MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF ELECTRICAL ENGINEERING

Scheme & Syllabus
of
Master of Technology Program
in
Electrical Engineering (Power Systems Management)

Malaviya National Institute of Technology, Jaipur

Department of Electrical Engineering

Scheme for **M.Tech (Power Systems Management)** as per R & R manual of PG Programmes

PROGRAM STRUCTURE

M. TECH. PROGRAMME STRUCTURE (FULL TIME)

Semester. I

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EET-661	Optimal Operation and Control of Power Systems	Programme Core	Theory	3	2	1	0
2	EET-663	Power System Restructuring and Deregulation	Programme Core	Theory	3	2	1	0
3	EET-665	Power Markets, Economics and System Operation	Programme Core	Theory	3	2	1	0
4	EEP-603	Power Systems Management Laboratory	Programme Core	Lab	3	0	0	6
5	PE(Odd)		Programme Elective	Theory	3	2	1	0
6	PE(Odd)		Programme Elective	Theory	3	2	1	0
				Total Credits	18			

Semester. II

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EET-662	Distributed Energy Integration	Programme Core	Theory	3	2	1	0
2	EET-664	Smart Energy Management Systems	Programme Core	Theory	3	2	1	0
3	PE(Even)		Programme Elective	Theory	3	2	1	0
4	PE(Even)		Programme Elective	Theory	3	2	1	0
5	PE(Even)		Programme Elective	Theory	3	2	1	0
6	OE		Open Elective	Theory	3	2	1	0
				Total Credits	18			

Semester. III

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EES-703	Seminar	Programme Core	Seminar	3			
2	EED-705	Dissertation	Programme Core	Dissertation	7			
				Total Credits	10			

Semester. IV

S.No.	Course Category	Type	Credit	L	T	P
1	Programme Core	Dissertation	14			

Total Credits in M.Tech.(PSM) Full Time

Semester	Credits
I	18
II	18
III	10
IV	14
Total Credits	60

M. TECH. PROGRAMME STRUCTURE (PART TIME)

Semester. I

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EET-661	Optimal Operation and Control of Power Systems	Programme Core	Theory	3	2	1	0
2	EET-663	Power System Restructuring and Deregulation	Programme Core	Theory	3	2	1	0
3	EET-665	Power Markets, Economics and System Operation	Programme Core	Theory	3	2	1	0
				Total Credits	9			

Semester. II

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EET-662	Distributed Energy Integration	Programme Core	Theory	3	2	1	0
2	EET-664	Smart Energy Management Systems	Programme Core	Theory	3	2	1	0
3	PE(Even)		Programme Elective	Theory	3	2	1	0
				Total	9			

Semester. III

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	PE(Odd)		Programme Elective	Theory	3	2	1	0
2	PE(Odd)		Programme Elective	Theory	3	2	1	0

3	EEP-603	Power System Management Laboratory	Programme Core	Lab	3	0	0	6
4	EES-703	Seminar		Seminar	3			
				Total Credits	12			

Semester. IV

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	PE(Even)		Programme Elective	Theory	3	2	1	0
2	PE(Even)		Programme Elective	Theory	3	2	1	0
3	OE		Open Elective	Theory	3	2	1	0
				Total Credits	9			

Semester. V

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EED-705	Dissertation	Programme Core	Dissertation	7			

Semester. VI

S.No.	Course Code	Course Title	Course Category	Type	Credit	L	T	P
1	EED-706	Dissertation	Programme Core	Dissertation	14			

Total Credits in M.Tech.(PSM) Part Time

Semester	Credits
I	9
II	9
III	12
IV	9
v	7
VI	14
Total Credits	60

PROGRAMME CORE(PC)

Code	Course	PRS	PRE	CWS	MTE	ETE
EET-661	Optimal Operation and Control of Power Systems	-	-	20	30	50
EET-662	Distributed Energy Integration	-	-	20	30	50
EET-663	Power System Restructuring and Deregulation	-	-	20	30	50
EET-664	Smart Energy Management Systems	-	-	20	30	50
EET-665	Power Markets, Economics and System Operation	-	-	20	30	50
EEP-603	Power Systems Management Laboratory	70	30	-	-	-
EES-703	Seminar	70	30	-	-	-
EED-705	Dissertation	-	-	-	30	70
EED-706	Dissertation	-	-	-	30	70

PROGRAMME ELECTIVE -PE(Odd)

Code	Course	PRS	PRE	CWS	MTE	ETE
EET-671	Grid Instrumentation and Communication Systems	-	-	20	30	50
EET-673	Electricity Trading and Risk Management	-	-	20	30	50
EET-675	Electric Power Project Evaluation and Pricing	-	-	20	30	50
EET-677	Risk Assessment of Power Systems	-	-	20	30	50
EET-679	Modelling and Planning of Energy Systems	-	-	20	30	50
EET-681	Sustainable Energy Sources	-	-	20	30	50
EET-683	Service Quality Management	-	-	20	30	50

PROGRAMME ELECTIVE -PE(Even)

Code	Course	PRS	PRE	CWS	MTE	ETE
EET-672	Machine Learning and Data Analytics	-	-	20	30	50
EET-674	AI Application to Power Systems Management	-	-	20	30	50
EET-676	Energy Policy, Governance and Regulations	-	-	20	30	50
EET-678	Power System Planning and Reliability	-	-	20	30	50
EET-680	Power Distribution Systems	-	-	20	30	50
EET-682	Power System Quality	-	-	20	30	50
EET-684	Stochastic Systems, Optimization and Control	-	-	20	30	50
EET-686	Power System Analysis	-	-	20	30	50
EET-688	Computer Methods in Power Systems	-	-	20	30	50
EET-690	Quantitative Techniques	-	-	20	30	50

DETAILED SYLLABUS

PROGRAMME CORE

Course Code: EET-661
Course Name : OPTIMAL OPERATION AND CONTROL OF POWER SYSTEMS
Credits : 3 (L2-T1-P0)
Course Type : PC
Prerequisites : None

Course Objectives:

- To introduce the concepts of economic operation of power system.
- To impart knowledge of system security and load frequency control.

Course:

- Optimal Power System Operation: Optimal Operation of generators on a bus bar, Economic dispatch problem of thermal units – Gradient method- Newton's method –Base point and participation factor method.
- Optimal Unit Commitment, Constraints in unit commitment, spinning reserve, Thermal Unit Constraints, Other constraints, Hydro constraints, Must Run, Fuel constraints, Unit commitment Solution methods: Priority-List methods, Dynamic Programming solution. Backward DP Approach, Forward DP Approach, Restricted Search Ranges, Strategies.
- Hydro-thermal co-ordination-Hydroelectric plant models –short term hydrothermal scheduling problem - gradient approach – Hydro units in series - pumped storage hydro plants-hydro-scheduling using Dynamic programming and linear programming.
- Reliability Considerations, Patton's Security Function, Security constrained Optimal Unit Commitment, Start-up considerations, Optimal Generation Scheduling, Representation of Transmission Loss by B-coefficients, Derivation of Transmission Loss formula. Representation of Transmission Loss by Power Flow equations, Optimal Load Flow solution. Inequality constraints, Optimal Scheduling of Hydrothermal System.
- Introduction to Power System Security. System State Classification, Security Analysis, Contingency analysis, modelling for contingency Analysis. Linear sensitivity factors, AC power flow methods, contingency selection, concentric relaxation, bounding, security constrained optimal power flow.
- Automatic generation and Voltage Control: Introduction Load Frequency Control, Turbine Speed Governing System, Model of Speed governing system. Turbine Model, Generator Load Model, Block diagram representation of Load Frequency Control and an Isolated System, Steady State Analysis, Dynamic Response, Control Area, Load frequency control and Economic Dispatch Control, Two-area load frequency control, Optimal Load Frequency Control (two- area), three modes of control viz. Flat frequency – tie-line control and tie-line bias control, Automatic Voltage Control, Introduction to Digital LF Controllers, Decentralized Control.
- Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control. Net interchange tie-line bias control. Optimal, sub-optimal and decentralized controllers. Discrete mode AGC.

Books:

- J. Wood and B. F. Wollenberg, "Power generation, operation and control".
- C L Wadhwa, "Electrical Power Systems", New age international.
- Olle Elgerd, "Electric Energy Systems Theory", TMH.
- D Kothari and I Nagrath, "Power System Engineering", TMH.

- Dhillon Kothari, “Power System Optimization”, Prentice-Hall of India Pvt. Ltd.
- N. S. Rau, “Optimization principles: Practical Applications to the Operation and Markets of the Electric Power Industry”.

Course Code: **EET-662**
Course Name : **DISTRIBUTED ENERGY INTEGRATION**
Credits : **3 (L2-T1-P0)**
Course Type : **PC**
Prerequisites : **None**

Course Objectives:

- To introduce the concept of distributed generation, microgrids, electric vehicles and energy storage.
- To familiarize the students with renewable generation system modelling, and their grid integration issues.
- To impart an understanding of economics, policies and technical regulations for DG integration.

Course:

- Distributed Generation: Reasons for growth, extent of DGs, Issues with DGs, Policy/institutional issues, market/financial, “Distributed Generation: Induction and Permanent Magnet Generators” Wiley-IEEE Pre issues, social/environmental issues, DG Plant Types, DG Machinery & its control, Integration issues, Technical impacts of DGs, Economic impact of DGs, Impact on transmission and generation systems, Security and reliability. International DG Integration Experience.
- Wind/PV System Modelling: Wind/PV variability and uncertainty. Forecasting methods and applications.
- System studies: Power flow studies, Fault studies, Stability studies, Transient studies, Inertia and Frequency Response studies. Power Quality Issues.
- System balancing & imbalance handling: Flexibility Issues, Ramping issues, Inertia and Frequency Response Issues, Role of storage and DR and related issues, Large scale storage for grid stability / Backup.
- Technical regulations for the interconnection of DGs to the power systems: Overview of technical regulations, Active power control, Frequency control, Voltage control, Technical solutions for new interconnection rules. Protection of DGs. Feasibility of integrating Large-Scale Grid Connected DG, Policy, Market and Regulatory Interventions, Regulatory challenges, Viability of DG integration in deregulated electricity market.
- Economics of DG: Value of power from DGs, Market value of power from DGs, Loss reduction, Investment reduction, Connection costs and charges, Distribution use of system charges, Allocation of losses in distribution networks with DG, Alternative framework for distribution tariff development.
- DGs in areas of limited transmission capacity. DGs in distribution networks. Active Management of Distribution systems. Ancillary Services with DGs, Markets for Ancillary Services. DER Management, Virtual Power Plants.
- Micro Grids: Concept, Design, Modelling, Operation and Analysis. Role in Energy Reliability, Cold Load Pick Up and Sustainability.
- Electric Vehicles: Technology, Components of EV and their modelling, Charging and Discharging Mechanisms, Driving & Plug-in pattern analysis, Scheduling issues, Challenges in EV integration, Bulk Electric Vehicles, Ancillary Services from EVs.
- Energy Storage: Type and modelling of storage systems. Scheduling issues, Ancillary services from energy storage, Role in Energy Security, Reliability and Stability.

Books:

- Math H. Bollen, Fainan Hassan, “Integration of Distributed Generation in the Power System”, Wiley-IEEE Press, 2011.
- Willis H. Lee and Scott W. G., “Distributed Power Generation Planning and Evaluation”, Marcel Dekker, Inc, New York, 2000.
- B. Fox, D. Flynn L. Bryans, N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, “Wind Power Integration: Connection and System Operational Aspects” IET, 2007.
- Loi Lei Lai, Tze Fun Chanss, 2007.
- Komarnicki, Przemyslaw, Lombardi, Pio, Styczynski, Zbigniew , “Electric Energy Storage Systems”, Springer, 2017.
- Garcia-Valle, Rodrigo, Peças Lopes, João A, “Electric Vehicle Integration into Modern Power Networks”, Springer, 2012.

Course Code: EET-663
Course Name : POWER SYSTEM RESTRUCTURING AND DEREGULATION
Credits : 3 (L2-T1-P0)
Course Type : PC
Prerequisites : None

Course Objectives:

- To familiarize the students with concepts and need for deregulated power systems.
- To impart the knowledge of Power Market Development in India and across the world.

Course:

- Traditional Power Industry Structure, Motivations for restructuring, Fundamentals of restructured system, Restructuring models, Different industry structures and ownership/ management forms for generation, transmission and distribution. Different structure model: Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model. Components of restructured systems, key market entities- ISO, TSO, GENCO, TRANSCO, DISCO, RETAILCO, Functions and responsibilities, Trading arrangements: Pool, bilateral & multilateral, Open Access Transmission Systems & Distribution Systems; Power system operation and control: Old vs. New. IT applications in restructured markets.
- Fundamentals of deregulation: Need and conditions for deregulation, Basics of public good economics, Components of Deregulation, Technical, economic & regulatory issues involved in deregulation of power industry. Privatization, Competition in the electricity sector, conditions, barriers, different types, benefits and challenges. Reregulation.
- Market development and institutional scenario: Comparative study and global experience of historical evolution, institutional development, contemporary systems, regulation, reforms, deregulation models, market trends, operation, critical issues, challenges, future directions of key electricity markets: UK, South American markets (Argentina, Brazil, Chile, Uruguay), US (California, New York, PJM, ERCOT, New England, Midwest), Scandinavian market (Norway, Denmark, Sweden, Finland), Canada, Australia, China, Japan, Germany, New Zealand, France.
- Power market development in India: Institutional structure in Indian Power sector, generation, transmission and distribution utilities. SO & LDCs. PFC, REC, ERCs, traders, Power Exchanges and their roles. Availability based tariff, Open access, Industry structure and regulatory framework, market development, RE policies, RPO, Tariff policies. Policy changes, regulatory changes, Critical issues / challenges before the Indian power sector.

Books:

- Loi Lei Lai, “Power System Restructuring and Deregulation”, John Wiley & Sons Ltd, England, 2001.

- Mohammad Shahidehpour, Muwaffaq Alomoush, “Restructured Electric Power Systems: Operation, Trading and Volatility”, Marcel Dekker, Inc., 2001.
- D. S. Kirschen and G. Strbac, “Fundamentals of power system economics”, John Wiley & Sons, 2004.
- Geoffrey Rothwell, Tomas Gomez (Eds.), “Electricity Economics Regulation and Deregulation”, IEEE Press Power Engineering Series, John Wiley & Sons, 2003.
- Steven Stoft, “Power System Economics: designing markets for electricity”, Wiley Interscience, 2002.
- Mohan Munasinghe, “Electric Power Economics”, Butterworth & Co. (Publishers) Ltd, 1990.
- Richard J. Gilbert, Edward P. Khan, “International Comparisons of Electricity Regulation”, Cambridge University Press, 2002.
- Barrie Murray, “Electricity Market – Investment, Performance and Analysis” John Wiley and Sons Publications, 1998.
- Sally Hunt, “Making Competition Work in Electricity”, 2002, John Wiley Inc.
- Lorrin Philipson, H. Lee Willis, “Understanding electric utilities and de-regulation”, Marcel Dekker Pub., 1998.
- Bhanu Bhushan, “ABC of ABT - A primer on Availability Tariff” - www.cercind.org
- Sally Hunt and Graham Shuttleworth, “Competition and Choice in Electricity”.
- Antonio Conejo, “Decision Making Under Uncertainty in Electricity Markets”.

Course Code:		**EET-664**
Course Name	**:**	**SMART ENERGY MANAGEMENT SYSTEMS**
Credits	**:**	**3 (L2-T1-P0)**
Course Type	**:**	**PC**
Prerequisites	**:**	**None**

Course Objectives:
- To introduce the concept of smart grid and its role in energy management systems.
- To familiarize the students with modelling of smart grids components.
- To give an understanding of smart cities.

Course:
- Smart grid and emerging technologies, Operating principles and models of smart gird components, Key technologies for generation, networks, loads and their control capabilities; decision-making tools. Hardware, Software, Communication. Approaches to estimation, scheduling, management and control of next generation smart grid.
- Component Modelling: Generation Systems, Network Modelling: Transmission and Distribution. Energy Storage Modelling: Various storage mediums, Distribution and grid scale storage.
- Load Modelling, Demand Side Management: Principles of DSM, rules and tools of DSM, fundamentals of demand response, Demand aggregation, DSM tools and practices.
- Computational methods for SEMS: Estimation, optimization algorithms, data mining techniques and its applications, artificial intelligence techniques, Grid computing: Architecture, functionalities and features, applications to security, reliability and market analysis.
- Distribution grids: Characteristics: Assets, topology, From passive to active grids. Distribution power flow. Metering for residential customers: ToU, RTP, CPP. Metering for industrial customers. Monitoring, Control and protection applications in distribution grids. Substation Automation and Equipment condition monitoring.
- Smart grid applications: Advanced Metering Infrastructure, Smart meters, Demand response and Demand side management, PHEV, application at the DSO side. Operation

and control issues associated with intermittent generation. Impact of smart grid component integration on distribution network operation.

- Smart cities: Components of Smart Cities, integrated approaches to smart city modelling, challenges, Smart Parking, Smart Roads, Smart Payments, Smart Vending Machines. Smart Home Systems: Home automation systems, building energy, smart appliances, Smart lighting.
- Integrated approaches to energy management: Electricity, Gas, Heating and Cooling system modelling.

Books:

- S. Rajakaruna, F. Shahnia and A. Ghosh, "Plug in Electric Vehicles in Smart Grids Energy Management", Springer 2015
- Faruqui, "Pricing in Competitive Electricity Market", Springer Science + Business Media.
- Fereidoon P. Sioshansi, "Smart Grid: Integrating Renewable, Distributed and Efficient Energy", Academic Press, Elsevier
- S. McClellan, "Smart Cities", Springer International Publishing

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Course Code: EET-665
Course Name : POWER MARKETS, ECONOMICS AND SYSTEM OPERATION
Credits : 3 (L2-T1-P0)
Course Type : PC
Prerequisites : None

Course Objectives:

- To introduce fundamentals and structure of electricity markets.
- To give the understanding of ancillary services.
- To impart knowledge of system operation in restructured power systems.

Course:

- Fundamentals of electricity markets: Market structure and operating mechanisms, bilateral and multi-lateral markets. Perfect Competition, Oligopolistic Market, Theories of Oligopoly. Market Types- Commodity, Power, Energy, Ancillary Services, Transmission.
- Modelling, operation and analysis of electricity markets, Market Equilibrium.
- Market Structure: Formulation of the market, Price formulation and drivers, Merit order, Carbon markets (emission rights), Impact of renewables, Mean reversion & Seasonality, Cross-border transmission capacity, Market participants (producers, suppliers, TSOs), Exchange members, Dispatch & asset-backed trading, Balancing, Intraday / prompt markets, Market coupling, Day ahead markets & Daily auctions, Hedging, Forward markets & the application of power futures.
- Electricity Markets Pricing: 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.
- Power system operation in restructured markets: Coordinated real time dispatch through balancing mechanism, Imbalance settlement methodologies. Transmission Congestion Management and Methodologies, Congestion Pricing, Effect of congestion on LMPs, Transmission Losses, Limits and Congestion, Country Practices, Dynamic Congestion Management. Available Transfer Capability Evaluation and Methodologies- market splitting, counter-trading. New Unit Commitment-Price based OPF in restructured markets.
- Ancillary Services: Classifications and definitions, Market for AS, AS management in various markets, Forward AS auction, country practices, Contingency reserves: Pricing and procurement, Voltage security and reactive power management.

Books:

- M. Shahidehpour, H. Yamin, and L. Zuyi, “Market Operations in Electric Power Systems”. New York: Wiley, 2002.
- Yong-Hua Song and Xi-Fan Wang (Eds.), “Operation of Market-oriented Power Systems”, Spinger-Verlag London Limited, 2003
- D. S. Kirschen and G. Strbac, “Fundamentals of power system economics”, John Wiley & Sons, 2004
- K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, “Operation of restructured power systems”, Kluwer Academic Publishers, 2001.

Course Code: EEP-603
Course Name : POWER SYSTEMS MANAGEMENT LABORATORY
Credits : 2 (L0-T0-P3)
Course Type : PC
Prerequisites : None

Course Objectives:

- To give the understanding of different software tools used for power system studies.
- To familiarize the students in solving different problems related to power system operation.

Course:

1) Load flow studies.
2) Short circuit studies.
3) Transient stability studies.
4) Unit commitment.
5) Voltage stability studies.
6) Economic Load Dispatch with Thermal / Hydro / Wind / Solar power plants.
7) Transmission line design.
8) Sub-station design.
9) Generation Expansion Planning studies.
10) Network Planning studies.
11) Market bidding studies.
12) Network pricing studies.
13) Network congestion studies.
14) DG integration studies.
15) Unbalanced system studies.
16) Simulation of FACTS controllers.
17) Simulation of Single-area and Two-area Systems.
18) Load forecasting.

Software: ETAP/ MiPOWER / MATLAB / LABVIEW / MATHEMATICA / PSCAD / EMTP / GAMS/ PSSE/ DIGSILENT

Books:

- Alireza soroudi, “Power System Optimization Modeling in GAMS”, Springer 2017
- Hadi Saadat, “Power System Analysis”, Mc-Graw Hill.
- M. Shahidehpour, H. Yamin, and L. Zuyi, “Market Operations in Electric Power Systems”. New York: Wiley, 2002.
- Hossein Seifi and Mohammad Sadegh Sepasian, “Electric Power System Planning Issues”, Algorithms and Solutions, Springer, 2011.

PROGRAMME ELECTIVE

Course Code: **EET-671**
Course Name : **GRID INSTRUMENTATION AND COMMUNICATION SYSTEMS**
Credits : **3 (L2-T1-P0)**
Course Type : **PE**
Prerequisites : **None**

Course Objectives:

- To familiarize the students with different grid instrumentation and communication.
- To develop an understanding of monitoring, control, acquisition and information processing of power system data.

Course:

- Digital Instrumentation: Introduction, Basic measurement system. Digital voltage measurement, Frequency measurement, Time measurement, Digital phase meter, Digital multi-meter. Digital displays. A/D and D/A circuits and their operation, errors.
- Basic concepts of digital filtering storage. Configuration and flowcharts for basic power measurement involving filtering, arithmetic operations and storage.
- Telemetry System: Introduction to Information Transmission. Basic ideas. Point to Point telemetering: Basic principles, pneumatic and electrical system, voltage and current telemetry, impulse codal telemetry. Power Line Carrier Principles.
- On-line computer control. Distributed digital control. Data acquisition systems. Emergency control, preventive control, system wide optimization. Signal and system Analyzers.
- Time-error and inadvertent interchange correction techniques. Online computer control. Distributed digital control. Data acquisition systems. Emergency control, preventive control, system wide optimization.
- Introduction to PMUs, technology and their placement. Applications.
- SCADA: Components of control systems, SCADA systems, types of control systems, PLC, components of SCADA Systems, communication media, interfaces and security; SCADA in power systems, Regional Grid and DCS based SCADA systems.
- Communication technology for smart grid operation: Analog vs digital communications, ISO/OSI layer model, Physical layer: power line carrier, wired, wireless, Protocols and interfaces: TCP/IP, Mbus, Field buses and remote communications.
- Information processing: SCADA and DCS systems, Advance control methods. Distribution management systems. Data aggregation, data centres and clearing houses. Role of State Estimation. Fault detection and diagnosis. Dependability aspects. Cybersecurity aspects, Privacy aspects.

Books:

- H S Kalsi, “Electronic Instrumentation”, Tata Mc Graw Hill, 2010.
- Mini S. Thomas, John D. McDonald, “Power System SCADA and smart grids”, CRC Press, Taylor and Francis.
- Hendrik c. Ferreira, *et al*, “Power Line Communication- Theory and Applications for narrow band and broad communication over power lines”, Willy Publications.

Course Code: **EET-672**
Course Name : **MACHINE LEARNING AND DATA ANAYLITCS**
Credits : **3 (L2-T1-P0)**
Course Type : **PE**
Prerequisites : **None**

Course Objectives:

- To develop an understanding for learning opportunities from data analysis.
- To familiarize students with learning algorithms and their applications to data analysis.

Course:

- Introduction, linear classification, perceptron update rule, Perceptron convergence, generalization, Maximum margin classification, Classification errors, regularization, logistic regression, Linear regression, estimator bias and variance, active learning, Active learning (cont.), non-linear predictions, kernals, Kernal regression, Support vector machine (SVM) and kernels, kernel optimization, Model selection, Model selection criteria, Description length, feature selection, Combining classifiers, Boosting, margin, and complexity, Margin and generalization, mixture models, Mixtures and the expectation maximization (EM) algorithm, EM, regularization, Clustering, Spectral clustering, Markov models, Hidden Markov models (HMMs), Bayesian networks, Learning Bayesian networks, Probabilistic inference.

Books:

- Steinwart, Ingo, Christmann, Andreas, "Support Vector Machines", Springer.
- Gareth James, Daniela Witten,Trevor Hastie and Robert Tibshirani, "An Introduction to Statistical Learning with Applications in R", Spinger.
- Tom Mitchell, "Machine Learning", New York, NY: McGraw-Hill, 1997.
- T. Hastie, R. Tibshirani, and J. H. Friedman, "The Elements of Statistical Learning: Data Mining, Inference and Prediction", New York, NY: Springer, 2001.

Course Code: EET-673
Course Name : ELECTRICITY TRADING & RISK MANAGEMENT
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To impart understanding of trading, auctions and strategic behaviour of players in power market.
- To give an understanding of handling risk in electricity markets.

Course:

- Trading, Reasons for trading, Trading venues, Trading platforms, Trading Organisation, The setup, What is required? Trading methods. Bidding strategies.
- Electricity Auctions: Generation Auction Markets, Auction Mechanism, Country Practices, Decision making and strategies in generation auction markets. LMP based markets, auction models and price formation, Spot Pricing Models, Decomposition model. Social surplus, Social welfare maximization, Profit maximization.
- Analysis of Generating Companies' strategic behaviour: Auction structures, Price based models, Quantity based models, Strategic Supply Functions.
- Market Power: Definition, Exercise of Market Power, Modelling Market Power, Mitigation of Market Power, Uncertainties and Risk Mitigation.
- Risk Management in Markets: Market risk, Short-term vs. Long-term, Counterparty (credit) risk, Margining, EMIR, Liquidity risk, Market liquidity, Funding liquidity, Operational risk, Quantifying Risk, Risk modelling techniques, Value-at-risk & stress testing, Parametric, historical simulation & Monte Carlo, impact of price volatility, relation with collateralization & margining,

- Risk-Hedging Contracts, Forward, Future, Option, Swap and Spot markets, Risk evaluation in Electricity Trading, Risk Management Tools, Role of financial Instruments in Market Dispatch and Congestion Management, Options, Contract for differences, Financial Transmission Rights. Arbitrage in Electricity markets. Trading Methods & Tools, Use of derivatives, Futures, Options, Swaps, Screen based trading.

Books:

- M. Shahidehpour, H. Yamin and L. Zuyi, "Market Operations in Electric Power Systems". New York: Wiley
- Markus Burger, "Manging Energy Risk –A practical guide for risk management in power, gas and other energy markets", Wiley.
- Hisham Khatib, "Economic Evaluation of Projects in the Electricity Supply Industry," IEEE Power and Energy Series 44, The institution of Electrical Engineers, London

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Course Code: EET-674
Course Name : AI APPLICATIONS TO POWER SYSTEMS MANAGEMENT
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To introduce the concept and applications of artificial neural networks.
- To familiarize the students with design concepts of pattern recognition and statistical reasoning.

Course:

- Introduction to AI: Definition, Applications, Components of an AI program; production system. Problem Characteristics. Overview of searching techniques. Knowledge representation: Knowledge representation issues; and overview. Representing knowledge using rules; procedural versus declarative knowledge. Logic programming, forward versus backward reasoning, matching. Control knowledge.
- Statistical Reasoning: Probability and Daye's theorem. Certainty factor and rule based systems. Bayesian Networks, Dampster Shafer theorem. Semantic nets and frames, Scripts. Examples of knowledge based systems.
- Pattern Recognition: Introduction, automatic pattern recognition scheme. Design Concepts, Methodologies, Concepts of Classifier, concept of feature selection. Feature selection based on means and covariances. Statistical classifier design algorithms; increment-correction and LMSE algorithms. Applications.
- Artificial Neural Networks: Biological Neuron, Neural Net, use of neural 'nets, applications, Perception, idea of single layer and multilayer neural nets, back-propagation, Hopfield nets, supervised and unsupervised learning.
- Expert Systems: Introduction. Study of some popular expert systems, Expert System building tools and Shells, Design of Expert Systems.

Books:

- Kevin Warwick, Arthur Ekwue and Raj Aggarwal, "Artilficial Intelligence Techniques in Power Systems", The institution of Electrical Engineers, 1997.
- N. P. Padhy, "Artificial Intelligence and Intelligent Systems", Oxford University Press, 2005.
- Sergios Theodoridis, Konstantinos Koutroumbas "Pattern Recognition", Elsevier, 2003.

Course Code: EET-675
Course Name : ELECTRIC POWER PROJECT EVALUATION AND PRICING
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To impart understanding of system economics and project evaluation for power systems.
- To impart knowledge of network pricing mechanisms.
- To give an understanding of tariff structures.

Course:

- Structure, Operation and Management of Electricity Supply Chain: Energy Sources, Power Generation, Transmission, Network Operation and System Operation, Distribution, Metering, Supply.
- System economics: Basic design principles, AC/DC systems. MV and LV network arrangements. Relationships between planning and economics. Cost optimisation. Choice of voltage level. Overhead lines and cable design. Economic conductor size. Network reliability and security. Losses.
- Electricity economics: Cost and Supply, Short term and long term marginal costs.
- Economic Evaluation of projects: Power system planning, investments and projects, Typical project cost components and cost structure of the power sector, Considerations in project evaluation, Different methods of comparing investment options, Debt/Equity Ratio and effect on Return on Investment, Concept of Cost of Capital, life cycle cost, annual rate of return, Internal Rate of Return, Time Value for Money, Discount Rate, and Net Present Value, Evaluation of Risk and Uncertainty, Financial evaluation of projects, Economic evaluation of projects, Environmental considerations and costs in project evaluation, Economics of reliability of the power supply, Different financing options for the power sector. Analysis of Power Purchase Agreements.
- Transmission Network pricing: Models of transmission pricing, Different transmission services, Congestion issues and management, Network cost evaluation methods, Cost allocation methods, Locational marginal price, firm transmission right. Wheeling transactions, charges and pricing strategies. Power Tracing. Country Practices of Transmission Network Pricing.
- Distribution Network Pricing, Connection and use of system charges, Use of system charges: infrastructure, entry and exit, and wheeling charge. Network Pricing for Distributed Generation. Country Practices of Distribution network pricing.
- 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, 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. Determination of tariff for renewable energy.

Books:

- Hisham Khatib, “Economic Evaluation of Projects in the Electricity Supply Industry,” IEEE Power and Energy Series 44, The institution of Electrical Engineers, London, 2003
- T.W. Berrie, “Electricity Economics and Planning”, Peter Peregrinus Limited, United Kingdom.
- Ahmad Faruqui and Kelly Eakin ,“Pricing in competitive electricity markets”. Springer science+ Business Media LLC

Course Code: EET-676
Course Name : ENERGY POLICY, GOVERNANCE AND REGULATIONS
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To impart knowledge on the energy sector restructuring, policy and regulatory aspects.
- To provide understanding of regulatory and legal framework for network industries.

Course:

- Economic Reforms and Sectoral Restructuring: Rationale and Mechanisms of the Economic Reform Process, Liberalization, Privatization, and Globalization, Restructuring of Infrastructure Sectors. Public Policy and Governance: Good Governance, Social Development and Social Accountability. Post-Reform Policy-Making and Governance in Monopoly Sectors: Restructuring, New Independent Regulatory Agencies and other Governance Arrangements, New Policies in these Sectors.
- Public policy for operation, development and management of Power Systems: Hydro Policy, Wind Policy, Solar Energy Policy, Distributed Generation Policy, Renewable generation policy. Public policy options in the International Perspective.
- Environment: The policy debate, Regulation and incentive for restricting emissions and other impacts, Other policy tools for environmental enhancement, Fuel labelling and power content labelling, Valuation of environmental factors. Electricity generation and climate change agreements, Environmental acts, PAT, Carbon Credits. Energy conservation, audit and accounting: Energy Conservation, Energy Accounting, Energy Auditing. Aims and approaches of auditing, types of energy audit, energy indices in residential, commercial and industrial sector.
- Regulation of network industries: Liberalization, competition, regulation, the role of regulators, regulator/market/user interaction in network industries; interconnection and costing of network services. Electricity regulation: Introduction, Rate-of-return regulation, price cap regulation, revenue cap regulation, Revenue Reconciliation, Performance based ratemaking, Rate structure. Power system regulation in India: Stakeholders in the power sector, Role of regulation and evolution of regulatory commissions in India, Types and methods of economic regulation, Regulatory process in India. Non price issues in electricity regulation: Quality of supply and service, Standards of performance by utility, Environmental and social considerations.
- Legal framework for power sector in India: Historical development and existing acts, regulations, laws pertaining to operation, management, and development of electrical power systems, Salient features of Electricity act 2003, Various guidelines and developments under this act.

Books:

- Loi Lei Lai, “Power System Restructuring and Deregulation”, John Wiley & Sons Ltd.
- Ross R. McKitrick , “Economic evaluation of Environmental policies”.
- Pieter Glasbergen, “Environmental Policy in an international Context: Perspectives” The Open University.
- Draft National Energy policy, NITI Aayog, Govt of India. Avail: http://niti.gov.in/writereaddata /files/new_initiatives/NEP-ID_27.06.2017.pdf
- The Electricity Act 2003, Govt of India. Avai: http://www.cercind.gov.in/Act-with-amendment.pdf.
- Energy Conservation Act 2001, Govt of India. Avail: http://powermin.nic.in/sites/default/files/ uploads/ecact2001.pdf.
- Y. P. Abbi, *et al*, “Hand Book on Energy Audit and Environment Management”, TERI.

Course Code: EET-677
Course Name : RISK ASSESSMENT OF POWER SYSTEMS
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To introduce the basic concepts of power system risk assessment.
- To familiarize the students with risk evaluation techniques for power systems.

Course:

- Basic Concepts of Power System Risk Assessment
- Outage Models of System Components: Models of Independent Outages, Models of Dependent Outages.
- Parameter Estimation in Outage Models: Point Estimation of Mean and Variance of Failure Data, Interval Estimation of Mean and Variance of Failure Data, Estimating Failure Frequency of Individual Components, Estimating Probability from a Binomial Distribution, Experimental Distribution of Failure Data and Its Test, Estimating Parameters in Aging Failure Models.
- Elements of Risk Evaluation Methods: Methods for Simple / Complex Systems.
- Risk Evaluation Techniques for Power Systems: Techniques Used in Generation-Demand Systems, Radial Distribution Systems, Substation Configurations, Composite Generation and Transmission Systems.
- Application of Risk Evaluation to Transmission Development Planning: Concept of Probabilistic Planning, Risk Evaluation Approach- Selecting the Lowest-Cost Planning Alternative, Applying Different Planning Criteria. Application of Risk Evaluation to Transmission Operation Planning: Concept of Risk Evaluation in Operation Planning, Risk Evaluation Method- Determining the Lowest-Risk Operation Mode.
- Application of Risk Evaluation to Generation Source Planning: Procedure for Reliability Planning, Simulation of Generation and Risk Costs- Selecting Location and Size of Co-generators, Making a Decision to Retire a Local Generation Plant.
- Selection of Substation Configurations: Load Curtailment Model, Risk Evaluation Approach- Selecting Substation Configuration, Selecting Transmission Line Arrangement Associated with Substations.
- Reliability-Centred Maintenance: Basic Tasks in RCM- Transmission Maintenance Scheduling, Workforce Planning in Maintenance.
- Probabilistic Spare-Equipment Analysis: Spare-Equipment Analysis Based on Reliability Criteria, Spare-Equipment Analysis Using the Probabilistic Cost Method- Determining Number and Timing of Spare Transformers, Determining Redundancy Level of 500 kV Reactors.
- Reliability-Based Transmission-Service Pricing: Basic Concepts, Calculation Methods, Rate Design.
- Probabilistic Transient Stability Assessment: Probabilistic Modelling and Simulation Methods.

Books:

- Li Wenyuan, Risk assessment of power systems.

Course Code: **EET-678**
Course Name : **POWER SYSTEM PLANNING & RELIABILITY**
Credits : **3 (L2-T1-P0)**
Course Type : **PE**
Prerequisites : **None**

Course Objectives:

- To impart knowledge of power system planning and forecasting.
- To give an understanding of generation, transmission and distribution system reliability.

Course:

- Objectives of planning, long and short term planning, planning of generation, transmission and distribution systems. Least Cost Power Planning, Integration of DSM.
- Load forecasting: Classification and characteristics of loads. Approaches to load forecasting. Forecasting methodology. Short-run and long run forecasting. Time series, Econometric, end use techniques. Energy forecasting. Peak demand forecasting, total forecasting, annual and monthly peak demand forecasting.
- Electricity price Forecasting: Issues of pricing and forecasting, Basics of Price forecasting, Categorisation, Factors, Price simulation Model, Price Volatility Analysis.
- Basic Reliability Concepts: General reliability function, exponential distributions, meantime to failure, Markov Chains and processes and their applications, simple series and parallel system models. recursive technique.
- Static Generating Capacity Reliability Evaluation: Outage definitions, loss of load probability methods, loss of energy probability method. Frequency and duration methods, load forecasting uncertainty. Spare value assessment, multiple bridge equivalents.
- Spinning Generating Capacity Reliability Evaluation: Spinning capacity evaluation, load forecast uncertainty.
- Transmission System Reliability Evaluation: Average interruption rate method. LOLP method. The frequency and duration method. Stormy and normal weather effects.
- Inter-connected Systems Generating Capacity Reliability Evaluation: Introduction, The loss of toad approach. Interconnections benefits. Reliability evaluation in two and more than two interconnected systems. Interconnection benefits.
- Distribution system reliability analysis: distribution network reliability, reliability performance. Distribution systems with distributed generation: Generation reliability modelling, Network reliability model, reliability and production indices.

Books:

- Roy Billinton, “Power System Reliability Evaluation”, Gordan & Breach Scain Publishers, 1990.
- J. Endrenyi, “Reliability modelling in Electric Power System”, John Wiley, 1980.
- Roy Billinton, Allan Ronald, “Reliability of Power System”, Plenum Press, 1996.
- David Elmakias, “New Computational Methods in Power System Reliability”, Springer-Verlag, 2008.
- Ali Chowdhury, Don Koval, “Power Distribution System Reliability: Practical Methods and Applications”, Wiley-IEEE Press, 2009.
- Richard E. Brown, “Electric Power Distribution Reliability”, CRC Press, 2002.
- Roy Billinton, “Reliability Evaluation of Power systems”.
- R. L. Sullivan, “Power System Planning”, Heber Hill, 1987.

Course Code: **EET-679**
Course Name : **MODELING AND PLANNING OF ENERGY SYSTEMS**
Credits : **3 (L2-T1-P0)**
Course Type : **PE**
Prerequisites : **None**

Course Objectives:

- To provide basic insight in the life cycle analysis of energy systems.
- To impart understanding of modelling and simulation techniques for energy system planning.

Course:

- Introduction: Energy policy analysis; need for energy modelling; classification of energy models; types of computer based tools for energy planning; national and rural energy planning; sectoral energy planning. Pattern of fuel consumption: Projection of energy demand, substitution of conventional sources by alternative and efficient technologies. Production functions. Input-output economics, macro- economic growth models.
- Life Cycle Analysis: LCA of energy systems, concept of life cycle costing and its use.
- Input-Output Models: Types and Characteristics of I-O models; use of I-O models; I-O transaction tables; method of estimation and sources of data; mathematical expression on the methodology of construction of I-O tables; case studies.
- Econometric Models: Statistical estimation techniques; time series; regression analysis; advantages and limitations of econometric models; elastic ties of energy demand; case studies. Demand functions, supply functions, cost functions, production functions, utility functions and Engel curves.
- Optimization Models: Linear and non-linear optimization models; advantage and limitation of optimization models; case studies of linear optimization models for national and rural energy planning.
- Process Analysis Models: End-use models; process analysis models for industrial, domestic and transport energy conservation; advantage and limitations of process analysis models; case studies.
- System Dynamic and other Simulation Models: Concept of closed system; causal loop diagram; flow diagram and system equations; dynamic behaviour of energy systems; advantages and limitations of simulation models; case studies. Dynamic models of the economy and "Simple" theory of business fluctuations. Multiple linear and non-linear regression analysis, energy per unit monetary value of consumer needs and services.
- Energy efficiency, Cost-benefit risk analysis. Environmental repercussions and the economic structure. Conflict between energy consumption and pollution. Systems Design and quantitative economic policy with particular references to energy. Potential & Economy of sustainable sources. Econometric in the context of multiple objectives, conflicting goals and decisions under uncertainty.
- Pattern of fuel consumption: Agricultural, domestic, industrial and community needs. Projection of Energy Demands, substitution of conventional sources by alternative sources and more efficient modern technologies.
- Hybrid and Integrated Energy Systems. Total Energy concept and Waste heat utilization.

Books:

- Aris Spanos, “Statistical Foundations of Econometric Modelling” Cambridge University Press.
- Richard W. Cottle & Mukund N. Thapa, “Linear & Non-linear Optimization” Springer.
- Fabio De Bellis, "Energy Systems Simulation and Optimization", Lambert academic.
- Henrik Lund, “A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions” Academic Press.

Course Code: EET-680
Course Name : POWER DISTRIBUTION SYSTEMS
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To familiarize the students with different components of power distribution systems.
- To impart knowledge in distribution network performance.
- To give an understanding of modern distribution grid management.

Course:

- Industrial and commercial distribution systems, Energy losses in distribution system, system ground for safety and protection, comparison of O/H lines and underground cable system.
- Distribution Network analysis: power flow, short circuit and loss calculations.
- Distribution system expansion planning: Configuration of distribution systems, load characteristics, load forecasting, design concepts, distribution transformers, distribution substation design, optimal location of substation, feeder design, design of radial lines, solution technique.
- Voltage regulation: Application of shunt capacitance for loss reduction, System harmonics, static VAR systems, loss reduction and voltage improvement.
- System protection: requirements, fuses and section analyzers, over current, under voltage and under frequency protection, coordination of protective device.
- Operation and maintenance: Power distribution system, sub-station equipment and distribution lines, distribution transformer.
- Quality of supply and services: Performance benchmarking, key performance indicators, performance improvement and operation management.
- Distribution loss reduction and efficiency improvement: concepts and principles of distribution losses, technical loss reduction, commercial loss reduction, metering and billing system.
- IT applications in distribution business management: Overview of Distribution Business and Information Technology, IT Systems Applications in the Network. IT interfaces in customer services: Customer Information and Satisfaction, Metering: Issues, Concerns and Innovations, Billing: Issues, Practices and Innovations, Collection: Issues and Innovations.
- Concepts of modern grid. Introduction to distribution automation, Layout of substations and feeders, Optimum siting and sizing of substations Distribution system load flow, configuration of distribution system, optimum capacitor placement. Optimum feeder switching for loss minimization and load control. Distribution system restoration. Distribution System Automation, Distribution system monitoring and control: Concept of modern distribution systems. Smart Metering. Power Distribution Sector In India: Sectoral Overview and enabling framework, distribution reforms, the changing perspective, RGGVY. APDRP. UDAY Scheme.

Books:

- Turan Gonen, “Electric Power Distribution System Engineering”, CRC Press, Taylor & Francis.
- Abdelhay A. Sallam, Om P. Malik, “Electric Distribution Systems,” Wiley-IEEE Press, May 2011.
- S. Chowdhury, S.P. Chowdhury and P. Crossley, “Microgrids and Active Distribution Networks,” IET, 2009.
- V. Kamraju, “Electrical Power Distribution Systems”, Tata McGraw-Hill.
- H. Lee Willis, “Power Distribution Planning Reference Book”.
- Websites of various distribution utilities in India

- http://rggvy.gov.in/
- www.bee-india.nic.in/
- www.powermin.nic.in/

Course Code: EET-681
Course Name : SUSTAINABLE ENERGY SOURCES
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To introduce various sustainable energy source technologies.
- To familiarize the students with characteristics and modelling various sustainable energy source.

Course:

- Conventional Sources of Energy: Coal, Hydro, Nuclear, Diesel and Gas Turbine Power Stations. Comparative study of power stations. Environmental Impacts and Sustainability of conventional sources of power.
- Renewable Generation technologies: Wind, PV, CHP, marine, biomass, Tidal, Geo-thermal, OTEC, MHD.
- Solar Power Generation: Basic characteristics of sunlight, solar energy resource, photovoltaic cell-characteristics, equivalent circuit, photo voltaic for battery charging. Solar power generation: Solar power plant, photo voltaic power generation.
- Wind Power Generation: Wind source, wind statistics, energy in the wind, aerodynamics, rotor design and types, braking systems, tower, control and monitoring system, power performance. Wind driven induction generators, power circle diagram, steady state performance, wind farm electrical design.
- Hybrid & Integrated Sources: wind-diesel, wind-solar, Micro-hydel, geothermal-tidal. Co-generation, Hydro-thermal Energy co- ordination.

Books:

- G. D. Rai, “Non-Conventional Energy Sources”, Khanna Publishers.
- B. H. Khan, “Non-Conventional Energy Resources”, Tata McGraw-Hill Education.
- G. S. Sawhney, “Non -Conventional Resources of Energy”, PHI.

Course Code: EET-682
Course Name : POWER SYSTEM QUALITY
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To impart knowledge about various aspects of power quality issues.
- To provide learning about power system transients, harmonics and conditioners.

Course:

- Overview, concept and definition of power quality (PQ), Electric power quality phenomena, Sources of pollution, International power quality standards and regulations, IEC and IEEE definitions, CBEMA and ITI Curves, general class of power quality problems, power quality disturbances, voltage fluctuations, transients, unbalance waveform distortion, power frequency variations. Power quality terms.

- Voltage variations, Voltage sags and short interruptions, sources of sags and interruptions, rapid voltage fluctuations, flicker, short duration outages, longer duration variations, voltage dips and voltage swells, voltage unbalance, sources, range and impact on sensitive circuits, Waveform distortion, standards, solutions and mitigations, equipment and techniques. Estimating voltage sag performance, Sensitivity of equipment to voltage sag.
- Transients: origin and classifications, capacitor switching transient, lightning-load switching, impact on users, protection, mitigation.
- Power system harmonics: harmonics, inter-harmonics, sub-harmonics, Difference between harmonics and transients, harmonic analysis, harmonic sources, definitions & standards, static converters, transformer magnetization and non-linearities, rotating machines, arc furnaces, fluorescent lighting, impacts within the power system, calculation and simulation, sources of harmonic distortion, harmonic power flow, voltage and current distortion, harmonic indexes, effects of harmonic distortion, mitigation and control techniques, filtering, passive and active, interference with communication harmonics.
- Power quality conditioners: shunt and series compensators, DSTATCOM-Dynamic voltage restorer, unified power quality conditioners-case studies.

Books:

- M.H.J. Bollen, “Understanding Power Quality Problems: Voltage sags and interruptions” IEEE Press, New York, 2000.
- J Arrillaga, N.R. Watson, S. Chen, “Power System Quality Assessment”, Wiley, New York, 2000.
- Math H. Bollen, Irene Gu, “Signal Processing of Power Quality Disturbances” Wiley-IEEE Press, 2006.
- Arindam Ghosh, Gerard Ledwich, “Power quality enhancement using custom power devices” Springer, 2002.
- Angelo B. Baggini, “Handbook of power quality”, Wiley 2008.
- Ewald F. Fuchs, Mohammad A. S. Masoum, “Power quality in power systems and electrical machines” Academic Press, 2008.
- Surya Santoso, H. Wayne Beaty, Roger C. Dugan, Mark F. McGranaghan, “Electrical Power Systems Quality” McGraw-Hill, 2002.

Course Code: EET-683
Course Name : SERVICE QUALITY MANAGEMENT
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To introduce the concept of quality and service management.
- To provide understanding on total quality management philosophies and frameworks.
- To develop in-depth knowledge on various tools and techniques for total quality management.

Course:

- Introduction to Quality Management: Quality – vision, mission and policy statements. Customer Focus - Part of Customer focus – customer perception of quality, Translating needs into requirements, customer retention. Dimensions of service quality. Cost of services quality.
- Concepts of services quality: Definitions of Service Quality and its Significance -Measuring Service Quality -Service Quality Gap Model - Service Quality Standards - Strategies for Improving Service Quality - Monitoring Service Quality. Concepts of Quality circle, Japanese 5S principles applicable to services.

- Applying statistical process control to services: Statistical process control (SPC) – application of SPC to services. Six sigma for services. Reliability concepts – definitions, reliability in series and parallel, product life characteristics curve. Business process Improvement (BPI) – principles, applications, process, benefits and limitations.
- Tools and techniques for service quality: Quality functions development (QFD) – Benefits, Voice of customer, information organization, House of quality (HOQ), building a HOQ, QFD process. Applying the seven old and new tools for service quality. Bench marking in services, FMEA.
- Quality systems implementation for services: ISO certification for services – quality management systems – guidelines for performance improvements. Quality Audits – Walkthrough audits. TQM culture –Leadership, quality council, employee involvement, motivation, empowerment, recognition and reward – TQM framework, benefits, awareness and obstacles.

Books:

- Dale H. Besterfield, Carol Besterfield – Michna, Glen H. Besterfield, Mary Besterfield – Sacre, Hermant – Urdhwareshe, Rashmi Urdhwareshe, Total Quality Management, Revised Third edition, Pearson Education, 2011.
- Shridhara Bhat K, Total Quality Management – Text and Cases, Himalaya Publishing House, First Edition 2002.
- Peter D. Mauch, “Service Quality Management: Theory and Application”, Create Space Independent Publishing Platform

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Course Code: EET-684
Course Name : STOCHASTIC SYSTEMS, OPTIMIZATION AND CONTROL
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To familiarize the students with stochastic system modelling.
- To help students in develop algorithmic skills for a stochastic system modelling.

Course:

- Review of probability theory, discrete and continuous probability distributions and densities; multiple random variables and joint distributions.
- Representation of deterministic and stochastic systems; properties of stochastic models; Introduction to uncorrelated, cross correlated and colored noise; problem of uncertainty management, Optimal filtering-Kalman filtering, Extended filtering, unscented filtering; control of load frequency in power systems and inter-connected complex power systems.
- Econometric modeling, formulation and specification of econometric model, types data-time series, cross section data, panel data and dummy variable data; regression analysis; Concept of volatility and its effects; volatility estimation, Autoregressive model including ARMA, ARIMA.
- Introduction to non-linear programming, Newton’s method; unconstrained optimization, steepest decent method; constrained optimization, reduced gradient method; Quadratic programming, Sequential quadratic programming.
- Decomposition techniques- direct decomposition and nested decomposition for multi stage problems, dual decomposition, Lagrangian decomposition, Augmented Lagrangian decomposition, Bi-level decomposition.
- Brownian motion and its properties and relationship with noise and rumor, Scenarios, Scenario tree, two and multistage problems, Scenario generation and reduction.
- Game theory, Games and solutions, Strategic and competitive games, Nash equilibrium.

Books:

- Aris Spanos, "Statistical Foundations of Econometric Modelling" Cambridge University Press.
- Antonio J. Conejo, E. Castillo, & R. Garcia-Bertrand "Decomposition Techniques in Mathematical Programming: Engineering and Science" Springer.
- Anatol'evich Rozanov , "Probability Theory: A Concise Course", Dover Publications Inc.
- David G. Luenberger, "Introduction to Linear & Nonlinear Programming" Addison Wesley.
- Peter Mörters, Brownian Motion (Cambridge Series in Statistical and Probabilistic Mathematics) Cambridge University Press.
- Antonio Conejo, "Decision making under uncertainty In Electricity Markets".

Course Code: EET-686
Course Name : POWER SYSTEM ANALYSIS
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To provide knowledge of power system analysis under faulty and unbalanced systems.
- To give an understanding of generators, transformers and network models for system analysis.
- To impart an understanding of modelling approaches for load flow studies.

Course:

- Fault Analysis: Positive. Negative and Zero Sequence equivalent circuits of lines, two and three winding transformers, induction machines and synchronous machines. Analysis of shunt and series faults, effect of neutral grounding.
- Unbalanced Operation of 3-phase Induction Motors: Characteristics with application of unbalanced voltage to a balanced motor and with application of balanced voltage to a motor having unbalanced impedances in the rotor circuit.
- Synchronous Machines: Short circuit currents and reactances of synchronous machine. Modelling of synchronous machine at no load and symmetrical load under steady state conditions, Sequence impedance of synchronous machines.
- Representation of transformers: Fixed tap setting transformer, tap changing under load transformers, Phase shifting transformers, algorithms for formation of bus admittance and impedance matrices.
- Linear Graph Theory: Study of linear graph theory, Network topology, incidence, Cut-set and Tie-set matrices and their interpretation. Calculation of Z-bus, Y-bus, Z-branch and Y loop matrices by singular and non-singular transformations. Algorithm for the calculation of Y-bus and Z-bus. Fault calculations using Z-bus.
- Load Flow Studies: Formulation of load flow problem. Various types of buses. Gauss-Siedel, Newton-Raphson and Fast Decoupled Algorithms. Calculation of reactive power at voltage controlled buses in the Gauss-Seidel iterative method using Y-bus, Representation of transformers - Fixed tap setting transformer, Tap changing under load transformers, Phase shifting transformers, Tie line control, Comparison of methods for load flow. Three-phase load flow, specified variables, derivation of equations.
- DC power flow, Single phase and three phase-AC-DC load flow, DC system model, Sequential Solution Techniques, Extension to Multiple and Multi-terminal DC systems, DC convergence tolerance.
- Short circuit studies. Sparsity exploitation in power system studies. Static equivalents for power systems.

- Introduction to power system security. System state classification, Security analysis, Contingency analysis. State estimation in power systems.

Books:

- J. Grainger and W. Stevenson, "Power System Analysis", Tata McGraw-Hill education.
- G. Kusic, "Computer-Aided Power Systems Analysis", CRC Press, Taylor & Francis.
- H. Saadat, "Power System Analysis", PSA Publishing.
- R. N. Dhar, "Computer Aided Power System operation and Analysis", TMH, New Delhi.
- M. A. Pai, "Computer Techniques in Power System Analysis", Tata Mc-Graw Hill New Delhi.
- Stagg and El Abiad, "Computer Methods in Power System Analysis", Mc-Graw Hill.
- T. K. Nagsarkar, M. S. Sukhija, "Power System Analysis", Oxford University Press.
- J. Arrillaga & N.R. Watson, "Computer Modelling of Electrical Power Systems", Wiley.

Course Code: EET-688
Course Name : COMPUTER METHODS IN POWER SYSTEMS
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:

- To provide students with an overview of power network and system modelling.
- To impart the knowledge of modelling studies for secure system operation.

Course:

- Three-Phase Networks: Introduction, Three-phase network elements, Three-phase balanced network elements. Transformation Matrices, Three-phase unbalanced network elements, incidence and network matrices for three-phase networks. Algorithm for formation of three-phase bus-impedance matrix. Modification of the three-phase bus impedance matrix for changes in the network.
- Short Circuit Studies: Short circuit calculations using Bus Impedance matrix, Short circuit calculations for balanced three- phase network using Bus Impedance matrix, Short circuit calculations using Loop Impedance matrix.
- Sensitivity Analysis and Optimal Load Flow: Classification of System variables, Sensitivity Analysis-Sensitivity Matrix, Development of G_x and G_u, Optimal Load Flow, Optimisation Technique, Gradient method. Formulation of Optimal Load-flow Problem and its Solutions, Consideration of Inequality Constraints. Comparison with Classic Economic Dispatch Method.
- Security Concept and Contingency Evaluation: Operating States of a Power System, Concept of security Monitoring. Techniques for Contingency Evaluation DC Load Flow, Fast Decoupled Load-flow, Preventive and corrective Measures.
- Load Forecasting & State Estimation: Estimation of average, periodic, stochastic components of load. Basic idea of state estimation of power system, method of least squares, statistics, errors, estimates, test for bad data, structure and formation of Hessian matrix, power system state estimation.

Books:

- J. Grainger and W. Stevenson, "Power System Analysis", Tata McGraw-Hill education.
- G. Kusic, "Computer-Aided Power Systems Analysis", CRC Press, Taylor & Francis.
- H. Saadat, " Power System Analysis", PSA Publishing.
- Y. Wallach, Calculation and programs for power system networks.
- R.N. Dhar, Computer Aided Power System operation and Analysis, Tata Mc-Graw Hill New Delhi.
- M.A. Pai, Computer Techniques in Power System Analysis Tata Mc-Graw Hill New Delhi.

- Computer Methods in Power System Analysis- Stagg and El Abiad, Mc-Graw Hill.
- T. K. Nagsarkar, M. S. Sukhija, “Power System Analysis” Oxford University Press.
- J. Arrillaga & N.R. Watson, “Computer Modelling of Electrical Power Systems”, Wiley.

Course Code: EET-690
Course Name : QUANTITATIVE TECHNIQUES
Credits : 3 (L2-T1-P0)
Course Type : PE
Prerequisites : None

Course Objectives:
- To provide basic insight on mathematical and statistical quantitative techniques.
- To familiarize the students with decision making and metaheuristic techniques.

Course:
- Mathematical Quantitative Techniques: Permutations and Combinations, Set Theory, Matrix Algebra, Determinants, Differentiation.
- Statistical Quantitative Techniques: Collection of data, Measures of Central Tendency & Dispersion, Probability concepts, conditional probability, Bayes Theorem & Applications, Bayesian decision analysis, Probability Distributions- Binomial, Poisson, Normal & Exponential, Sampling & Sampling Distributions, Testing of Hypothesis.
- Correlation, Regression & Multivariate Analysis, Index Numbers, Forecasting methods & Time Series Analysis. Interpolation and Extrapolation, Statistical Quality Control, Ratio Analysis, Stochastic process introduction.
- Decision Analysis: Introduction to decision analysis and process. Decision Trees & Utility Theory, Decision Making under uncertainty, under risk, under certainty & under conflict. Game Theory.
- Linear Programming: Queuing Theory, Game Theory, Decision Theory, Replacement Theory. Graphical, simplex method, dual simplex, Sensitivity Analysis & Duality. Integer Programming. Transportation, Transhipment & Assignment Models.
- Multi-Criteria Decision making: Linear Goal Programming, Scoring Models, Fuzzy outranking, Introduction to concepts of Analytic Hierarchy Process & Analytic Network Process.
- Inventory models (Static, dynamic, probabilistic & stochastic), Waiting Line / Queing models steady state operation. Simulation concepts & applications for inventory & Q-ing situations.
- Network models; shortest route, maximal flow problem. PERT, CPM.
- Glimpses of Metaheuristics (Tabu, Simulated Annealing & Genetic algorithm), Markov chains & Decision Processes, Sequencing, Dynamic Programming & Nonlinear Programming (Quadratic & Geometric Programming, Sequencing, Branch and Bound Technique). Case studies & applications.

Books:

- C. R. Kothari, “Quantitative Techniques”, Vikas Publishing House.
- Antonio Conejo, “Decision Making Under Uncertainity In Electricity Markets”.
- J.K. Sharma, “Operations Research : Theory and Application”.
- N. P. Bali, P. N. Gupta & C. P. Bali, “A Textbook of Quantitative Techniques”, Laxmi Publications.
