting losses and with & without generator limits, Economic dispatch including losses	8
3	**Unit Commitment Solution Methods:** Priority-List Methods, Dynamic-Programming Solution, Forward DP Approach	7
4	**Optimal Power Flow:** • Linear Programming Method with Only Real Power Variables • Linear Programming with AC Power Flow Variables and Detailed Cost Functions • Security-Constrained Optimal Power Flow • Interior Point Algorithm	8
5	**Power System Security** : Overview of Security Analysis, Factors Affecting Power System Security, Contingency Analysis: Detection of Network Problems, Linear Sensitivity Factors, Calculation of Network Sensitivity Factors (Problems up to 3-4 bus system), Contingency Selection	8
6	**State Estimation in Power Systems:** Maximum Likelihood Weighted Least-Squares Estimation, State Estimation of an AC Network An Introduction to Advanced Topics in State Estimation, • Detection and Identification of Bad Measurements • Estimation of Quantities Not Being Measured • Network Observability and Pseudo-measurements • Application of Power Systems State Estimation	9

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. George Kausic. Computer Aided Power System Analysis, Prentice Hall Publication.2008
2. Allen. J. Wood., Bruce. F. Wollenberg., Power Generation operation and Control, Wiley India, Second Edition, 2007.
3. Hadi Saadat, Power System Analysis**,** TMH Publication, Second Edition, 2002.
4. Kothari. D. P, Nagrath. I. J., Modern Power System Analysis, TMH Publication, Third Edition, 2008

Reference Books:

1. Computer Methods in Power System Analysis : G.W.Stage A.H.Elabiad, McGraw Hill Book Co.
2. Computer Techniques in Power System Analysis : M.A. Pai, Tata McGraw Hill Publication.
3. Electric Energy System Theory : O.I.Elgard, Tata McGraw Hill Publication.
4. Computer Aided Power System Operation and Analysis: R.N.Dhar, Tata McGraw Hill Publication.
5. Modern Power System Analysis : I.J.Nagrath, D.E.Kothar, Tata McGraw Hill, New Delhi.

Subject Code	Subject Name	Credits
PSE1011	**Application of Power Electronics in Power System**	**04**

Module	Contents	Hours
1	**Introduction**- Steady state and dynamic problems in AC systems- Transmission interconnections- Flow of power in an AC system- Loading capability- Power flow and dynamic stability considerations of a transmission interconnection- Relative importance of controllable parameters- FACTS Controllers- Basic types of FACTS controllers- Brief description and definitions- Benefits from FACTS technology- HVDC or FACTS	10
2	**Static shunt compensators and Static series compensation**- Objectives of shunt compensation- Methods of controllable Var generation- - Objectives of series compensation- Variable impedance type series compensation(only TCSC) , Switching converter type series compensation(only SSSC)	10
3	**Static voltage and phase angle regulators**- Objectives of voltage and phase angle regulators- TCVR and TCPAR, Switching converter based voltage and phase angle regulators	10
4	**Load compensation using DSTATCOM**- Compensating single phase loads- Ideal three phase shunt compensator structure-Series compensation of power distribution system- Rectifier supported DVR- DC Capacitor supported DVR- Fundamental Frequency series compensator characteristic	10
5	**Unified Power Quality Conditioner**- UPQC configuration-Right shunt UPQC characteristic- Left shunt UPQC characteristic	08

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Narain G. Hingorani and Laszlo Gyugyi, "Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems," IEEE Press.
2. Arindam Ghosh and Gerard Ledwich, " Power Quality Enhancement Using Custom Power Devices," Kluwer Academic Publishers
3. Roger C. Dugan, Mark F. McGranaghan and H.WayneBeaty "Electrical Power System Quality" , Mc Graw Hill

4. J. Arrillaga, N.R.Watson and S.Chen " Power System Quality Assessment," John Wiley & Sons
5. Yong Hua Song "Flexible AC transmission system" Institution of Electrical Engineers, London

Reference Book/* Journals*:

1. Jos Arrillaga and Neville R Watson "Power System Harmonics" Wiley Publications
2. G.T.Heydt , "Electric Power Quality," Stars in a Circle Publications
3. IEEE Transaction on Power Systems
4. IEEE Transaction on Power Delivery
5. IEEE Transaction on Power Electronics

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Subject Code	Subject Name	Credits
PSE1012	**Restructured Power System**	**04**

Module	Detailed content	Hours
1	**Power Sector in India** Introduction to various institutions in Indian Power sector such as CEA, Planning Commissions, PGCIL, PFC, Ministry of Power, state and central governments, REC, utilities and their roles. Critical issues / challenges before the Indian power sector, Salient features of Electricity act 2003, Various national policies and guidelines under this act.	8
2	**Power sector restructuring and market reform** Different industry structures and ownership and management models for generation, transmission and distribution. Competition in the electricity sector- conditions, barriers, different types, benefits and challenges Latest reforms and amendments. Different market and trading models / arrangements, open access, key market entities- ISO, Genco, Transco, Disco, Retailco, Power market types, Energy market, Ancillary service market, transmission market, Forward and real time markets, market power.	12
3	**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, standards of performance by utility, environmental and social considerations) Global experience with electricity reforms in different countries.	14
4	**Transmission Planning and pricing** Transmission planning, Different methods of transmission pricing, Different transmission services, Congestion issues and management, Transmission cost allocation methods, Locational marginal price, firm transmission right. Transmission ownership and control, Transco and ISO, Transmission pricing Model in India, Availability based tariff, role of load dispatch centers (LDCs) Salient features of Electricity act 2003, Price based	14

	Unit commitment, concept of arbitrage in Electricity markets, game theory methods in Power System, and security constrained unit commitment. Ancillary services for restructuring, Forward ancillary service auction. Power purchase agreements.	

Assessments:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. "Know Your Power", A citizens Primer On the Electricity Sector, Prayas Energy Group, Pune
2. Sally Hunt, "Making Competition Work in Electricity", 2002, John Wiley Inc
3. Electric Utility Planning and Regulation, Edward Kahn, American Council for Energy Efficient Economy

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, Hatim Yatim, Zuyi Li.
7. Bhanu Bhushan, "ABC of ABT - A primer on Availability Tariff" - www.cercind.org

Website:

1. www.mercindia.com
2. www.cercind.org
3. www.prayaspune.org

Subject Code	Subject Name	Credits
PSE1013	**Modern Control System**	**04**

Module	Contents	Hours
1	State Space Representation, Solution of State Equation, State Transition Matrix, Canonical Forms - Controllable Canonical Form, Observable Canonical Form, Jordan Canonical Form.	08
2	Controllability and Observability, Canonical Realizations, Duality, Decomposition of Uncontrollable and Unobservable realizations, Popov test. Effect of state feedback on controllability and observability, Design of State Feedback Control through Pole placement. Full order observer and reduced order observer.	10
3	Introduction to nonlinear systems, Types of nonlinearities, describing functions, describing function analysis of nonlinear control systems. Introduction to phase-plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase-plane analysis of nonlinear control systems.	10
4	Stability in the sense of Lyapunov, Lyapunov's stability and Lypanov's instability theorems. Direct method of Lypanov for the Linear and Nonlinear continuous time autonomous systems.	08
5	Calculus of Variations: problems of Lagrange,. Mayer and Bolza. Euler-Language equation and transversality conditions, Lagrange multipliers. Pontryagin's maximum principle; theory; application to minimum time, energy and control effort problems, and terminal control problem.	12

Assessments:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. "Modern Control System Theory " by M. Gopal, New Age International Publishers, 2nd edition, 1996
2. D.E.Kirk, "Optimal Control Theory", Prentice-Hall. 1970.
3. M. Vidyasagar, "Nonlinear Systems Analysis". 2nd Edition.Prentice Hall, 1993.

Reference Books:

1. "Modern Control Engineering ", by K. Ogata, Prentice Hall of India, 3rd edition, 1998
2. "Control Systems Engineering", by I.J. Nagarath and M.Gopal, New Age International (P)
3. "Digital Control and State Variable Methods " by M. Gopal, Tata McGraw-Hill Companies, 1997.
4. "Systems and Control" by Stainslaw H. Zak , Oxford Press, 2003.

Subject code	Subject Name	Credits
PSE1014	**Advanced Power Electronic Converters**	**04**
Module	Detailed Contents	Hours
1	**DC – DC Switched mode Converters** Review of Buck Converter, Boost Converter, Buck – Boost ,Duty cycle derivation, Different conduction modes (CCM & DCM), Voltage and Current waveforms, Calculation of output voltage ripple,	04
2	**Power Supply Applications:** Overview of switching power supplies, fly back, forward converters, transformer core selection, control of switch mode dc power supplies, power supply protection, designing to meet power supply specifications	06
3	**Resonant converters** Switch - mode inductive current switching, Zero Voltage & Zero Current switching , Resonant switch converters, Basic resonant circuit concepts, Resonant switch converters, ZCS and ZVS resonant switch converters , Comparison of ZCS and ZVS topologies. Load resonant converters, resonant switch converters, resonant dc-link Converters, high -frequency-link integral half cycle converters.	10
4	**Synchronous Rectifier:** Synchronous Rectification with Basic Switching Power Supply Topologies, Selection Criteria for components, Control of Synchronous Rectifier, Current- Mode Control Methods, Discrete and Integrated Approach for Synchronous Rectification.	10
5	**Bi-directional converter :** Various topologies of bi-directional converters, and their applications. Bidirectional dc-dc converters. Advantages over conventional converters. Matrix converter: basic topology, operation, control issues, control schemes, commutation issues in matrix converter. Applications in wind energy systems.	12
6	**Multi Level Inverter:** Need for multilevel inverters, Three level and four level inverter operation and analysis. Applications of multilevel inverters.	06

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. N.Mohan, T.M.Undeland, W.P Robbins, “Power Electronics, Converters, Applications & Design,” Wiley India Pvt.Ltd.
2. B.K Bose, Modern Power Electronics, Evolution, Technology & Applications, Jaico Publishers
3. M.H.Rashid, “*Hand book of Power Electronics”* , Academic Press,2001
4. D. Grahame Holmes, Thomas A. Lipo, T. A. Lipo *“Pulse width modulation for power converters: principles and practice”* Wiley-IEEE press,2003

References

1. Arindam Ghosh, Gerard Ledwich “Power Quality Enhancement using Custom Power Devices”,Kluwer Academic publishers,2002
2. IEEE Transactions on Power Electronics
3. IEEE Transactions Industrial Electronics
4. IECON ,APEC Proceedings etc

Subject Code	Subject Name	Credits
PSE1021	**Artificial Intelligence & its Application in Power System**	**04**

Module	Contents	Hours
1	**Fuzzy Logic:** Introduction to Neuro, Fuzzy and soft Computing, Fuzzy Sets, Basic Definition and Terminology, Set theoretic Operations, Member Function Formulation and parameterization, Fuzzy Rules and Fuzzy Reasoning, Extension principle and Fuzzy Relations, Fuzzy If-Then Rules, Fuzzy Reasoning, Fuzzy Inference Systems, Mamdani Fuzzy Models, Sugeno Fuzzy Models.	11
2	**Neural Networks:** Introduction, Supervised Learning Neural Networks, Perceptrons, Adaline, Back propagation Multilayer perceptrons, Radial Basis Function Networks, Unsupervised Learning and Other Neural Networks, Competitive Learning Networks, Kohonen Self Organizing Networks, Learning Vector Quantization, Hebbian Learning.	11
3	**Neuro Fuzzy Modelling:** Adaptive Neuro-Fuzzy Inference Systems, Architecture, Hybrid Learning Algorithm, learning Methods.	08
4	**Evolutionary computing:** Genetic algorithm: Basic concept , encoding , fitness function, Reproduction, Basic genetic programming concepts, differences between GA and Traditional optimization methods, Applications, Variants of GA. Simulated Annealing, Particle Swarm optimization	10
5	**Applications:** Fuzzy logic based controller for Electric Drive, ANN-based Speed Estimation, Flux &Torque Estimation in Induction Motor Drives Application of ANN and Fuzzy logic in Power System – Reliability, load forecasting, Load Dispatch.	08

Assessments:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Sivandudam and Deepapublisher,"Principles of soft computing" John mikey India.
2. J.S.R.Jang, C.T.Sun and E.Mizutani, "Neuro -Fuzzy and Soft Computing", PHI.
3. B.Yegnanarayana, "Artificial Neural Network",PHI
4. JacekM.Zurada, "Introduction to Artificial Neural Systems", Jaico Publishing House
5. Simon haykin, "Neural Network" , Macmillan Publication,1994

6. H.J.Zimmermann, “Fuzzy set Theory & its Applications”, Allied Publishers Ltd.
7. D. Prianleav, “Fuzzy control”, Narosa Publication.
8. Davis E.Goldberg,”Genetic Algorithms: Search, Optimization and Machine Learning” Addison,Wesley.

Reference Books:

1 Shaykins- Neural Networks: A comprehensive foundation
2 S.Rajasekharan and G.A.V.Pai,”Neural Networks, Fuzzy Logic and Genetic Algorithms”, PHI, 2003
1. R.Eberhart, P.simpson and R.Dobbins,” Computational Intelligence, PC Tools”, AP Professional, Boston 1996.
2.M.H.Rashid, “ Power Electronics Handbook”, Academic Press 2nd Ed.

Subject Code	Subject Name	Credits
PSE1022	**Non-Conventional Energy Sources and Systems**	**04**

Module	Contents	Hours
1	**Introduction**-Worlds Production and reserves of commercial energy sources, India's Production and reserves, energy alternatives The Solar Option, The Nuclear Option, Tar sands and Oil Shale, Tidal Energy, Geothermal Energy	04
2	**Solar Radiation**- The sun and earth, solar radiation- availability, measurement and estimation, The sun and earth movement, angle of Sunrays, on solar collector radiation, Estimation solar radiation empirically	04
3	**Solar Thermal applications-**solar thermal conversion devices and storage applications, Liquid flat plate collector, Solar air heater, concentric collectors, thermal energy storage, solar pond,	04
4	**Solar Photovoltaic-** Introduction to solar cells , solar cell characteristics, losses in solar cells , Model of a solar cell , emerging solar cell Technologies Solar PV modules from solar cells , Mismatch in module , hot spots in the module , Bypass diode , Design and structure of PV modules , PV module power output , I-V and power curve of module BOS of PV system**,** Batteries, Battery charge controllers ,DC to DC Converters , DC to AC Converters for AC loads ,Supporting structures for mounting the PV panels , MPPT, Different algorithms for MPPT, Types of PV systems	12
5	**PV system Design and Applications-** Design methodology of standalone PV system , Wire sizing in PV system, Precise sizing of PV System, Economic analysis of PV system	06
6	**Wind Energy**- History of wind energy, Wind machine types, classification, and parameters, , general concepts of airfoils and aerodynamics, Analysis of wind flow, measurement of wind speed, Power in wind, performance calculations of wind turbine	06
7	**Fuel Cell**- Introduction to fuel cell, principle of operation of fuel cell, stack configuration, Fuel cell Performance, Polymer electrolyte fuel cell, alkaline fuel cell, phosphoric acid fuel cell, molten carbonate fuel cell, solid oxide fuel cells, components of fuel cell, thermodynamics of fuel cell, Fuel cell systems, applications	06
8	**Other Sources**- Biomass- Biomass as a source of energy, introduction, energy plantation, methods of obtaining energy from biomass, photosynthesis, biomass gasification, factors affecting bio-digestion, classification of biogas plants, thermal gasification of biomass, pyrolysis Tide- Basic principle of tide power, components of tidal power plant, operation methods of utilization of tidal energy, Ocean Thermal Electric Conversion (OTEC)- Introduction, open cycle OTEC systems, closed cycle OTEC systems	06

Assessments:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. S. P Sukhatme "Solar Energy- Principle of Thermal collector and storage," Third edition, TMH publication
2. Chetan Singh Solanki , "Solar Photo Voltaics" ,PHI learning Pvt Ltd., New Delhi,2009
3. "Fuel Cell Handbook", EG&G Technical Services, Inc,USDept of Energy, seventh edition,2004
4. Rashid M.H, " Power Electronics Handbook" ,Academic Press,California,USA,2001
5. J. A. Duffie and W. A. Beckman "Solar Engineering of Thermal Processes," second edition, John Wiley, New York, 1991
6. G D Rai "Non-Conventional Energy Sources," Khanna Publications

Reference Books:

1. "Fuel Cell System", Leo J.M.J. Blomen and michael N. Mugerwa, New York, Plenum Press, 1993.
2. Green M.A " Solar Cells": Operating Principles, technology and System Applications, Prentice Hall Inc, Englewood Cliffs N.J, U.S.A, 1982
3. J.F. Manwell, J.G. McGowan " Wind Energy Explained, theory design and applications," Wiley publication
4. James Larminie, Andrew Dicles "Fuel Cell Systems Explained," Wiley publication
5. "Principles of Solar Engineering", D. Y. Goswami, F. Kreith and J. F. Kreider, Taylor and Francis, Philadelphia, 2000
6. "Biomass Regenerable Energy", D. D. Hall and R. P. Grover, John Wiley, New York, 1987.
7. "Renewable Energy Resources", J. Twidell and T. Weir, E & F N Spon Ltd, London, 1986.

Subject Code	Subject Name	Credits
PSE1023	**Evaluation of Power System Reliability**	**04**

Module	Detailed content	Hours
1	**Introduction:** Reliability definitions, Morkov model , failure rate, repair rate, hazard rate. Network modeling- series system, parallel system and complex systems. cut set and tie set method, fault trees	8
2	**Generating capacity –Probability methods:** Generation system model, loss of load indices, Scheduled outages, Forced outage rate uncertainty. Loss of Energy indices **Generating capacity – frequency and duration method:** Generation model, System risk indices, example	8
3	**Interconnected systems:** Reliability evaluation of two interconnected systems, Operating Reserve, PJM method, modified PJM method, Security function approach	8
4	**Composite power system reliability evaluations:** Conditional probability approach, System and load point indices concept and numerical evaluation. Data requirement for composite system reliability evaluation	8
5	**Distribution systems:** Evaluation technique, customer-oriented indices, load point and energy oriented indices, inclusion of weather effects. Common mode failures.	7
6	**Substation and switching stations:** Active and Passive failure, Effect and simulation of failure modes, numerical analysis.	5
7	Introduction to Monte Carlo Simulation- concept and application	4

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

1. Roy Billinton and Ronald N Allan, 'Reliability Evaluation of Power System', Plenum, Press, 1984
2. Roy Billinton and Ronald N Allan, “Reliability evaluation of Engineering System-Concepts and Tecniques” second edition plenum press, 1992
3. Roy Billinton and Ronald N Allan 'Reliability Assessment of Large Electric Power Systems', Kluwer academic publishers, 1988
4. Roy Billinton, Wenyuan Li “Reliability assessment of electric power systems using Monte Carlo methods” Plenum, Press, 1994

Subject Code	Subject Name	Credits
PSE1024	**Distributed Generation and Microgrid**	**04**

Module	Contents	Hours
1	**Introduction:** 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. Impact of grid integration of NCE sources on existing power system: reliability, stability and power quality issues, Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants	12
2	**Distributed Generations (DG):** Concept of distributed generations, topologies, selection of sources, regulatory standards/ framework: IEEE 1547, DG installation classes, requirements for grid interconnection, limits on operational parameters,: voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues, security issues in DG implementations	14
3	**Microgrids:** Concept of microgrid, 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, Power quality issues in microgrids, regulatory standards, Microgrid economics, Introduction to smart microgrids	22

Assessments:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. "Voltage Source Converters in Power Systems: Modeling, Control and Applications", Amirnaser Yezdani, and Reza Iravani, IEEE John Wiley Publications
2. "Power Switching Converters: Medium and High Power", DorinNeacsu, CRC Press, Taylor &Francis, 2006
3. "Solar Photo Voltaics", Chetan Singh Solanki, PHI learning Pvt. Ltd., New Delhi,2009

4. "Fuel Cell Handbook", EG&G Technical Services, Inc, US Dept of Energy, seventh edition, 2004
5. M.H.Rashid, "Power Electronics Handbook", Academic Press 2nd Ed.

References books /websites

a. "IEEE-1547-2003: IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems" IEEE standards 2003
b. "IEEE 1547-2: IEEE Guide for Monitoring, Information Exchange, and Distributed Resources Interconnected Electric Power Systems" IEEE
c. "IEEE 1547-4 : IEEE Guide for Design Operation & Integration of Distributed Resources Island System with Electric Power System, IEEE standards
d. Consortium for Electric Reliability Technology Solutions (CERTS) white paper on Integration of Distributed Energy Resources: The CERTS MicroGrid Concept
e. "Fuel Cell System", Leo J.M.J. Blomen and michael N. Mugerwa, New York, Plenum Press, 1993.
f. "Wind Energy Explained, theory design and applications," J.F. Manwell, J.G. McGowan Wiley publication
g. "Biomass Regenerable Energy", D. D. Hall and R. P. Grover, John Wiley, New York, 1987.
h. "Renewable Energy Resources" John Twidell and Tony Weir, Tyalor and Francis Publications, Second edition

Subject Code	Subject Name	Credits
PSL101	**Lab Practice I**	**01**

Module	Detailed content
1	Eigen analysis of small scale system
2	Small signal stability analysis of non- linear systems using linearization.
3	Programming/Simulations of Load flow analysis of 3-4 bus systems
4	Simulations of various types of fault.
5	Simulations of various types of Protection Schemes.
6	To develop feed forward neural network and error back propagation algorithm
7	Simulations of Contingency analysis.
8	Simulations of VSC based Compensator

Minimum Six Practical/Simulation/Program should be performed based on above contents

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
PSL102	**Lab Practice II**	**01**

Module	Detailed content
1	Simulations of Switched Mode Power Supply
2	Simulations of Power Factor Correction Scheme.
3	Simulations of Synchronous Rectifier
4	Simulations of Bidirectional Converter
5	Simulations of Multilevel inverter
6	Simulations of PWM Inverter
7	Simulations of Uncompensated Transmission Line.
8	Simulation of a transmission line with Static Series/Shunt Compensation.
9	Simulations of UPQC

Minimum Six Practical/Simulation/Program should be performed based on above contents

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
PSC201	**Power System Modeling**	**04**

Module	Contents	Hours
1	**Introduction:** Components of power system. The need for modeling of power system, different areas of power system analysis.	4
2	**Modeling of Synchronous Machine:** Synchronous Machine, Park's Transformation, Per Unit Quantities, Equivalent Circuits of synchronous Machine, Determination of parameters of equivalent circuits, Analysis of Steady State Performance, Transient Analysis of synchronous machine.	12
3	**Modeling of non-electrical Components:** Simplified models of non-electrical components like boiler, steam & hydro-turbine & governor system.	8
4	**Modeling of Transmission Line and Transformer:** Modeling of Transmission line, Transformation to D-Q components, steady state equations, D-Q transformation using $\alpha - \beta$ variables. Transformer modeling such as tap-changing & phase-shifting transformer.	8
5	**Modeling of excitation system:** Types of excitation systems, Modeling of excitation system components, Models of standard excitation systems.	8
6	**Modeling of SVC and Loads:** Type of SVC and controllers, SVC control characteristics, modeling of SVC. Basic load modeling concepts, modeling of induction motors	8

Assessments:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text books:

1. "Power system Dynamics Stability and Control" P Kundur, Tata McGraw Hill

Reference books:

1. "Power system Dynamics Stability and Control" K R Padiyar B S Publication.
2. "Power system Dynamics Stability" Peter W. Sauer and M A Pai Pearson Education Asia.
3. "Power system Control and Stability" P M Anderson and A.A Fouad.
4. "Power Systems Modelling and Fault Analysis" Nasser Tleies, Elsevier, 2008.

Subject Code	Subject Name	Credits
PSC202	**Electrical Power Quality**	**04**

Module	Contents	Hours
1	**Introduction**-power quality-voltage quality-overview of power quality phenomena- voltage and current variations, events, overview of voltage magnitude events	08
2	**Power quality measures and standards**-THD-TIF-DIN-C-message weights-flicker factor-transient phenomena-occurrence of power quality problems-power acceptability curves-IEEE guides, standards and recommended practices, Related problems.	10
3	**Harmonics**-Harmonic distortion- voltage vs current distortion in power system-individual and total harmonic distortion-RMS value of a harmonic waveform, Related problems	06
4	**Harmonic introducing devices and its effects**-SMPS-Three phase power converters-arcing devices- saturable devices-harmonic distortion of fluorescent lamps- power quality problems created by drives and its impact on machines-effect of power system harmonics on power system equipment and loads.	06
5	**Power factor compensation-** power factor compensation in linear circuits-Basic relationship**,** complex power, apparent power and power factor, power factor compensation in linear sinusoidal circuits **,** Non-linear circuits with sinusoidal supply-Basic relationship**,** complex power, apparent power and power factor, power factor compensation in linear sinusoidal circuits- Problems related to power factor calculation is included.	10
6	**Harmonic compensation**- Passive Compensation- Passive Filtering-harmonic filter design- active filters-shunt active filters- Generation of reference current using instantaneous PQ theory- Other methods for generation of reference current(two more)- methods of implementation- Basic schematic and working of series active filter-unified power quality conditioner.	08

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Roger C. Dugan, Mark F. McGranaghan and H.WayneBeaty, “Electrical Power System Quality,” MC Graw Hill
2. G.T.Heydt , “Electric Power Quality,” Stars in a Circle Publications

3. J. Arrillaga, N.R.Watson and S.Chen, " Power System Quality Assessment," John Wiley & Sons
4. W. Shepherd and P. Zand, " Energy flow and power factor in non-sinusoidal circuits" Cambridge university press
5. IEEE-519: 1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems

Reference Book/Journals:

1. Jos Arrillaga, B.C.Smith, Neville R Watson and A.R.Wood, "Power System Harmonics Analysis" Wiley 1997
2. Math H.J.Bollen, " Understanding Power Quality Problems,Voltage Sag and Interruptions " Wiley-IEEE Press
3. IEEE Transactions on Power Systems
4. IEEE Transactions on Power Delivery
5. IEEE Transaction on Power Electronics

Subject Code	Subject Name	Credits
PSC203	**Power System Stability and Control**	**04**

Module	Contents	Hours
1	**Introduction: Power System stability:** Basic concepts and definitions: Rotor angle stability, Voltage stability or voltage collapse and Mid-term and long-term stability. Classification of stability.	6
2	**Synchronous Machine Representation in Stability Studies:** Simplification essential for large-scale studies, Simplified model with amortisseurs neglected, Constant flux linkage model and reactive capability limits.	12
3	**Small Signal Stability:** Fundamental concepts of stability of dynamic system, Eigen properties of the state matrix, Small signal stability of a single machine infinite bus system, Effects of excitation system, Power system stabilizer, Small signal stability of multi-machine systems and Methods of improving small signal stability.	15
4	**Transient Stability:** An elementary view of transient stability, Numerical integration methods, Simulation of power system dynamic response, Analysis of unbalanced faults and Methods of improving transient stability.	15

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Books Recommended:

Text books:

1. "Power system Dynamics Stability and Control" P Kundur, Tata McGraw Hill

Reference books:

1. "Power system Dynamics Stability and Control" K R Padiyar B S Publication.
2. "Power system Dynamics Stability" Peter W. Sauer and M A Pai Pearson Education Asia.
3. "Power system Control and Stability" P M Anderson and A.A Fouad.

Subject Code	Subject Name	Credits
PSE2031	**DSP and its Applications in Power System**	**04**

Module	Contents	Hours
1	**Introduction** Review of microprocessor, microcontroller and digital signal processors architecture, Fixed and floating-point processors Number formats and operations: Fixed point 16 bit numbers representations of signed integers and fraction, Floating Point Numbers. Review of commonly used DSP processors in power electronics applications, introductions to TMS320F2812 and TMS320C2000 processors	06
2	**DSP Architecture, peripherals and programming** Introduction to Digital control using DSP, Overview of TMS320C2000 Digital signal controller family – Features, Architecture, Interrupt and Reset, Memory map - On-chip memories: Flash, RAM, and Boot ROM – External memory Interface. Clock system- Digital I/O -CPU Timers – Analog to Digital Converter (ADC), Pulse Width Modulator (PWM), High Resolution PWM, Capture Module, Quadrature Encoder Pulse Module. Controller Area Network, Serial Communication Interface, Serial Peripheral Interface, I^2C and Multi-channel Buffered Serial port. Programming: assembler, linker processes, code structure, Code composer studio	16
3	**Mathematical tools for Real Time DSP implementation** Review of numerical integration: Euler's implicit and explicit method, Heun's Method, Trapezoidal Method. Implementation of low pass filter. Review of reference frame transformation theory. Design of controllers for closed loop applications in power electronics: PI, Type II and Type III controllers	08
4	**DSP Applications in Power Electronics** Speed control of Induction motor, BLDC motor, Digital control of DC/DC converter, LED Lighting.	06
5	**DSP Applications in Power Systems** Issues of harmonics and unbalanced currents in power systems, Implementation of Active filters in DSP under balanced and unbalanced condition, harmonic oscillator and 3 phase lock loop, Static VAR Compensator, Hardware in Loop simulations. Design of a DSP controlled Solar PV based Converter/Inverter system:	12

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination

Books Recommended:

Text Books:

1. "Power Electronics, Converters, Applications & Design",N.Mohan, T.M.Undeland, W.P Robbins, Wiley India Pvt.Ltd.
2. "Modern Power Electronics and AC Drives", B. K Bose, Perason Education
3. Hamid Toliyat and Steven Campbell "DSP Based Electromechanical Motion Control" CRC Press
4. Sen M. Kuo and Woon-SengGan "Digital Signal Processors - Architectures, Implementations, and Applications" Prentice Hall

References books /websites

1. C2000 Teaching ROM CD
2. Code Composer Studio v4: http://processors.wiki.ti.com/index.php/Category:Code_Composer_Studio_v4

Subject Code	Subject Name	Credits
PSE2032	**Smart Grid**	**04**

Module	Detailed Contents	Hours
1	**Introduction to Smart Grid:** Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient & Self Healing Grid, Present development & International policies in Smart Grid. Case study of Smart Grid. CDM opportunities in Smart Grid	08
2	**Smart Grid Technologies: Part 1:** Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers	08
3	**Smart Grid Technologies: Part 2:** Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).	10
4	**Power Quality Management in Smart Grid:** Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.	10
5	**Information and Communication Technology for Smart Grid:** Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN). Bluetooth, ZigBee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Basics of CLOUD Computing & Cyber Security for Smart Grid. Broadband over Power line (BPL). IP based protocols	12

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley

2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, “Smart Grids”, Wiley Blackwell

References/Journal Papers:

1. Smart Grid Technologies: Communication Technologies and Standards Vehbi C. Güngör, DilanSahin, TaskinKocak, SalihErgüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 7, NO. 4, NOVEMBER 2011
2. Smart Grid – The New and Improved Power Grid: A Survey” , Xi Fang, Satyajayant Misra, Guoliang Xue, *Fellow, IEEE*, andDejun Yang,
3. *IEEE transaction on SmartGrids*

Subject Code	Subject Name	Credits
PSE2033	**Energy Management and Auditing**	**04**

Module	Contents	Hours
1	**Energy Scenario:** Present Energy Scenario, Energy Pricing, Energy Sector Reforms, Energy Security, Energy Conservation and its Importance, Energy Conservation Act-2001 and its Features. Basics of Energy and its various forms, Material and Energy balance	04
2	**Energy Management & Audit:** Definition, Energy audit- need, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit Instruments energy management, Roles and responsibilities of energy Manager and Accountability, Financial analysis techniques, Financing options, Energy performance contracts and role of ESCOs. Defining monitoring & targeting, Elements of monitoring& targeting, Data and information-analysis, Techniques - energy consumption, Production, Cumulative sum of differences.	06
3	**Energy Efficiency in Electrical system:** Electricity billing, Electrical load management and maximum demand Control, Maximum demand controllers; Power factor improvement, Automatic power factor controllers, efficient operation of transformers, Energy efficient transformers; Induction motors efficiency, motor retrofitting, energy efficient motors, Soft starters, Variable speed drives; Performance evaluation of fans and pumps, Flow control strategies and energy conservation opportunities in fans and pumps, Energy efficiency measures in lighting system, Electronic ballast, Occupancy sensors, Energy efficient lighting controls Factors affecting selection of DG system, Energy performance assessment of diesel conservation avenues	14
4	**Energy Conservation in Thermal Systems** Types of boilers, Combustion in boilers, Performances evaluation, Feed water treatment, Blow down, Energy conservation opportunities in boiler, Properties of steam, Assessment of steam distribution losses, Steam leakages, Steam trapping, Condensate and flash steam recovery system, Identifying opportunities for energy savings. Classification, General fuel economy measures in furnaces, Excess air, Heat Distribution, Temperature control, Draft control, Waste heat recovery. Insulation-types and application, Economic thickness of insulation, Heat savings and application criteria. Introduction, Mechanism of fluidized bed combustion, Advantages, Types of FBC boilers, Operational features, Retrofitting FBC system to conventional boilers, Saving potential.	14

	HVAC system: Coefficient of performance, Capacity, Factors affecting Refrigeration and Air conditioning system performance and savings opportunities. Classification and Advantages of Waste Heat Recovery system, analysis of Waste heat recovery for Energy saving opportunities	
5	**Energy Performance Assessment:** On site Performance evaluation techniques, Case studies based on: Motors and variable speed drive, Fans and pumps, HVAC system calculations; Lighting System: Installed Load Efficacy Ratio(ILER) method Financial Analysis: simple payback period, NPV, IRR,	10

Assessments:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1.Handbook of Electrical Installation Practice. , By Geofry Stokes, Blackwell Science
2.Designing with light: Lighting Handbook., By Anil Valia, Lighting System
3.Energy Management Handbook., By W.C. Turner, JohnWiley and Sons
4.Handbook on Energy Audits and Management., edited by Amit Kumar Tyagi, Tata Energy Research Institute (TERI).

Reference Book/Websites:

1.Energy Management Principles., By C.B.Smith, Pergamon Press
2.Energy Conservation Guidebook., Dale R. Patrick, Stephen Fardo, Ray E. Richardson,Fairmont Press
3.Handbook of Energy Audits., By Albert Thumann,William J. Younger, Terry Niehus, CRC Press

Websites:

1. *www.energymanagertraining.com*
2. *www.bee-india.nic.in*

Subject Code	Subject Name	Credits
PSE2034	**Optimization Techniques & its Applications in Power System**	**04**

Module	Contents	Hours
1	**Introduction to optimization , Optimization techniques**	4
2	**Linear Programming (LP):** Simplex Method of solving LPP, revised simplex method, duality, decomposition principle, and transportation problem. Electric power system models, Constrained optimization, Theorems and procedure, Linear programming, mathematical model, solution technique, duality**.**	8
3	**Non-Linear Programming(NLP):** Classification, sensitivity method for Unconstrained optimization techniques-Direct search and Descent methods, constrained optimization techniques, direct and indirect methods	7
4	**Dynamic Programming (DP):** Multistage decision processes, concept of sub-optimization and principle of optimality, conversion of final value problem into an initial value problem.	7
5	**Genetic Algorithm:** Definition and concept used in GA, coding of variables, fitness function. Schemata theorem, General algorithm of GA, Unconstrained and constrained optimization using Genetic Algorithm, global optimization using GA. Applications to power system, Economic Load Dispatch in thermal and Hydro-thermal system using GA,	8
6	**Applications to Electric power systems:** Non linear programming, classification sensitivity method & barrier method for solving NLP, Unit commitment of generating units using dynamic Programming	7
7	**Optimal Power flow (OPF):** OPF-fuel cost minimization, OPF-VAR Planning, LP and NLP techniques to Optimal flow problems.	7

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Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by

students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. "Optimization - Theory and Applications", S.S.Rao, Wiley-Eastern Limited
2. "Introduction of Linear and Non-Linear Programming ", David G. Luenberger, Wesley Publishing Company
3. "Electric Power System of Optimizations" James A Momoh

Reference Book:

1. "Computational methods in Optimization ", Polak, Academic Press
2. "Optimization Theory with Applications" Pierre D.A., Wiley Publications

Subject Code	Subject Name	Credits
PSE2041	**Industrial Drives & Control**	**04**

Module	Contents	Hours
1	**Scalar Control of Induction Motor:**Variable frequency operation of three phase symmetrical induction machine: scalar control methods(voltage fed inverter control and current fed inverter control),Efficiency Optimization control by flux program	12
2	**Vector control of Induction Machine:**Introduction,direct or feedback vector control, flux vector estimation, indirect or feed forward vector control, vector control of line side PWM rectifier, stator flux oriented vector control, vector control of current fed inverter drive, sensorless vector control, Direct Torque and Flux Control, Adaptive control	20
3	**Wound rotor Iinduction Motor Control:** static rotor resistance control, static Scherbius drive, Improvement in power factor, introduction to variable speed constant frequency (VSCF) generation	08
4	**Sinusoidal SPM Machine Drives:** V/Hz control, self control model, Vector control	08

Assessments:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. "Modern Power Electronics and A.C. Drive", B. K. Bose, , PHI.
2. "Electric Motor Drives: Modeling, Analysis and Control" ,R.Krishnan,.PHI
3. "Control of Electrical drives", W. Leonhard, , Springer-Verlag,.

Reference Books:

1. "Power Semiconductor Controlled Drives" ,G. K. Dubey, Prentice-Hall International.
2. "Fundamentals of Electrical Drives", G. K. Dubey, Narosa Publishing House.
3. "Analysis of Electric Machinery" P.C. Krause, McGraw Hill, New York
4. "Power Electronics and Motor Drives" Bimal Bose, Elsevier,Academic Press, 2006

Subject Code	Subject Name	Credits
PSE2042	**Extra High Voltage Transmission**	**04**

Module	Contents	Hours
1	INTRODUCTION Standard transmission voltage-different configurations of EHV and UHV lines-average values of line parameters-power handling capacity and line loss-costs of transmission lines and equipment-mechanical considerations in line performance.	9
2	CALCULATION OF LINE PARAMETERS Calculation of resistance, inductance and capacitance for multi-conductor lines-calculation of sequence inductances and capacitances-line parameters for different modes of propagation-resistance and inductance of ground return, numerical example involving a typical 400/220 kv line using line constant program	10
3	VOLTAGE GRADIENT OF CONDUCTORS Charge-potential relations for multi-conductor lines-surface voltage gradient on conductors-gradient factors and their use-distribution of voltage gradient on sub conductors of bundle-voltage gradients on conductors in the presence of ground wires on towers.	10
4	CORONA EFFECTS Power losses and audible: I2R loss and corona loss-audible noise generation and characteristics-limits for audible noise-Day-night equipment noise level-radio interference: corona pulse generation and properties-limits for radio interference fields.	9
5	ELECROSTATIC FIELD OF EHV LINES Effect of EHV line on heavy vehicles-calculation of electrostatics filed of AC lines-effects of high field on humans, animals, and plants-measurements of electrostatics fields-electrostatic induction in unexercised circuit of a D/c line- induced voltages in insulated ground wires-electromagnetic interference.	10

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Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

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Books Recommended:

Text Books:

1. Rakosh Das Begamudre*"Extra high voltage AC Transmission Enginnering",* Second New Age International Pvt. Ltd.1990.
2. Power Engineer's Handbook, Revised and Enlarged 6th Edition, TNEB Engineer's Association.

Subject Code	Subject Name	Credits
PSE2043	**High Voltage Insulation System Design**	**04**

Module	Contents	Hours
1	**Study of Conduction and Breakdown**: Gas Dielectrics, Air Insulation, SF6 Insulation, Liquid dielectrics, Solid Dielectrics, Vacuum Dielectrics, and Composite Dielectrics.	06
2	**Generation and Measurement of High Voltages and high Currents**: Generation of high voltage AC & DC, Generation of impulse voltage & impulse current. Measurement of high voltage AC & DC, Measurement of impulse voltage & impulse current.	10
3	**Applications of Insulating Materials:** Applications in Power Transformers, Rotating Machines, Circuit Breakers, Cables, Power Capacitors, Electronic Equipment	04
4	**The Phenomenon of Partial Discharge (PD) :** Introduction, Definition of terms, typical electrode configurations with PD, internal discharges and surface discharges, external discharges, equivalent circuits, PD characteristics of parameters, wave-form and characteristics of an individual PD pulse, train of PD current pulses, train of PD pulses in relation to the temporarily, Assigned instantaneous value of the high voltage, non electrical PD characteristics parameters.	08
5	**Insulation Coordination :** Insulation coordination Insulation level, Statistical approach to insulation coordination, Correlation between insulation and protection levels.	04
6	**Diagnostics for electrical insulation:** Self restoring, non self restoring insulation, insulation resistance measurement (volume and surface resistance & resistivity), basics of diagnostics for oil – paper Insulation system, dissolved gas analysis.	06
7	**Nondestructive Insulation Test Techniques :** Loss in a Dielectric, Measurement of Resistivity , Measurement of Dielectric Constant and Loss Factor , High Voltage Schering Bridge, Measurement of Large Capacitance, Schering Bridge Method for Grounded Test Specimen, Schering Bridge for Measurement of High Loss Factor , transformer Ratio Arm Bridge, Partial Discharges, Bridge Circuit, Oscilloscope as PD Measuring Device, Recurrent Surge Generator .	10

Assessments:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. High voltage engineering by Kamaraju and Naidu
2. High voltage engineering by Knffel and Abdullah
3. Electrical insulation in power system, by Qureshi, Malik and Alaraine
4. High voltage engineering by C.LWadhawa.
5.

Reference Books:

1. High voltage and electrical insulation engineering by Ravindra Arora & Wolfgang Mosch.
2. www.ieemalearn.com

Subject Code	Subject Name	Credits
PSE2044	**Entrepreneurship Development**	**04**

Module	Contents	Hours
1	**Entrepreneurship concept** – Entrepreneurship as a Career – Entrepreneurial Personality - Characteristics of Successful, Entrepreneur – Knowledge and Skills of Entrepreneur.	10
2	**Business Environment** - Role of Family and Society - Entrepreneurship Development Training and Other Support Organisational Services - Central and State Government Industrial Policies and Regulations - International Business.	10
3	**Sources of Product for Business** - Prefeasibility Study - Criteria for Selection of Product - Ownership - Capital - Budgeting Project Profile Preparation - Matching Entrepreneur with the Project - Feasibility Report Preparation and Evaluation Criteria.	06
4	**Finance and Human Resource** Mobilization Operations Planning - Market and Channel Selection - Growth Strategies - Product Launching.	12
5	**Monitoring and Evaluation of Business** - Preventing Sickness and Rehabilitation of Business Units- Effective Management of small Business	10

Assessments:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Books Recommended:

Text Books:

1. Hisrich, Entrepreneurship, Tata McGraw Hill, New Delhi, 2001.
2. S.S.Khanka, Entrepreneurial Development, S.Chand and Company Limited, New Delhi, 2001.

Reference Books:

1. Mathew Manimala, Entrepreneurship Theory at the Crossroads, Paradigms & Praxis, Biztrantra ,2nd Edition ,2005
2. Prasama Chandra, Projects – Planning, Analysis, Selection, Implementation and Reviews, Tata McGraw-Hill, 1996.

3. P.C.Jain (ed.), Handbook for New Entrepreneurs, EDII, Oxford University Press, New Delhi, 1999.
4. Staff College for Technical Education, Manila and Centre for Research and Industrial Staff Performance, Bhopal, Entrepreneurship Development, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1998.
5. P. Saravanavel, Entrepreneurial Development, Ess Pee kay Publishing House,

Subject Code	Subject Name	Credits
PSL201	**Lab Practice III**	**01**

Module	Detailed content
1	Simulation examples of abc to dq0 transformation
2	Simulation model of synchronous machines
3	Simulation model of excitation systems
4	Simulation model of turbine-governor systems
5	Simulation model of static loads
6	Simulation models of dynamic loads
7	Simulation model of transformer
8	Simulation model of transmission line
9	Simulation model of SVC
10	Simulation model of SVC with controllers
11	Simulation model of single machine connected to infinite bus system
12	Simulation model of multi machine system
13	Steady state analysis of synchronous machine simulation model
14	Transient analysis of synchronous machine simulation model

Minimum Six Simulations should be performed based on above contents

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
PSL202	**Lab Practice IV**	**01**

Module	Detailed content
1	Computer programs of un-constrained optimization techniques
2	Computer programs of constrained optimization techniques
3	Generation of various signals such as sine, cos, square, exponential.
4	Generation of various sequences such as unit impulse, unit step, unit ramp, sine, cos.
5	Linear Convolution of two input sequences.
6	FIR low -pass filter design using Kaiser window.
7	Buffer worth band pass IIR filter design.
8	To find FFT/DFT of a sequence
9	To develop feed forward neural network and error back propagation algorithm.
10	Harmonic Analysis and Simulation of transmission system
11	Harmonic Analysis and Simulation Electrical Machines
	Harmonic Analysis and Simulation of Power Electronic Devices
12	Simulations of AC Drives
13	Simulations of DC Drives

Minimum Six Simulations should be performed based on above contents

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
PSS301	**Seminar**	**03**

Guidelines for Seminar

- Seminar should be based on thrust areas in Electrical Engineering
- Students should undergo literature survey and identify the topic of seminar and finalize in consultation with Guide/Supervisor. Students should use multiple literatures and understand the topic and compile the report in standard format and present in front of Panel of Examiners appointed by the Head of the Department/Institute of respective Program.
- Seminar assessment should be based on following points
  - Quality of Literature survey and Novelty in the topic
  - Relevance to the specialization
  - Understanding of the topic
  - Quality of Written and Oral Presentation

IMPORTANT NOTE:

1. Assessment of Seminar will be carried out by a pair of Internal and External examiner. The external examiner should be selected from approved panel of examiners for Seminar by University of Mumbai, OR faculty from Premier Educational Institutions /Research Organizations such as IIT, NIT, BARC, TIFR, DRDO, etc. OR a person having minimum Post-Graduate qualification with at least five years' experience in Industries.

2. Literature survey in case of seminar is based on the broader area of interest in recent developments and for dissertation it should be focused mainly on identified problem.

3. At least 4-5 hours of course on Research Methodology should be conducted which includes Literature Survey, Problems Identification, Analysis and Interpretation of Results and Technical Paper Writing in the beginning of 3rd Semester.

Subject Code	Subject Name	Credits
PSD301/ PSD401	**Dissertation (I and II)**	**12/ 15**

Guidelines for Dissertation

- Students should do literature survey and identify the problem for Dissertation and finalize in consultation with Guide/Supervisor. Students should use multiple literatures and understand the problem. Students should attempt the solution to the problem by analytical/simulation/experimental methods. The solution to be validated with proper justification and compile the report in standard format.

Guidelines for Assessment of Dissertation I

- Dissertation I should be assessed based on following points
  - Quality of Literature survey and Novelty in the problem
  - Clarity of Problem definition and Feasibility of problem solution
  - Relevance to the specialization
  - Clarity of objective and scope
- Dissertation I should be assessed through a presentation by a panel of Internal examiners appointed by the Head of the Department/Institute of respective Program.

Guidelines for Assessment of Dissertation II

- Dissertation II should be assessed based on following points
  - Quality of Literature survey and Novelty in the problem
  - Clarity of Problem definition and Feasibility of problem solution
  - Relevance to the specialization or current Research / Industrial trends
  - Clarity of objective and scope
  - Quality of work attempted
  - Validation of results
  - Quality of Written and Oral Presentation
- Dissertation II should be assessed through a presentation jointly by Internal and External Examiners appointed by the University of Mumbai.

Students should publish at least one paper based on the work in reputed International /

National Conference (desirably in Refereed Journal)