PhD Elective Courses
Department of Electrical Engineering

APPROVED BY

BOARD OF STUDIES (BOS)
7th MEETING, November 03, 2020

Department of Electrical Engineering

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List of PhD Elective Courses

Sr. No.	Course Code	Course Title	L	T	P	Credits	Contact Hours
1.	EE-621	Linear System Theory	3	0	0	3	3
2.	EE-623	Power Markets, Economics and System Operation	3	0	0	3	3
3.	EE-625	Stochastic Systems, Optimization and Control	3	0	0	3	3
4.	EE-627	Computational Intelligence and Algorithms	3	0	0	3	3
5.	EE-629	Numerical Methods in Electromagnetics	3	0	0	3	3
6.	EE-631	High Voltage Testing Techniques	3	0	0	3	3

EE-621 **Linear System Theory** **[3 0 0]**

Course Objectives:

1. To introduce the concept of spaces and results from linear algebra
2. To introduce state space model and stability analysis
3. To understand the concept of controllability and observability

Linear Algebra: Basis vector and Orth normalization, Linear algebraic equations, Similarity transform, Diagonal form, Jordan form, Lyapunov equation, Quadratic form, Positive definiteness, Singular value decomposition, Partitioned matrices.

State Space Model and Stability: Solution to LTI state space equation, Solution of linear time varying (LTV) Equations, Input-output stability of LTI system, Internal stability, Stability of LTV system.

Controllability and Observability: Controllability and Observability for linear systems, Canonical decomposition, Conditions in Jordan form, Kalman canonical form, stabilizability and Detectability for linear systems.

Design of Linear Feedback Control System: state feedback and output feedback, Pole assignment using state feedback, Observers, Separation principle for feedback controller, Regulation and Tracking.

Text Books:

1. Chi-Tsong Chen, Linear System Theory and Design, Oxford University Press, third edition, 1999.
2. Brogan, William L. *Modern control theory*. Pearson education india, 1991.
3. Kailath, Thomas. *Linear systems*, New Jersey, Prentice-Hall, 1980.

EE-623 Power Markets, Economics and System Operation [3 0 0]

Course Objectives:

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

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.

Text Books:

1. M. Shahidehpour, H. Yamin, and L. Zuyi, “Market Operations in Electric Power Systems”. New York: Wiley, 2002.
2. Yong-Hua Song and Xi-Fan Wang (Eds.), “Operation of Market-oriented Power Systems”, SpingerVerlag London Limited, 2003

3. D. S. Kirschen and G. Strbac, “Fundamentals of power system economics”, John Wiley & Sons, 2004
4. K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, “Operation of restructured power systems”, Kluwer Academic Publishers, 2001.

EE-625 Stochastic Systems, Optimization and Control [3 0 0]

Course Objectives:

1. To familiarize the students with stochastic system modelling.
2. To help students in develop algorithmic skills for a stochastic system modelling.
3. To learn about decomposition technique and game theory

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.

Text Books:

1. Aris Spanos, "Statistical Foundations of Econometric Modelling" Cambridge University Press.
2. Antonio J. Conejo, E. Castillo, & R. Garcia-Bertrand "Decomposition Techniques in Mathematical Programming: Engineering and Science" Springer.
3. Anatol'evich Rozanov , "Probability Theory: A Concise Course", Dover Publications Inc.

4. David G. Luenberger, “Introduction to Linear & Nonlinear Programming” Addison Wesley.
5. Peter Mörters, Brownian Motion (Cambridge Series in Statistical and Probabilistic Mathematics) Cambridge University Press.
6. Antonio Conejo, “Decision making under uncertainity In Electricity Markets” Springer

EE-627 Computational Intelligence and Algorithms [3 0 0]

Course Objectives:

1. To enable Problem-solving through various searching techniques.
2. To apply these techniques in applications which involve perception, reasoning and learning.
3. To Learn genetic algorithm and differential evolution and to Learn swarm optimization and ant colony for feature selection
4. To apply Computational Intelligence techniques primarily for machine learning.

Introduction to algorithm, Newton' s method, optimization algorithm, No-Free-Lunch Theorems, Nature Inspired Metaheuristics, Analysis of Algorithms, Nature Inspired Algorithms, Parameter tuning and parameter control.

Introduction to Genetic algorithm, Gene representation and fitness function, Selection and fitness scaling using roulette wheel, Recombination and mutation, Elitism, Multi-objective GA, Pareto front Genetic algorithm toolbox in matlab.

Swarm intelligence, PSO algorithm, accelerated PSO, implementation and convergence analysis, binary PSO, The Firefly algorithm: algorithm analysis and implementation, Ant colony optimization toward feature selection.

Learning, Types of Machine Learning, Supervised Learning, The Brain and the Neuron, Regression and Classification with Linear Models, Artificial Neural Networks, Self-organizing neural networks: feature extraction, data visualization, Nonparametric Models, Convolution neural networks, Programming in Matlab

Neural Network Representation , Problems, Perceptrons, Multilayer Networks and Back Propagation Algorithms, Advanced Topics, Models of Evaluation and Learning. Support Vector Machines , Reinforcement Learning and Transfer learning

Text Books:

1. Jason Bell, Machine learning – Hands on for Developers and Technical Professionals, First Edition, Wiley, 2014
2. Xin-She Yang, Nature Inspired Optimization Algorithm,Elsevier First Edition 2014.
3. Engelbrecht A, Computational Intelligence: An Introduction (2nd ed.), John Willey & Sons, 2007
4. Russell S., Norwig P, Artificial Intelligence: A Modern Approach, (2nd ed.), Prentice Hall, 2013.
5. Tom M. Mitchell, Machine Learning, McGraw-Hill Education (India) Private Limited, 2013

EE-629 Numerical methods in Electromagnetics [3 0 0]

Course Objectives:

1. To provide foundation in formulation and computation of Electromagnetic Fields using analytical and numerical methods.
2. To impart in-depth knowledge on the Finite Element Method in solving Electromagnetic field problems.
3. Understand the concepts and analysis approaches for numerical dispersion of FDTD electromagnetic simulations.
4. Understand the mathematical basis and numerical modeling of charge simulation method for electrical design of high voltage equipments

Maxwell's equations, Applications of Computational Electromagnetics, Electrostatics and Magneto statics, Wave equation and propagation, Scalar and vector potentials, Surface equivalence principle, Green's Function, Boundary conditions, Linear algebra for computational EM

Limitations of the conventional design procedure, need for the field analysis based design, problem definition, boundary conditions, solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method.

Finite element methods: Introduction and history of FEM, FEM in the method of moments framework; 1 and 2D basis functions in FEM, Weak form of FEM; Robin boundary conditions; example of solving the 1D wave equation using FEM, 2D edge-based (vector) FEM: Weak form of FEM; shape functions, radiation boundary conditions, total and scattered field formulations, assembly of equations, numerical aspects in computing 2D FEM matrix elements, and overall procedure

Finite Difference Time Domain: Introduction to FDTD: update equations, computational stencil in 2D, Analysis, convergence, accuracy and numerical dispersion; incorporating dielectric and dispersive materials; absorbing boundary conditions, failure of ABCs and introduction of perfectly matched layers (PML), Hybrid methods in CEM -- Finite Element - Boundary Integral method

Charge simulation method: Introduction to CSM, Principle of CSM, Charge configurations and Potential coefficients, Modelling accuracy and analysis, CSM for multi-dielectric problems, Design and analysis of electric fields in simple geometries

Text Books:

1. Matthew. N.O. Sadiku, "Elements of Electromagnetics", Fourth Edition, Oxford University Press, First Indian Edition 2007

2. K.J.Binns, P.J.Lawrenson, C.W Trowbridge, “The analytical and numerical solution of Electric and magnetic fields”, John Wiley & Sons, 1993.
3. Nicola Biyanchi , “Electrical Machine analysis using Finite Elements”, Taylor and Francis Group, CRC Publishers, 2005.
4. Nathan Ida, Joao P.A.Bastos , “Electromagnetics and calculation of fields”, Springer Verlage, 1992.
5. S.J Salon, “Finite Element Analysis of Electrical Machines” Kluwer Academic Publishers, London, 1995, distributed by TBH Publishers & Distributors, Chennai, India

EE-631 **High voltage Testing Techniques** **[3 0 0]**

Course Objectives:

1. To analyse the breakdown mechanism of solids, liquids and gaseous dielectrics.
2. To gain in-depth knowledge on characteristics and behavior of dielectrics under static and alternating fields.
3. To analyse and calculate the circuit parameters involved in generation of high voltages.
4. To acquire knowledge on required tests and the procedures for various high voltage power apparatus as per Indian and international standards.
5. To measure the dielectric loss and partial discharge involved in non-destructive high voltage tests.

Requirements of HV generation in laboratory, Generation of High voltages, AC voltages: cascade transformers-series resonance circuits; DC voltages: voltage doubler-cascade circuits-electrostatic machines Generation of Impulse voltages and currents: single stage and multistage circuits-wave shaping, tripping and control of impulse generators Generation of switching surge voltage and impulse currents

Objectives of high voltage testing - classification of testing methods- self restoration and non-self restoration systems-standards and specifications - measurement techniques - Diagnostic testing - online measurement

Insulation materials and -systems: insulation systems in practice, dielectric losses, ageing and life expectancy. Classifications of insulation based on temperature withstand limits. Materials for outdoor insulation. Applications of nanofilled materials for outdoor and indoor insulation.

Testing of insulators, bushings, air break switches, isolators, circuit breakers, power transformers, voltage transformers, current transformers, surge diverters, cable – testing methodology - recording of oscillograms - interpretation of test results.

Dynamic properties of dielectrics-dielectric loss and capacitance measurement - partial discharge measurements - PD equivalent model – PD quantities - Digital PD instruments and measurements - acoustic emission technique and UHF Techniques for PD identification - Corona and RIV measurements. Artificial Pollution tests- salt-fog method, solid layer method - Dimensions of High voltage laboratory, equipment - fencing, earthing and shielding - circuits for high voltage experiments.

Text Books:

1. Dieter Kind, Kurt Feser, “High Voltage Test Techniques”, SBA Electrical Engineering Series, New Delhi, 1999.
2. M. S. Naidu, V. Kamaraju, "High Voltage Engineering", McGraw-Hill, 1995.
3. M. Khalifa, "High Voltage Engineering: Theory and Practice", Dekker, 1990.
4. Kuffel and Zaengal , “High Voltage Engineering”, Newnes, 2000.
5. IS, IEC and IEEE standards for Dielectric Testing of High Voltage Apparatus.