CURRICULUM AND SYLLABI

M.Tech.

in

POWER SYSTEMS

(With effect from Academic Year 2018-2019)

DEPARTMENT OF ELECTRICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
CALICUT - 673601

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Vision of the Department of Electrical Engineering

To be nationally and internationally recognized in providing electrical engineering education and training candidates to become well-qualified engineers who are capable of making valuable contributions to their profession and carrying out higher studies successfully.

Mission of the Department in pursuance of its vision

To offer high quality programs in the field of electrical engineering, to train students to be successful both in professional career as well as higher studies and to promote excellence in teaching, research, collaborative activities and contributions to the society.

The Program Educational Objectives (PEOs) of M. Tech. Programme in POWER SYSTEMS

PEO1	To equip the engineering graduates with enhanced knowledge and skills in the area of power systems so as to excel in various sectors in modern power industry/utility and/ or teaching and/or higher education and / or research.
PEO2	To transform engineering graduates to expert power engineers so that they could comprehend, analyze, design and create novel products and strategic solutions to real life problems in the areas of power systems that are technically sound, economically feasible and socially acceptable.
PEO3	To train engineering graduates to exhibit professionalism, keep up ethics in their profession and relate engineering issues to address the technical and social challenges.
PEO4	To improve the communication skills and willingness to work in groups and to develop multidisciplinary approach in problem solving.

The Programme Outcomes (POs) of M. Tech. Programme in POWER SYSTEMS

PO1	An ability to independently carry out research/ investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	Ability to utilize the acquired knowledge to take up administrative challenges including the management of projects in the field of Power Systems having multidisciplinary nature with a perspective to maintain lifelong learning process.
PO5	Willingness and ability to upkeep professional ethics and social values while carrying out the responsibilities as a Power System engineer/researcher in devising solutions to real life engineering problems in an independent manner.

Curriculum for M. Tech. Programme in Power Systems

This Programme is offered in four semesters. The structure of M.Tech.programme shall have the following Course categories:

SEMESTER 1

Course Code	Course Title	L	T	P/S	C
MA6003D	Mathematical Methods for Power Engineering	3	-	-	3
EE6201D	Computer Methods in Power System Analysis	3	-	-	3
EE6203D	Distributed Generation & Microgrid	3	-	-	3
EE6301D	Power Electronic Circuits	3	-	-	3
	Elective -1	3	-	-	3
EE6291D	Power Systems Lab	-	-	2	1
EE6293D	Seminar	-	-	2	1
Total Credits					17

SEMESTER 2

Course Code	Course Title	L	T	P/S	C
EE6202D	Power System Dynamics and Control	3	-	-	3
EE6204D	FACTS and Custom Power	3	-	-	3
EE6206D	Digital Protection of Power systems	3	-	-	3
EE6426D	Distribution Systems Management and Automation	3	-	-	3
	Elective -2	3	-	-	3
	Elective -3	3	-	-	3
EE6292D	Real Time Simulation Lab	-	-	2	1
Total Credits					19

Note: The students shall undergo Industrial Training in a reputed industry / R&D organization during summer vacation.

SEMESTER 3

Course Code	Course Title	L	T	P/S	C
EE7291D	Project – Part 1	-	-	20	10
Total		-	-	20	10

SEMESTER 4

Course Code	Course Title	L	T	P/S	C
EE7292D	Project – Part 2	-	-	28	14
Total		-	-	28	14

LIST OF ELECTIVES

Sl. No	Code	Title	Credits
1	EE6221D	Power Quality Issues and Remedial Measures	3
2	EE6222D	Wide Area Monitoring & Control of Power Systems	3
3	EE6223D	Power System Planning and Reliability	3
4	EE6224D	Distributed Processing of Power Systems	3
5	EE6226D	Hybrid and Electric Vehicles	3
6	EE6101D	Systems Theory	3
7	EE6102D	Optimal and Robust Control	3
8	EE6103D	Measurements and Instrumentation	3
9	EE6105D	Digital Control: Theory and Design	3
10	EE6108D	Nonlinear Systems and Control	3
11	EE6121D	Data Acquisition and Signal Conditioning	3
12	EE6125D	Adaptive Control Theory	3
13	EE6126D	Advanced Topics in Control Systems	3
14	EE6140D	Advanced Soft Computing Techniques	3
15	EE6303D	Dynamics of Electrical Machines	3
16	EE6304D	Modern Digital Signal Processors	3
17	EE6306D	Power Electronic Drives	3

18	EE6322D	Static VAR Controllers and Harmonic Filtering	3
19	EE6323D	Digital Simulation of Power Electronic Systems	3
20	EE6327D	Implementation of DSP Algorithms	3
21	EE6329D	Advanced Microprocessor Based Systems	3
22	EE6401D	Energy Auditing & Management	3
23	EE6403D	Computer Controlled Systems	3
24	EE6405D	Artificial Intelligence & Automation	3
25	EE6421D	Smart Grid Technologies and Applications	3
26	EE6422D	Engineering Optimization and Algorithms	3
27	EE6428D	SCADA Systems & Application	3
28	EE6429D	Wireless & Sensor Networks	3
29	EE6430D	Network & data Security	3
30	EE6432D	Advanced Algorithms & Data Structure Analysis	3
31	EE6434D	Internet of Things and Applications	3
32	EE6501D	High Voltage Engineering	3
33	EE6503D	Power System Transients	3
34	EE6506D	EHV Power Transmission	3
35	EE6521D	HVDC Transmission	3
36	EE6522D	High Voltage Power Transformers and Circuit Breakers	3
37	EC6302D	Communication Networks	4
38	EC6434D	Linear & Nonlinear Optimization	3
39	MA8154D	Wavelet Theory	3

Notes:

1. A minimum of 60 credits have to be earned for the award of M. Tech Degree in this Programme.
2. Communicative English and Audit courses are optional. Industrial Training during summer is optional.
3. List of Electives offered in each semester will be announced by the Department
4. Any other PG level course of NITC approved by senate offered in the Institute can also be credited as elective with the prior approval from the Programme Coordinator.

MA6003D MATHEMATICAL METHODS FOR POWER ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply notions of vector spaces and linear transformations in engineering problems.
CO2: Diagonalise linear operators and quadratic forms.
CO3: Handle various linear programming problems and apply the simplex method for solving linear programming problems in various fields of science and technology.
CO4: Solve constrained and unconstrained nonlinear programming problems.
CO5: Apply the concept of random variables, functions of random variable and their probability distribution in problems involving uncertainty.
CO5: Classify stochastic processes using autocorrelation function.

Module 1: Linear Algebra (10 hours)

Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernels and Images, Matrix representation of linear transformation, Change of basis, Eigen values and Eigen vectors of linear operator

Module 2: Optimisation Methods I (10 hours)

Mathematical formulation of Linear Programming Problems, Simplex Method, Duality in Linear Programming, Dual Simplex method.

Module 3: Optimisation Methods II (10 hours)

Non Linear Programming preliminaries, Unconstrained Problems, Search methods, Fibonacci Search, Golden Section Search, Constrained Problems, Lagrange method, Kuhn-Tucker conditions

Module 4: Operations on Random Variables (9 hours)

Random Variables, Distributions and Density functions, Moments and Moment generating function, Independent Random Variables, Marginal and Conditional distributions, Conditional Expectation, Elements of stochastic processes, Classification of general stochastic processes.

References:

1. Kenneth Hoffman and Ray Kunze, *Linear Algebra*, 2nd ed., PHI, 1992.
2. Erwin Kreyszig*, Introductory Functional Analysis with Applications*, John Wiley & Sons, 2004.
3. Irwin Miller and Marylees Miller, *John E. Freund's Mathematical Statistics*, 6th ed., PHI, 2002.
4. J. Medhi, *Stochastic Processes*, New Age International, New Delhi., 1994
5. A Papoulis*, Probability, Random Variables and Stochastic Processes*, 3rd ed., McGraw Hill, 2002
6. John B Thomas, *An Introduction to Applied Probability and Random Processes*, John Wiley, 2000
7. Hillier F S and Liebermann G J, *Introduction to Operations Research*, 7th ed., McGraw Hill, 2001
8. Simmons D M, *Non Linear Programming for Operations Research*, PHI, 1975

EE6201D COMPUTER METHODS IN POWER SYSTEM ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Formulate network admittance and impedance matrix for various analyses of power systems.
CO2: Execute load flow and short circuit analysis on large scale AC, DC and AC-DC power systems using digital techniques.
CO3: Conduct optimal scheduling and unit commitment of generators.
CO4: Execute state estimation and contingency analysis on large scale power systems using digital techniques.

Module 1: (10 hours)

Network modelling - System Graph. Loop, Cutest and Incidence Matrices - Y Bus Formation – Mutually coupled branches in Y Bus - solution techniques for linear networks -Guassian Elimination, LU Factorization, Network reduction techniques - Sparsity programming and Optimal Ordering - [ZBUS] Building Algorithm with Mutually coupled branches - digital simulation.

Module 2: (10 hours)

Power Flow Analysis: Newton-Raphson Method. Decoupled and Fast Decoupled Methods, DC Power Flow, AC-DC Load Flow Analysis, Load Flow under Power Electronic Control

Fault Analysis: Sequence Matrices. Symmetrical and Unsymmetrical Short-Circuit Analysis of Large Power Systems - Phase Shift in Sequence Quantities Due To Transformers - digital simulation

Module 3: (9 hours)

Power System Optimization - Unit Commitment - Priority List and Dynamic Programming Methods - Optimal Load Flow Solution - Optimal scheduling of Hydrothermal System - Optimum Reactive Power Dispatch and control, Economic scheduling in deregulated environment - AI Applications - digital simulation

Module 4: (10 hours)

Power System Security, Factors Affecting Security. State Transition Diagram. Contingency Analysis Using Network Sensitivity Method And AC Power Flow Method, Z bus method, Correcting The Generation Dispatch Using Sensitivity Methods, State Estimation, Bad data detection, State estimation with phasor measurements.- digital simulation

References:

1. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003
2. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
3. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
4. George L. Kusic, *Computer Aided Power System Analysis*, Prentice Hall of India (P) Ltd., New Delhi, 1989.
5. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation and Control*, John Wiley & Sons, New York, 1984.
6. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems,* Wiley, New York, 1983.

7. A.K. Mahaianabis, D.P. Kothari, S.I. Ahson, *Computer Aided Power System Analysis & Control,* Tata McGraw Hill, New Delhi, 1988.
8. O.I. Elgard, *Electric Energy System Theory: An Introduction*, 2^{nd} ed., McGraw Hill, New York, 1982.
9. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
10. T. J. E. Miller, *Reactive power control in Electrical system*, John Wiley & Sons, New York, 1982.
11. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.

EE6203D DISTRIBUTED GENERATION & MICROGRID

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyze the concept of distributed generation and technologies
CO2: Investigate the technical challenges of Distributed Generation technologies
CO3: Design the microgrid architectures and its control operation
CO4: Explore smartgrid technologies and infrastructure

Module 1: (10 hours)

Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy - Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors - unit sizing of DGs - Case studies

Module 2: (10 hours)

Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters - Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units - Optimal placement of DGs - Case studies

Module 3: (10 hours)

Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) - Local Controllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids - Interconnection of Microgrids

Module 4: (9 hours)

Introduction to Smart Grids (SG) - Factors affecting the growth of SG - The global reality in the field of smart grids and transition into future grids - Smart Agents - Electronics and communications infrastructure in SG - ICT Technologies - smart meters - metering infrastructures - metering equipment - communication of metering equipment - communication protocols - Metering Data Management Systems (MDMS) - Application of SGs - Interconnections issues between SGs

References:

1. N. Hatziargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 1st Edition, 2014
2. J. N. Twidell &A. D. Weir, *Renewable Energy Sources*, University press ,Cambridge, 2001
3. James Larminie , Andrew Dicks , *Fuel Cell Systems,* John Weily & Sons Ltd, 2000
4. J. F. Manwell , J. G. McGowan, A. L. Rogers , *Wind Energy Explained*, John Weily & Sons Ltd 2009
5. Loi Lei Lai, Tze Fun Chan, *Distributed Generation- Induction and Permanent Magnet Generators*, IEEE Press, John Wiley & Sons, Ltd., England. 2007.
6. Amirnaser Yezdani, and Reza Iravani, *Voltage Source Converters in Power Systems: Modeling, Control and Applications*, IEEE John Wiley Publications, 2009.

EE6301D POWER ELECTRONIC CIRCUITS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse and design the Diode rectifiers and filters circuits
CO2: Design and implement various types of controlled rectifiers
CO3: Explain about various PWM techniques of 2-level DC to AC converters
CO4: Evaluate and design inverters with advanced PWM techniques
CO5: Design current controlled voltage source inverters

Module 1: Line Frequency Uncontrolled and Controlled Rectifiers and Inverters (13 hours)

C / LC filter Design for Single Phase diode rectifiers. Three Phase half wave rectifier with resistive load. Three phase full wave rectifier. Double Y type rectifier. Three Phase Rectifier Circuits. Input Line Current Harmonics and power factor. Line Notching and its control.
Single Phase: Half Wave Controlled Rectifier with R, RL, RLE loads, With Freewheeling diode. Full Wave Controlled Rectifier with various kinds of loads. Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonics and Power Factor- Inverter Mode of Operation.
Three Phase: Half Wave Controlled rectifier with RL Load. Half Controlled Bridge with RL Load. Fully Controlled Bridge with RL Load. Input Side Current Harmonics and Power Factor - Dual Converters. Circulating Current Mode and Non-Circulating Current Mode.

Module 2: Switch-Mode dc-ac Inverters (13 hours)

Basic Concepts. Single Phase Inverters. PWM Principles. Sinusoidal Pulse Width Modulation in Single Phase Inverters. Choice of carrier frequency in SPWM. Spectral Content of output. 3rd Harmonic injection to enhance the source utilisation. Bipolar and Unipolar Switching in SPWM - Blanking Time Maximum Attainable DC Voltage Switch Utilization. Reverse Recovery Problem and Carrier Frequency Selection. Output Side Filter Requirements and Filter Design - Ripple in the Inverter Output - DC Side Current.
Three Phase Inverters -Three Phase Square Wave /Stepped Wave Inverters. Three Phase SPWM Inverters. Choice of Carrier Frequency in Three Phase SPWM Inverters. Output Filters. DC Side Current. Effect of Blanking Time on Inverter Output Voltage.

Module 3: Introduction to high power converters (13 hours)

Converters for High Power Applications: Standard Modulation Strategies - Programmed Harmonic Elimination. Multi-Pulse Converters and Interface Magnetics - Space Vector Modulation – Minimum ripple current PWM method. Current Regulated Inverter – Current Regulated PWM Voltage Source Inverters. Methods of Current Control. Hysteresis Control. Variable Band Hysteresis Control. Fixed Switching Frequency Current Control Methods. Switching Frequency Vs accuracy of Current Regulation Areas of application of Current Regulated VSI.

References:

1. Ned Mohan, *Power Electronics: Converters, Applications, and Design*, John Wiley and Sons, 2006.
2. P.C. Sen, *Power Electronics,* Tata McGraw Hill, 2003.
3. G.K.Dubey et.al *Thyristorised Power Controllers,* Wiley Eastern Ltd., 2005.
4. Dewan & Straughen *Power Semiconductor Circuits,* John Wiley &Sons, 1975.
5. M.D.Singh & K.B.Khanchandani, *Power Electronics,* Tata McGraw Hill, 2007
6. B. K Bose, *Modern Power Electronics and AC Drives,* Pearson Education (Asia), 2007,09.

EE6291D POWER SYSTEMS LAB

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:

CO1: Apply modern software tools for power system analysis.
CO2: Analyze simulation results and do effective documentation.
CO3: Develop software solutions for real life power system problems

List of Experiments

1. Formation of incidence matrices and bus admittance matrix of a power network using Matlab.
2. Power flow analysis of standard test systems using ETAP / Mi Power/ DigSilent power factory.
3. Short-circuit analysis of standard test systems using ETAP/ Mi Power/ DigSilent power factory.
4. Transient stability analysis of standard test systems using ETAP.
5. Facts device modeling and analysis using PSCAD/EMTDC package.
6. Travelling wave characteristics of transmission lines for different types of terminations using PSCAD.
7. Modeling and analysis of automatic load frequency control of multi-area power systems using Matlab/Simulink.
8. Determination of synchronous machine reactance and time constant parameters.
9. Performance analysis of energy efficient induction motor.
10. Perform contingency analysis using DSA Tool.

References:

1. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
2. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed., John Wiley & Sons, 2008.
3. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
4. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
5. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.
6. P. Kundur, *Power System Stability and Control*, McGraw Hill Education Pvt Ltd, 2006.
7. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
8. M. A. Pai, Dheeman Chatterjee, *Computer Techniques in Power System Analysis*, McGraw Hill Education (India) Pvt Ltd., 2014.

EE6293D SEMINAR

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:

CO1: Identify promising new directions of various cutting edge technologies
CO2: Study research papers for understanding of a new field, in the absence of a textbook, summarize and review them
CO3: Prepare detailed report describing the project and results
CO4: Effectively communicate by making an oral presentation before an evaluation committee

Individual students will be asked to choose a topic in any field of Power System, preferably from outside the M.Tech syllabus and give seminar on the topic for a bout thirty minutes. A committee consisting of at least three faculty members specialized on different fields of engineering will assess the presentation of the seminars and award the marks to the students. Each student will be asked to submit two copies of a write up of the seminar talk – one copy will be returned to the student after duly certifying by the Chairman of the assessing committee and the other copy will be kept in the departmental library.

EE6202D POWER SYSTEM DYNAMICS AND CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Design and analyze Automatic Generation control (AGC) and AVR for power systems considering economic dispatch.
CO2: Model and analyze dynamical systems to address various power system stability problems.
CO3: Execute digital simulation of large power system for small signal and transient stability analyses and develop stability enhancement methods.
CO4: Model and analyze voltage stability

Module 1: (10 hours)

Generation Control Loops. AVR Loop. Performance and Response. Automatic Generation Control of Single Area and Multi Area Systems. Static and Dynamic Response of AGC Loops – analysis using digital simulation - Economic Dispatch and AGC, AGC in a Deregulated Environment, Recent advances in AGC

Module 2: (10 hours)

Small signal angle instability (low frequency oscillations) - Power System Model for Low Frequency Oscillation Studies, damping and synchronizing torque analysis, Eigen value Analysis, Improvement of System Damping with Supplementary Excitation Control, Standard models for PSS representation-supplementary modulation control of FACTS devices, sub-synchronous frequency oscillations - Sub Synchronous Resonance and Countermeasures, IEEE Benchmark models for SSR studies

Module 3: (10 hours)

Transient Stability Problem, Modeling of Synchronous Machine, Loads, Network, Excitation Systems, Turbine And Governing Systems, Trapezoidal Rule of Numerical Integration Technique For Transient Stability Analysis, Simultaneous Implicit Approach for Transient Stability Analysis of Multi-machine Systems, Data For Transient Stability Studies, analysis using digital simulation - Transient Stability Enhancement Methods

Module 4: (9 hours)

Voltage Stability Problem. Real and Reactive Power Flow in Long Transmission Lines. Effect of ULTC and Load Characteristics on Voltage Stability. Voltage Stability Limit. Voltage Stability Assessment Using PV Curves. System Modelling-Static and Dynamic Analysis-Voltage Collapse Proximity Indices. Voltage Stability Improvement Methods.

References:

1. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed. John Wiley & Sons, 2008
2. P. Kundur, *Power System Stability and Control*, McGraw Hill, New York, 1994.
3. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation And Control*, 2nd ed., John Wiley And Sons, New York, 1996.
4. O.I. Elgard, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill, New York, 1982
5. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
6. M A Pai, D P Sen Gupta, K R Padiyar, *Small Signal Analysis of Power Systems*, Narosa Series in Power and Energy Systems, 2004
7. Leonard L Grigsby, *Power Systems*, Electrical Power Engineering Handbook, CRC Press, New York, 2007.

8. C. Van Custem, T. Vournas, *Voltage Stability Of Electric Power Systems*, Rlever Academic Press, 1998.
9. Yao-Nan-Yu, *Electric Power System Dynamics,* Academic Press, 1983
10. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer Modeling of Electrical Power Systems*, Wiley, New York, 1983.
11. I.J. Nagrath, O.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.

EE6204D FACTS AND CUSTOM POWER

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyze passive and active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.
CO2: Analyze operation and control of various FACTS devices.
CO3: Digital simulation and case study of various FACTS controllers.
CO4: Design and analyze Custom power devices for power quality improvement.

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Module 1: (10 hours)

Power flow in Power Systems – Steady-state and dynamic problems in AC systems – Voltage regulation and reactive power flow control in Power Systems – control of dynamic power unbalances in Power System - Power flow control -Constraints of maximum transmission line loading - Benefits of FACTS Transmission line compensation- Uncompensated line -shunt compensation - Series compensation –Phase angle control.– reactive compensation at transmission and distribution level – Static versus passive VAr Compensators

Module 2: (10 hours)

Static shunt compensators: SVC and STATCOM - Operation and control of TSC, TCR and STATCOM - Compensator control - Comparison between SVC and STATCOM.
Static series compensation: GCSC, TSSC, TCSC, SSSC -Static voltage and phase angle regulators - TCVR and TCPAR - Operation and Control –Applications – Digital simulation and analysis - SSR and damping schemes

Module 3: (9 hours)

Unified Power Flow Controller: Circuit Arrangement, Operation and control of UPFC- Basic Principle of P and Q control- independent real and reactive power flow control- Applications - Interline power flow controller – Transient stability improvement and power oscillation damping -Digital simulation and analysis.

Module 4: (10 hours)

Power quality problems in distribution systems – Custom power devices - mitigation of harmonics, passive filters, active filtering – shunt, series and hybrid filters and their control – Distribution STATCOM, Dynamic Voltage Restorer – Unified Power Quality Conditioner - Digital simulation and analysis- Custom Power Devices for Isolation, Protection and Reconfiguration-STS, SCL,SCB.

References:

1. K R Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International Publishers, 2007.
2. X P Zhang, C Rehtanz, B Pal, *Flexible AC Transmission Systems- Modelling and Control*, Springer Verlag, Berlin, 2006.
3. N.G. Hingorani, L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.

4. K.S.Sureshkumar , S.Ashok , *FACTS Controllers & Applications*, e-book ed., Nalanda Digital Library, NIT Calicut,2003.
5. G T Heydt , *Power Quality*, McGraw-Hill Professional, 2007.
6. T J E Miller, *Static Reactive Power Compensation*, John Wiley and Sons, Newyork, 1982.
7. F.P. Beer and E.R. Johnston, *Vector Mechanics for Engineers – Statics*, McGraw Hill Book Company, 2000.

EE6206D DIGITAL PROTECTION OF POWER SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes

CO1: Explain various digital protective schemes for transmission lines and power apparatus.
CO2: Select and design instrument transformers for a specific protection scheme design.
CO3: Realise numerical relays in hardware platform.
CO4: Conduct testing and coordination of relays.

Module 1: (8 hours)

Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions; Classification – analog - digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

Module 2: (13 hours)

Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms-travelling wave protection schemes; Relay Schematics and Analysis- Over Current Relay-Instantaneous/Inverse Time –IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types Characteristics. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples

Module 3: (11 hours)

Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection - line protection - distance protection–long EHV line protection - Power line carrier protection Motors protection; Pilot wire and Carrier Current Schemes; Reactor protection – Protection of boosters - capacitors in an interconnected power system. System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Re-closing and synchronizing.

Module 4: (7 hours)

Integrated and multifunction protection schemes -SCADA based protection systems- Fault Tree Analysis; Testing of Relays- Field test procedures for protective relays.
Adaptive relaying- AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection

References:

1. A T John and A K Salman, *Digital protection for power systems-IEE power series-15*, Peter Peregrines Ltd,UK,1997
2. C.R. Mason, *The art and science of protective relaying*, John Wiley &sons, 2002
3. Donald Reimert, Protective relaying for power generation systems, Taylor & Francis-CRC press 2006
4. Gerhard Ziegler, *Numerical distance protection*, 2nd ed., Siemens, 2006
5. A.R.Warrington, *Protective Relays, Vol .1&2*, Chapman and Hall, 1973.

6. T S.Madhav Rao, *Power system protection static relays with microprocessor applications*, Tata McGraw Hill Publication, 1994
7. *Power System Protection Vol. I, II , III&IV*, The Institution Of Electrical Engineers, Electricity Association Services Ltd., 1995
8. Helmut Ungrad , Wilibald Winkler, Andrzej Wiszniewski*, Protection techniques in electrical energy systems*, Marcel Dekker, Inc. 1995
9. Badri Ram , D.N. Vishwakarma, *Power system protection and switch gear*, Tata McGraw Hill, 2001
10. Blackburn, J. Lewis, *Protective Relaying, Principles and Applications*, Marcel Dekker, Inc., 1986. Anderson, P.M, Power System Protection,. McGraw-Hill, 1999
11. Singh L.P ,*Digital Protection, Protective Relaying from Electromechanical to Microprocessor*, John Wiley & Sons, 1994
12. Wright, A. and Christopoulos, C*, Electrical Power System Protection*, Chapman & Hall, 1993,
13. Walter A. Elmore, J. L. Blackburn, *Protective Relaying Theory and Applications*, ABB T&D Co. Marcel Dekker, Inc. 2004
14. Arun G. Phadke, James S. Thorp, *Computer Relaying for Power Systems*, Marcel Dekker, Inc 2009
15. P M Anderson, *Power System Protection*, IEE Press, 2012
16. Edward Wilson Kimbark, *Power System Stability, Volume II: Power Circuit Breakers and Protective Relays,* Wiley-IEEE Press, March 1995.
17. IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book, IEEE Standard 242-198.

EE6426D DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the architecture, functions and implementation strategies of Distribution Automation Systems and Distribution Management Systems.

CO2: Apply Custom power devices for improving power quality and explain the issues related to the integration of Distributed Generation and Custom Power components in a distribution system.

CO3: Evaluate the performance of electrical distribution system on the basis of reliability indices calculation.

CO4: Perform electrical distribution system design for industrial and commercial buildings with emphasis given to Electrical Safety and Earthing Practices.

CO5: Describe the wireless and wired communication systems, communication protocols and architectures for control and automation of Distribution system.

Module 1: (10 hours)

Distribution Automation System: Necessity, System Control Hierarchy- Basic Architecture and implementation Strategies for DA- Basic Distribution Management System Functions- Outage management-

Integration of Distributed Generation and Custom Power components in distribution systems- Distribution system Performance and reliability calculations

Module 2: (9 hours)

Electrical System Design: Distribution System Design- Electrical Design Aspects of Industrial, Commercials Buildings- Electrical Safety and Earthing Practices at various voltage levels- IS Codes

Module 3: (11 hours)

Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface-Case Studies

Module 4: (9 hours)

Power Quality and Custom Power: Concept- Custom Power Devices - Operation and Applications

Deregulated Systems: Reconfiguring Power systems- Unbundling of Electric Utilities- Competition and Direct access

References:

1. James Northcote – Green, Robert Wilson, *Control and Automation of Electrical Power Distribution Systems*, CRC Press, New York, 2007.
2. Turan Gonen, *Electric Power Distribution System Engineering,* McGraw Hill Company. 1986
3. M.V Deshpande, *Electrical Power System Design,* Tata-McGraw Hill, 1966
4. IEEE Press, *IEEE Recommended practice for Electric Power Distribution for Industrial Plants*, published by IEEE, Inc., 1993
5. Pansini, *Electrical Distribution Engineering*, The Fairmont Press, Inc., 2007
6. IEEE Standerd 739, *Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilitie,* 1984

7. G H Heydt, *Electric Power Quality,* McGram Hill, 2007
8. Wilson K. Kazibwe and Musoke H Semdaula *Electric Power Quality Control Techniques,* Van Nostarand Reinhold New York, 2006
9. Lakervi & E J Holmes, *Electricity distribution network design,* 2nd ed., Peter Peregrimus Ltd. 1995

EE6292D REAL TIME SIMULATION LAB

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:
CO1: Apply real time simulation tools in power system analysis.
CO2: Analyze simulation results and do effective documentation.
CO3: Develop real time solutions for power utility problems.

List of experiments

1. Familiarization of Real Time Simulator - Modelling , Control and Data Acquisition
2. Design and testing of PLL for Grid interconnection of microgrid.
3. Determination of I-V characteristics of different configurations of pv cells using solar simulator
4. Performance analysis of a three-phase induction machine as an induction generator in the grid connected and self-excited modes
5. Performance analysis of a three-phase synchronous machine in the isolated and grid connected modes of operation.
6. Experiments on SCADA systems
   a) SCADA- Transmission Module RTU in Local and Remote Mode.
      i. Ferranti Effect
      ii. VAR Compensation (Series and Shunt)
      iii. Transmission Line Modelling
   b) SCADA- Distribution Module RTU in Local and Remote Mode.
      i. Load Shedding
      ii. Transformer Loading
      iii. Study of Communication Link
7. High voltage lab
   a) Study of cable insulation testing
   b) Study of impulse generator
8. Study of ac network analyzer
9. DSpace based experiments
   a) Implementation of speed control of DC motor / induction motor
   b) Maximum power point tracking (MPPT) for a photovoltaic (PV) module
   c) Performance analysis of electric vehicle
10. STATCOM and FACTS based Experiments.
    a) Reactive Power Compensation using solar and wind based STATCOM.
    b) Power Factor Compensation and Voltage Regulation using three phase FACTS controller

References:

1. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
2. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed., John Wiley & Sons, 2008.
3. Francisco M. Gonzalez-Longatt, José Luis Rueda , *Power Factory Applications for Power system Analysis*, Springer,2014
4. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
5. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
6. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.
7. P. Kundur, *Power System Stability and Control,* McGraw Hill Education Pvt Ltd, 2006.

8. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
9. M. A. Pai, Dheeman Chatterjee, *Computer Techniques in Power System Analysis*, McGraw Hill Education (India) Pvt Ltd., 2014.

EE6221D POWER QUALITY ISSUES AND REMEDIAL MEASURES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain various power quality issues, remedial measures and standards.
CO2: Develop models and analyse harmonics in networks and components
CO3: Design active power factor correction based on static VAR compensators and its control techniques
CO4: Analyze series and shunt active power filtering techniques for harmonic cancellation and isolation
CO5: Explain voltage quality improvement techniques and NEC grounding requirements and solutions to grounding and wiring problems

Module 1: (8 hours)

Introduction-power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-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

Module 2: (10 hours)

Harmonics-individual and total harmonic distortion-RMS value of a harmonic waveform-triplex harmonics-important harmonic introducing devices-SMPS-Three phase power converters-arcing devices saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipments and loads. Modeling of networks and components under non-sinusoidal conditions transmission and distribution systems-shunt capacitors-transformers-electric machines-ground systems-loads that cause power quality problems-power quality problems created by drives and its impact on drives.

Module 3: (11 hours)

Power factor improvement- Passive Compensation- Passive Filtering- Harmonic Resonance- Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End Converters, Control Methods for Single Phase APFC- Three Phase APFC and Control Techniques- PFC Based on boost conversion technique and Bilateral Single Phase and Three Phase Converters. Static VAR compensators- SVC and STATCOM.

Module 4: (10 hours)

Active Harmonic Filtering-Shunt Injection Filter for single phase, three-phase three-wire and three-phase four-wire systems. d-q domain control of three phase shunt active filters- series active power filtering techniques for harmonic cancellation and isolation. Uninterruptible Power Supplies- Constant Voltage Transformers - Dynamic Voltage Restorers for sag , swell and flicker problems. Grounding and wiring - introduction - NEC grounding requirements- reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.

References:

1. G.T. Heydt, *Electric power quality*, McGraw-Hill Professional, 2007.
2. Math H. Bollen, *Understanding Power Quality Problems*, IEEE Press, 2000.
3. J. Arrillaga, *Power System Quality Assessment*, John wiley, 2000.
4. J. Arrillaga, B.C. Smith, N.R. Watson & A. R.Wood, *Power system Harmonic Analysis*, Wiley, 1997.

5. E Fuchs, M.A.S. Masoum, *Power Quality in Power Systems and Electrical Machines*, Elsevier Inc., 2008.
A. Moreno, *Power Quality-Mitigation Technologies in a disturbed environment*, Springer, 2007.
6. W.E.Kazibwe, M.H.Sendaula, *Electric Power Quality Control Techniques*, Van Nostrand Reinhold, 1993.
7. IEEE Transaction and IET Journal papers

EE6222D WIDE AREA MONITORING & CONTROL OF POWER SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain Synchrophasor Measurement Techniques
CO2: Implement and test wide area measurement systems
CO3: Realize optimal placement of PMU and state estimation using PMU data
CO4: Monitor, analyse and control power system conditions in real time

Module 1: (11 hours)

Phasor Measurement Techniques: Basic Concepts and Definitions SCADA vs PMU, Synchrophasors, Frequency, and ROCOF, Steady-State and Dynamic Conditions in Power Systems, Classical Phasor Versus Dynamic Phasor, Basic Definitions of Accuracy Indexes, Algorithms for Synchrophasors, Frequency, and ROCOF, Methods to Calculate Synchrophasors based on a Steady-State Model and Dynamic Signal Model, Evaluation of Frequency and ROCOF, Dynamic Behavior of Phasor Measurement Algorithms

Module 2: Phasor Measurement Units and Phasor Data Concentrators (10 hours)

Phasor measurement units and Phasor data concentrators: WAMS architecture, Sensors for PMUs, International Standards for Instrument Transformers, Accuracy of Instrument Transformers, Transducer Impact on PMU Accuracy, Hardware for PMU and PMU Integration, PMU Architecture, Data Acquisition System, Synchronization Sources, Communication and Data Collector, Distributed PMU, International Standards for PMU and Tests for Compliance, IEC 61850

Module 3: (10 hours)

State Estimation and PMUs: Formulation of the SE Problem, Network Observability-SE Measurement Model, SE Classification, State estimation with phasor measurents, Linear state estimation, Dynamic estimators.
Optimal PMU placement, meta-heuristic and deterministic algorithms, Integer Linear Programming Technique

Module 4: (10 hours)

WAMS applications- real-time analysis and technologies to detect, locate and characterize power system disturbances, monitoring power system oscillatory dynamics- Interpretation and visualization of wide-area PMU measurements, power system control with phasor feedback, discrete event control.

References:

1. Antonello Monti, Carlo Muscas, Ferdinanda Ponci, *Phasor Measurement Units and Wide Area Monitoring Systems*, Academic Press, 2016
2. A.G. Phadke, J.S. Thorp, *Synchronized Phasor Measurement and Their Applications*, Springer 2008
3. Yong Li, Dechang Yang, Fang Liu, Yijia Cao, Christian Rehtanz, *Interconnected Power Systems: Wide-Area Dynamic Monitoring and Control Applications*, Springer, 2015
4. Ali Abur, Antonio Gómez Expósito, *Power System State Estimation: Theory and Implementation*, CRC Press, 2004

5. Ma J., Makarov Y., Dong Z, *Phasor Measurement Unit and its Applications on Modern Power Systems*, Springer, 2010
6. IEEE Power & Energy Society, *IEEE Standard for Synchrophasor Data Transfer for Power Systems*, IEEE New York, 2011
7. Xu B, Abur A, *Optimal Placement of Phasor Measurement units for State Estimation*, PSERC, Final Project Report, 2005
8. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed., John Wiley & Sons, 2008
9. P. Kundur, *Power System Stability and Control,* McGraw Hill, New York, 1994.

EE6223D POWER SYSTEM PLANNING AND RELIABILITY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain basic reliability concepts and reliability measures.
CO2: Develop analytical models for power system reliability analysis.
CO3: Implement and use algorithms for power system reliability analysis
CO4: Design and build reliable power system.

Module 1: (9 hours)

System Planning: Objectives of system planning: Long term and short term planning-stages in planning – Policy studies -Planning standardization studies- System and Network Reinforcement studies
Load forecasting: Classification of loads-Forecast methodology- Energy forecasting-Non weather sensitive forecast-Weather sensitive forecast- Total forecast-Annual and monthly peak load forecasting

Module 2: (7 hours)

Generator System Models- State Load Model- Probability Methods- Unit Unavailability- Outage Probability. Generating Capacity Limits- Recursive Techniques- Capacity Expansion Analysis - Scheduled Outages - Reliability Indices

Module 3: (11 hours)

Reliability analysis of isolated and Interconnected Systems - Two Systems with Tie- Probability Array Methods- Reliability Indices- Variable Reserve and Maximum Peak Load Reserve- Multi Connected Systems. Distribution System- Interruption Indices- System Performance- risk prediction- Radial Systems-Effect of Load Transfer- Line Failures- Parallel and Mesh Networks- Industrial Systems.
Capacity state classification- Average –Interruption rate method – LOLP method

Module 4: (12 hours)

Introduction to system modes of failure – the loss of load approach – frequency & duration approach – spare value assessment – multiple bridge equivalents
Generation system cost analysis-Production costing –Fuel inventories-Energy transaction and off-peak loading
Transmission system Expansion Planning: Tellegen's theorem-Network sensitivity. Network Decision-Problem formulator solution using DC load flow. An overview of distribution system planning

References:

1. Sullivan, R.L., *Power System Planning*, Heber Hill, 1987.
2. Roy Billington, *Power System Reliability Evaluation*, Gordan& Breach Scain Publishers, 1990.
3. Endrenyi, J., *Reliability modelling in Electric Power System*, John Wiley, 1980.
4. Dong, Z., Zhang, P. Ma, J., Zhao, J., Ali, Meng, K., Yin, *Emerging Techniques in Power System Analysis*, Springer, 1st edition 2010.
5. S.C. Savulescu, *Real-Time Stability assessment in modern power system control centres*, John Wiley & Sons, January 2009
6. Bo Bergman, Jacques de Mare, Thomas Svensson, Sara Loren, *Robust Design methodology for reliability*, John Wiley & Sons, October 2009

7. Ali A. Chowdhury, Don O. Koval, *Power distribution system reliability-Practical methods and applications*, John Wiley & sons Inc., IEEE Press 2009
8. Richard E.Brown, *Electric power distribution reliability*, Taylor & Francis Group LLC, 2009.
9. Elmakias, David (Ed.) *New Computational Methods in Power System Reliability*, Studies in Computational Intelligence, Springer 2008
10. Turen Gonen, *Electric power distribution system engineering*, McGraw Hill New York, 1986

EE6224D DISTRIBUTED PROCESSING OF POWER SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain functions of Distributed Energy Management Systems and Advantages of Distributed Processing

CO2: Design of Parallel and Distributed processing algorithms for vertically Integrated Power Systems and Restructured Power Systems

CO3: Apply parallel and distributed processing algorithms for load Flow analysis, state estimation and security assessment for power Systems

CO4: Design and implement distributed Control of Voltage and reactive Power and explain Transmission Congestion Management

Module 1: (9 hours)

Distributed Energy Management Systems: Functional Requirements of EMS - Complexity of Power Grid- Necessity for Distributed Processing - Vertically Integrated Power Systems-Central control center and Area control center - SCADA - Distributed EMS- Restructured Power Systems- Advantages of Distributed Processing.

Module 2: (9 hours)

Parallel and Distributed Processing of Power systems: Parallel Systems- Distributed Systems- Comparison- Design of Parallel and Distributed algorithms- Distributed Processing of vertically Integrated Power Systems and Restructured Power Systems- Computer networks for Distributed Processing- Data Communication – Message Passing Interface

Module 3: (10 hours)

Parallel and distributed Load Flow: Mathematical Model- Parallel load flow Computation- Distributed load flow computation- System Partitioning and Algorithms- Parallel and distributed Load Flow for Distribution Systems-case studies and simulation results.
Parallel and distributed State Estimation: Components of State Estimation- Mathematical Model- Parallel State Estimation- Distributed State Estimation

Module 4: (11 hours)

Distributed Power System Security Analysis: Power System Security Analysis- - Distributed Contingency Selection, Distributed Static Security Analysis- Distributed Dynamic Security Analysis.
Distributed Control of Voltage and reactive Power- Decentralised closed loop primary control, distributed secondary voltage/VAR control, Reactive Power Bidding, Centralized Tertiary voltage / VAR optimization.
Transmission Congestion Management: Agent Based modeling – Multi Agent based Scheme for Congestion Management and Congestion mitigation.

References:

1. Mohammed Shahidehpour and Yauyu Wang, *Communication and Control in Electric Power Systems*, John Wiley & Sons, 2005
2. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
3. Dimitri Bertsekas, John N. Tsitsiklis, *Parallel and Distributed Computation: Numerical Methods*, Prentice Hall Inc., 1989

4. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems*. Wiley, New York, 1983.
5. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation and Control*, John Wiley & Sons, New York, 1984.
6. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003
7. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
8. Mohammad Shahidehpour, M. Alomoush, *Restructured Electrical Power Systems: Operation: Trading, and Volatility*, CRC Press, 2001
9. George L. Kusic, *Computer Aided Power System Analysis,* Prentice Hall of India (P) Ltd., New Delhi, 1989.
10. Ali Abur, Antonio Gómez Expósito, *Power System State Estimation: Theory and Implementation*, CRC Press, 2004

EE6226D HYBRID AND ELECTRIC VEHICLES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain performance characteristic and model dynamics of hybrid and electric vehicles
CO2: Analyse the architecture of drive trains and electric propulsion units of electric and hybrid vehicles
CO3: Analyse various energy storage devices used in hybrid and electric vehicles and select the electric drive system
CO4: Explore energy management strategies used in hybrid and electric vehicles

Module 1: (9 hours)

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies - Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.

Module 2: (10 hours)

Hybrid and Electric Drive-trains: Basic concept of traction, introduction to various drive-train topologies, power flow control in drive-train topologies, fuel efficiency analysis.

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Module 3: (10 hours)

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Analysis of various energy storage devices – Battery, Fuel Cell, Super, Flywheel - Hybridization of different energy storage devices.

Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor and power electronics, selecting the energy storage technology, Communications, supporting subsystems

Module 4: (10 hours)

Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification, comparison and implementation issues of energy management strategies.

Case Studies: Design of a Hybrid Electric Vehicle (HEV) and Battery Electric Vehicle (BEV).

References:

1. I. Husain, *Electric and Hybrid Electric Vehicles*, CRC Press, 2003
2. M. Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2005
3. A. E. Fuhs, *Hybrid Vehicles and the Future of Personal Transportation*, CRC Press, 2009

4. C. C. Chan and K. T. Chau, *Modern Electric Vehicle Technology, Oxford Science Publication*, 2001
5. G. Lechner and H. Naunheimer, *Automotive Transmissions: Fundamentals, Selection, Design and Application*, Springer, 1999
6. Gianfranco, *Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure And The Market*, Pistoia Consultant, Rome, Italy, 2010
7. M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, 3rd ed., Pearson, 2004
8. V. R. Moorthi, *Power Electronics: Devices, Circuits and Industrial Applications*, Oxford University Press, 2007
9. R. Krishnan, *Electric motor drives: modeling, analysis, and control*, Prentice Hall, 2001
10. P. C. Krause, O. Wasynczuk, S. D. Sudhoff, *Analysis of electric machinery*, IEEE Press, 1995
11. L. Guzella, A. Sciarretta, *Vehicle Propulsion Systems*, Springer, 2007

EE7291D PROJECT – PART 1

Pre-requisites: Nil

L	T	P	C
0	0	20	10

Total hours: 260

Course Outcomes:

CO1: Pursue their interest in power systems through design, research, theoretical and experimental approach.

CO2: Identify a topic of interest and demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.

CO3: Gain the expertise to use new tools and techniques for development of cost-effective and environment friendly designs.

CO4: Effectively communicate by making an oral presentation of the progress of work before an evaluation committee, develop the ability to write good technical report and to publish the work in reputed conferences/journals.

Main Project will be done by the individual students normally in two semesters. Students are exposed to various topics in power systems and allied areas and the recent developments through the class seminars so as to inculcate interest in these topics. Faculty members propose projects /broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. Student can also select the topic for the interdisciplinary project too after discussions with guide. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as external guide and with internal guide from Department.

Students are required to undertake detailed technical work in the chosen area using one or more of the following: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The assessment of the project will be done at the end of the semester by a committee consisting of three or four faculty members specialized in various fields of Electrical Engineering. The students will present their project work before the committee. The complete project report is not expected at the end this semester. However, a 30-40 page typed report based on the work done will have to be submitted by the students to the assessing committee. The Department level evaluation shall have 50% weight in the final grading- 50% weight will be given to the assessment by the individual guide. Marks will be reported based on 100 as maximum. Result shall be finalized at the Department level.

EE7292D PROJECT – PART 2

Pre-requisites: EE7291D PROJECT – PART 1

L	T	P	C
0	0	28	14

Total hours: 364

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in previous semester work and to meet the requirements as stated in project proposal.

CO2: Attain the results of the detailed analytical studies conducted, lay down validity and design criteria, and interpret the results for application to the power system problems.

CO3: Report the concept and detailed design solution and to effectively communicate the research contributions and publish in reputed journals/conference.

EE7292D PROJECT – PART 2 is a continuation of EE7291D PROJECT – PART 1 in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals. The project evaluation committee of the M. Tech programme shall assess the project work during the fourth semester in two stages. Two internal evaluations shall be conducted in the department level followed by final viva-voce examination by the committee including an external examiner. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the project evaluation committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the project evaluation committee.

EE6101D SYSTEMS THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Integrate the concepts of linear algebra to be applied in systems theory
CO2: Explain the various tools used for the analysis of both LTI and LTV systems
CO3: Apply various techniques for the analysis of system stability
CO4: Analyze and categorize systems with respect to various properties

Module 1: (8 hours)

Basics of linear algebra - Vector spaces, dimension, basis, subspaces, dual spaces, annihilators, direct sum, linear transformations, matrix representations, similarity, rank and nullity.

Module 2: (9 hours)

Linear Systems –State space models, explicit solutions to linear differential equations, solution to LTI and LTV systems, Solutions to homogeneous and non homogeneous cases, Computation of matrix exponentials using Laplace transforms and Jordan Normal form, positive definite matrices, quadratic forms.

Module 3: (10 hours)

Minimal realizations and co-prime fractions, canonical lforms,Markovparameters,Hankelmatrices
Stability - Internal or Lyapunov stability, Lyapunov stability theorem, Eigen value conditions for Lyapunov stability,Input -Output stability: BIBOstability, Time domain conditions for BIBO stability. Frequency domain conditions for BIBOstability. BIBO versus Lyapunov stability

Module 4: (12 hours)

Controllability and Observability - Controllable and reachable subspaces, Physical examples and system interconnections, Reachability and controllability Gramians, Controllabilty matrix(LTI), Eigen vector test for controllability, Lyapunov test for controllability, Controllable decomposition and block diagram interpretation, Stabilizable system, Eigen vector test for stabilizability, Popov-Belevitch_Hautus (PBH) Test for stabilizability, Lyapunov test for stabilizability. Feedback stabilization based on Lyapunov test, Unobservable and unconstructable subspaces, Physical examples, observability and Constructability Gramians, Gramian based reconstruction, Duality (LTI), Observable decompositions, Kalman decomposition theorem, Detectability, detectability tests, State estimation, Eigen value assignment by output injection, Stabilization through output feedback

References:

1. Chi-Tsong Chen, *‘Linear System Theory and Design’,* Oxford University Press,1984
2. John S. Bay, *‘Fundamentals of Linear State Space Systems’,* Mc-Graw Hill, 1999
3. Thomas Kailath, *‘Linear System’,* Prentice Hall, 1990
4. Gillette, *‘Computer Oriented Operation Research’*, Mc-Graw Hill Publications.
5. K. Hoffman and R. Kunze, *‘Linear Algebra’*, Prentice-Hall (India), 1986.
6. F.M. Callier and C.A. Desoer, *‘Linear System Theory’*, Springer Verlag, 1991
7. P. Halmos, *‘Finite Dimensional Vector Spaces’*, Springer, 1984

EE6102D OPTIMAL AND ROBUST CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the various concepts in the mathematical area of 'calculus of variation' for solving optimal control problems.

CO2: Develop methods of problem formulation pertaining to optimal control and design of optimal controllers

CO3: Analyse robustness of systems and develop skills useful in controlling systems when accurate mathematical models are unavailable

CO4: Design and synthesis robust controllers for practical systems

Module 1: (10 hours)

Calculus of variations: Examples of variational problems, Basic calculus of variations problem, Weak and strong extrema, Variable end point problems, Hamiltonian formalism and mechanics: Hamilton's canonical equations.
From Calculus of variations to Optimal control :Necessary conditions for strong extrema, Calculus of variations versus optimal control, optimal control problem formulation and assumptions, Variational approach to the fixed time, free end point problem.
The Pontryagin's Minimum principle: Statement of Minimum principle for basic fixed endpoint and variable end point control problems, Proof of the minimum principle, Properties of the Hamiltonian, Time optimal control problems. Minimum energy problems.

Module 2: (10 hours)

Linear Quadratic Regulator: Finite horizon LQR problem-Candidate optimal feedback law, Ricatti differential equations (RDE), Global existence of solution for the RDE. Infinite horizon LQR problem-Existence and properties of the limit, solution, closed loop stability.LQR using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations .Numerical solution of Riccatti Equations-Linear Quadratic tracking control: Tracking a reference input with compensators of known structure, Tracking by regulator redesign, Command generator tracker, Explicit model following design. Linear Quadratic Guassian controller (LQG) and Kalman-Bucy Filter: LQG control equations, estimator in feedback loop, steady state filter gain, constraints and minimizing control, state estimation using Kalman-Bucy Filter, constraints and optimal control.

Module 3: (10 hours)

Robust Control - Control system representations, System stabilities, Co-prime factorization and stabilizing controllers, Signals and system norms, Modelling of uncertain systems - Unstructured Uncertainties-Additive, multiplicative and other forms. Parametric uncertainty, Interval Systems, Structured uncertainties, Linear fractional transformation Robust design specifications: Small gain theorem and robust stabilization, Performance considerations, Structured singular values. Design - Mixed sensitivity optimization, 2-Degree of freedom design, Sub-optimal solutions, H_2 /H_∞ Systems.

Module 4: (9 hours)

Loop-shaping design procedures: Robust stabilization against Normalized co-prime factor perturbation, Loop shaping design procedures, μ - Analysis and Synthesis - Consideration of robust performance, μ-

synthesis: D – K iteration method, Schur Compliment & Linear Matrix Inequalities: Some standard LMI problems – eigen - value problems, generalized eigen - value problems; Algorithms to solve LMI problems – Ellipsoid algorithm, interior point methods.

References:

1. D. - W.Gu, P. Hr.Petkov and M.M.Konstantinov, *Robust Control Design with MATLAB*, Springer, 2005.
2. Alok Sinha, *Linear Systems-Optimal and Robust Controls*, CRC Press, 2007.
3. S. Skogestad and Ian Postlethwaite, *Multivariable feedback control*, John Wiley & Sons, Ltd, 2005.
4. G.E. Dullerud, F. Paganini, *A course in Robust control theory-A convex approach*, Springer, 2000.
5. Kemin Zhou with J.C. Doyle and K. Glover, *Robust and Optimal control*, Prentice Hall, 1996.
6. Kemin Zhou, John Comstock Doyle, Keith Glover, *Robust and optimal control*, PrenticeHall, 1996.
7. Kemin Zhou, John Comstock Doyle, *Essentials of robust control*, Prentice Hall, 1998.
8. Stephen Boyd, Laurent El Ghaoul, Eric Feron, *Linear Matrix Inequalities in System and Control Theory*, SIAM, 1994.

EE6103D MEASUREMENTS AND INSTRUMENTATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Recognize about general units errors and significant digits in measurements.
CO2: Discuss about analog instruments and null balance methods for measurements.
CO3: To various digital measurement techniques.
CO4: Outline the applications of Data Acquisition Systems and virtual instrumentation.

Module 1: Units, Significant Digits and Errors in Measurements (8 Hours)

C.G.S electrostatic and electromagnetic systems of units- Practical and legal units and their relationship to the absolute units- Dimensions of electrical quantities- The M.K.S. system of units- International and absolute units and standards, significant digits.
Measurement and Error-Accuracy and precision- Types of errors- Systematic and random errors, propagation of errors.

Module 2: Analog Instruments and Null Balance Methods for Measurements (13 hours)

Analog Indicating instruments- Moving iron instruments- Moving coil instruments- Permanent magnet and dynamometer type instruments- electrostatic instruments- thermal instruments- induction instruments- rectifier instruments
Null balance methods of measurement-potentiometer Principles-Bridge configuration-AC Bridges- Classification of AC bridge circuits- DC bridge analysis- Extension of instrument range-current transformer theory- voltage transformers.

Module 3: Digital Measurement Techniques (11 hours)

Digital Measurement techniques - counters and timers. Time measurement- phase measurement- capacitance measurement- frequency measurement- ratio of two frequencies- high frequency- low frequency- peak frequency-Voltage measurement using digital techniques- ADC's Digital Multimeter.
Graphical measurement techniques- CRO-DSO

Module 4: Data Acquisition Systems and Virtual Instrumentation (7 hours)

Analog and digital data acquisition systems-Virtual instrumentation- concepts- virtual versus real instrumentation - physical quantities and analog interfaces, hardware and software- user interfaces- applications of virtual instrumentation.

References:

1. A.D. Helfrick, W.D. Cooper, *Modern Electronic Instrumentation and Measurement Techniques*, Prentice-Hall of India pvt ltd, 1994.
2. Golding and Widdis, *Electrical measurements and measuring instruments*, Reem publications, Newdelhi, 5th Edn, 2009
3. Ernest Frank, *Electrical measurement analysis*, Tata McGraw-hill publishing company ltd, Bombay,1959
4. G.W. Johnson, *LabVIEW graphical programming practical application in Instrumentation and Control*, McGraw Hill, New York, 1997.

EE6105D DIGITAL CONTROL: THEORY AND DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Develop mathematical models of Digital Control Systems
CO2: Design and analyse digital control systems using classical techniques
CO3: Design and analyse SISO and MIMO digital control systems in the state space domain
CO4: Apply various techniques for the stability analysis of nonlinear digital control systems

Module 1: Introduction to Digital Control (9 hours)

Introduction -Discrete time system representation –Sample & Hold-Mathematical modeling of sampling process – Data reconstruction-Design of the hardware and software architecture - Software requirements-Selection of ADC and DAC- Choice of the sampling period –Prefilter/Antialiasing filters -Effects of quantization errors - Phase delay introduced by the ZOH-Sampling period switching- Dual-rate control
Modeling discrete-time systems by pulse transfer function -Revisiting Z-transform -Mapping of s-plane to z-plane -Pulse transfer function - Pulse transfer function of closed loop system - Sampled signal flow graph - Stability analysis of discrete time systems -Jury stability test - Stability analysis using bi-linear transformation

Module 2: Design of Sampled Data Control Systems (10 hours)

Design of PID controller-Filtering the derivative action- Integrator windup- Bumpless transfer between manual and automatic mode - Incremental form-Root locus method - Controller design using root locus - Root locus based controller design using MATLAB - Nyquist stability criteria - Bode plot - Lead compensator design using Bode plot - Lag compensator design using Bode plot - Lag-lead compensator design in frequency domain-Deadbeat response design -Design of digital control systems with deadbeat response - Practical issues with deadbeat response design - Sampled data control systems with deadbeat response

Module 3: Discrete State Space Model and State Feedback Design (9 hours)

Introduction to state variable model for SISO systems- Various canonical forms - Characteristic equation, state transition matrix - Solution to discrete state equation-Controllability, observability and stability of discrete state space models -Controllability and observability - Stability
Pole placement by state feedback - Set point tracking controller - Full order observer - Reduced order observer-Servo Design- State feedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers -Output feedback design - Output feedback design: Theory - Output feedback design:Examples. Introduction to Multivariable & Multi-input Multi-output (MIMO) Digital Control Systems

Module 4: Nonlinear Digital Control Systems (11 hours)

Discretization of nonlinear systems - Extended linearization by input redefinition - - input and state redefinition - output differentiation - Extended linearization using matching conditions - Nonlinear difference equations - Logarithmic transformation- Equilibrium of nonlinear discrete-time systems - Lyapunov stability theory- Lyapunov functions - Stability theorems -Rate of convergence - Lyapunov stability of linear systems - Lyapunov's linearization method- Instability theorems - Estimation of the domain of attraction - Stability of analog systems with digital control-Hybrid Systems - State plane analysis - Discrete-time nonlinear controller design- Controller design using extended linearization- Controller design based on Lyapunov stability theory - Input-output stability and the small gain theorem- Absolute stability

References:

1. *B.C Kuo , Digital Control Systems (second Edition),Oxford University Press, Inc.,* New York, 1992
2. G.F. Franklin, J.D. Powell, and M.L. Workman*, Digital control of Dynamic Systems,* Addison-Wesley Longman, Inc., Menlo Park, CA , 1998.
3. M. Gopal, *Digital Control and State Variable Methods, 3rd ed.,* Tata McGraw Hill Publishing Company, 2009.
4. John F. Walkerly*, Microcomputer architecture and Programs, John Wiley and Sons Inc.,* New York, 1981.
5. K. Ogata, *Discrete Time Control Systems,* Addison-Wesley Longman Pte. Ltd., Indian Branch ,Delhi, 1995.
6. C. H. Houpis and G.B. Lamont*, Digital Control Systems,* McGraw Hill Book Company, 1985.
7. C.L.Philips and H.T Nagle,Jr., *Digital Control System Analysis and Design,* Prentice Hall, Inc., Englewood Cliffs,N.J.,1984
8. M. Sami Fadali Antonio Visioli*, Digital Control Engineering Analysis and Design*, 2nd ed., Academic Press,225 Wyman Street, Waltham, MA 02451, USA.

EE6108D NONLINEAR SYSTEMS AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse nonlinear systems using classical techniques
CO2: Analyse stability of non linear systems using advanced techniques
CO3: Analyse nonlinear feedback systems using time and frequency domain techniques
CO4: Design controllers for nonlinear systems using advanced methods

Module 1: Introduction and Classical Techniques (10 hours)

Characteristics of nonlinear systems – examples of systems exhibiting nonlinear phenomena- second order nonlinear autonomous systems- vector field representation- classification of equilibrium points – qualitative behavior near equilibrium points- limit cycles – existence of periodic orbits- Poincare-Bendixon criterion- Poincare index of equilibrium points- stability of periodic solutions- analysis of systems with piecewise constant inputs using phase plane analysis-Jump response.

Module 2: Lyapunov Stabilty (10 hours)

Existence and uniqueness of solutions of nonlinear state equations- stability of nonlinear systems - Lyapunov stability - local linearization and stability in the small – Centre manifold theorem- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems- Variable gradient method- La Salle's Invariance theorem – Input to state stability - L stability - L stability of state models-Small gain theorem- Passivity- Positive real transfer functions-L_2 and Lyapunov stability-Passivity theorems- Loop transformation.

Module 3: Time Domain Analysis of Feedback Systems and Perturbation Techniques (7 hours)

Absolute stability of feedback interconnections of a linear part and nonlinear part- Circle criterion- Popov criterion- Frequency theorem- Harmonic linearization- filter hypothesis- Describing function of standard nonlinearities- amplitude and frequency of limit cycle using SIDF. Pertubation techniques- Regular perturbation- Singular perturbation-Reduced model- boundary- layer model- Tikhonov's theorem- slow and fast manifolds.

Module 4: Nonlinear System Design Tools (12 hours)

Control problems- stabilization via linearization - integral control via linearization- Gain scheduling- Feedback linearization-stabilization and tracking via state feedback control. Sliding mode control- Regulation via integral control- Lyapunov redesign- stabilization and nonlinear damping-Backstepping- Passivity based control- High gain observers. Linear Quadratic Regulators / Linear Quadratic Guassian Regulators - Numerical Solution for Riccatti Equations.

References:

1. Hassan K Khalil, *'Nonlinear Systems'*, Prentice - Hall International (UK) 1996
2. Slotine& W.LI, *'Applied Nonlinear Control'*, Prentice Hall, EngelwoodNewJersey 1991
3. AIsidori, *'Nonlinear Control systems'* Springer verlag New york 1995
4. S. Wiggins, *'Introduction to Applied Nonlinear Dynamical Systems and chaos'*, Springer Verlag New York 1990

5. H. Nijmeijer& A.J. Van Der schaft, *'Nonlinear Dynamic control Systems'*, Springer Verlag Berlin 1990.
6. Arther E Gelb & Vender Velde, *'Multiple input Describing function and Nonlinear System Design'*, MC Graw Hill 1968
7. Z Vukic, L Kuljaca, *'Nonlinear Control Systems',* Marcel Dekker, Inc., Newyork.

EE6121D DATA ACQUISITION AND SIGNAL CONDITIONING

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain characteristics of transducers and various signal conditioning techniques.
CO2: Design filters for signal conditioning.
CO3: Explain signal conversion (analog to digital and digital to analog) as well as transmission techniques
CO4: Describe various interfacing techniques and standards for communication between instruments.

Module 1: Transducers & Signal Conditioning (10 hours)

Data Acquisition Systems (DAS)- Introduction . Objectives of DAS. Block Diagram Description of DAS-General configurations - Single and multichannel DAS-Transducers for the measurement of motion, force, pressure, flow, level, dc and ac voltages and currents (CTs, PTs for supply frequency as well as high frequency, Hall Effect Current Sensors, High Voltage Sensors , Opto-sensors, Rogowski Coil, Ampflex Sensors etc.) - Signal Conditioning: Requirements - Instrumentation amplifiers: Basic characteristics . Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Transmitters .Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters.

Module 2: Filtering and Sampling (10 hours)

Review of Nyquist.s Sampling Theorem- Aliasing. Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band-rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters. Op-amp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers

Module 3: Signal Conversion and Transmission (10 hours)

Analog-to-Digital Converters(ADC) -Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion . Conversion Processes , Speed, Quantization Errors . Successive Approximation ADC . Dual Slope ADC . Flash ADC . Digital-to-Analog Conversion (DAC) . Techniques, Speed, Conversion Errors, Post Filtering-Weighted Resistor, R-2R, Weighted Current type of DACs- Multiplying Type DAC-Bipolar DACs- Data transmission systems-Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

Module 4: Digital Signal Transmission And Interfacing (9 hours)

DAS Boards- Introduction. Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-232C-USB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interrupt-based Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling. Circular Queues

References:

1. Ernest O Doeblin., *'Measurement Systems: Application and Design',* McGraw Hill (Int. edition) 1990
2. George C.Barney, *'Intelligent Instrumentation'*, Prentice Hall of India Pvt Ltd., New Delhi, 1988.

3. Ibrahim, K.E., *'Instruments and Automatic Test Equipment*', Longman Scientific & Technical Group Ltd., UK, 1988.
4. John Uffrenbeck, *'The 80x86 Family ,Design, Programming, And Interfacing*', Pearson Education , Asia, 2002
5. Bates Paul, *'Practical digital and Data Communications with LSI*', Prentice Hall of India, 1987.
6. G.B. Clayton, *'Operational Amplifiers*', Butterworth &Co, 1992
7. A.K Ray, *'Advanced Microprocessors and Peripherals*', Tata McGrawHill, 1991
8. Oliver Cage, *'Electronic Measurements and Instrumentation'.*, McGraw-Hill, (Int. edition) 1975

EE6125D ADAPTIVE CONTROL THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Integrate the concepts of norms and spaces to be applied in adaptive control theory
CO2: Apply identification techniques for design of adaptive controller
CO3: Explain direct and indirect adaptive control techniques
CO4: Describe advanced adaptive control methods along with case studies and computer simulations

Module 1: Preliminaries (10 hours)

Norms and Lp spaces-positive definite matrices-input –output stability-Lp stability-small gain theorem-Positive real functions and stability-Analysis of Dynamical Systems ,Analysis of Solutions to Differential Equations., Equilibria and Stability. Invariant Sets. Lyapunov Stability Theory and Performance Analysis., Nonautonomous Systems., LaSalle Extensions, Barbalat Lemma. Basic approaches to adaptive control - Applications of adaptive control. Introduction to types of Adaptive Control-Model Reference-Variable Structure-Sliding Mode- Neuro-Fuzzy-Learning Control-Intelligent Control using schematic diagrams and literature survey.

Module 2: Identification (10 hours)

Identification problem- Identification of linear time-invariant systems. Adaptive observers. Sufficient richness condition for parameter convergence. Equation error and output error methods Gradient *and* least-squares algorithms: Linear error equation. Gradient and normalized gradient algorithms. Least-squares algorithms (batch, recursive, recursive with forgetting factor). Convergence properties. Identification for Control.
Frequency-domain analysis and averaging approximations: Averaging of signals. Averaging theory for one-time scale and two-time scale systems. Applications to adaptive systems.

Module 3: Model Reference Adaptive Control (10 hours)

Indirect adaptive control: Pole placement adaptive control. Model reference adaptive control. Predictive control.Singularity regions and methods to avoid them.
Direct adaptive control: Filtered linear error equation. Gradient and pseudo-gradient algorithms.Strictly positive real transfer functions and Kalman-Yacubovitch-Popov lemma. Lyapunov redesign. Passivity theory. Direct model reference adaptive control. One case study of MRAC and computer based design.

Module 4: Methods in Adaptive Control (9 hours)

Adaptive Backstepping., Adaptive Output Feedback Control, Adaptive NeuroControl., Examples of Adaptive Control. One case study and computer simulation.

References:

1. K.J. Astrom and B. Wittenmark, '*Adaptive Control',* 2nd ed., Addison-Wesley, 1995.
2. P.A. Ioannou& J. Sun, '*Robust Adaptive Control'*, Prentice Hall, Upper Saddle River, NJ, 1996..
3. I.D. Landau, R. Lozano, and M. M'Saad, '*Adaptive Control'*, Springer Verlag, London, 1998.
4. K.S. Narendra and A.M. Annaswamy, '*Stable Adaptive Systems'*, Prentice-Hall, 1989.
5. S. Sastry and M. Bodson*, 'Adaptive Control: Stability, Convergence, and Robustness'*, Prentice-Hall, 1989.

EE6126D ADVANCED TOPICS IN CONTROL SYSTEMS

Pre-requisite: EE6101D Systems Theory

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply the concepts of fuzzy and neuro-fuzzy systems in various control engineering problems
CO2: Explain the characteristics of MIMO systems and design MIMO controllers
CO3: Integrate the knowledge of chaotic systems in control and physiological systems
CO4: Design and analyse variable structure systems

Module 1: Neuro-Fuzzy Modelling and Control of Systems (10 hours)

Fuzzy Models- Mamdani and Takagi Sugeno Models- Construction of fuzzy models . Neural networks . Adaptive networks . supervised learning . Adaptive neuro-fuzzy inference systems- ANFIS architecture-ANFIS as a universal approximator - Simulation examples.

Module 2: Linear Multi-Input-Multi-Output Control Systems (10 hours)

Representations of MIMO systems- Equivalent transformations- Canonical forms- Solution of state equations- System response - Controllability and pole allocation- Observability and state estimator- System characterization by transfer matrix- Noninteractive and model matching control design.

Module 3: Chaos, fractals, applications and Aerospace Guidance Systems (10 hours)

Non linear systems . chaos . fractals . dimensions . attractors .Lorenz attractor . Mandelbrot set, bifurcations,synthesis of some chaotic systems using neural net work. some control applications. fractals and chaos in medicine and physiology .
Introduction . trajectory aspects . inertial and optical sensors . inertial guidance for cruise vehicles, guidance and control of rocket vehicles . guidance and control of mobile-launched ballistic missiles.

Module 4: Variable Structure Systems (9 hours)

Introduction . Variable Structure Systems (VSS) . VSS for fast response . VSS for stability . VSS with sliding mode . Sliding mode motion . Existence Condition - Second order control problem . Sliding mode motion on switching line . Sliding mode motion on switching surface . Design of stable switching surface . Invariance Conditions in VSS . Variable structure model following control (VSMFC)

References

1. Robert Babuska : *'Fuzzy Modelling and Control',* International Series in Intelligent Technologies, Kluwer Academic Publications . 1998
2. Jang J SR ,Sun C T, Mizutani E : *'Neuro-fuzzy and Soft Computing . MATLAB curriculum Series*', Prentice Hall International, 1997
3. Apte Y.S., *'Linear Multivariable Control Theory*', Tata McGraw Hill Publishing Co. Ltd., 1994.
4. Chen C.T., '*Linear System Theory and Design*', Holt Reinhart and Winston Inc., 1984
5. Wolovich W.A., *'Linear Multivariable Systems*', Springer- Verlag , New york- Heidelberg- Berlin, 1974.
6. Thomas Kailath, *'Linear Systems*', Prentice Hall Inc., Englewood Cliffs, N.J. , 1980
7. Leondis C T. *'Guidance and Control of Aerospace Vehicles*', McGraw Hill Book Company Inc New York 1963
8. U. Itkis . *'Control Systems of variable structure*', New York, Wiley, 1976
9. A.S.I. Zinober (Edited by) *'Deterministic Control of Uncertain Systems*', British Library Cataloguing in Publication Data, Peter Peregrinus Ltd. 1990

10. B. Drazenovic, *'The invariance conditions in variable structure systems*', Automatica, Vol. 5, pp 287-295, 1969.
11. K.K.D. Young, *'Design of Variable Structure Model Following Control Systems*', IEEE Transactions on Automatic Control, Vol. 23, pp-1079-1085 – 1978
12. A.S.I. Zinobar, O.M.E. El-Ghezawi and S.A.Billings – *'Multivariable variable structure adaptive model following control systems*' . Proc. IEE., Vol. 129., Pt. D., No.1, pp-6-12, 1982

EE6140D ADVANCED SOFT COMPUTING TECHNIQUES

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Construct intelligent systems and control using Artificial neural network
CO2: Integrate theoretic foundations of Fuzzy Logic Systems to be used in engineering applications.
CO3: Describe the concepts of genetic algorithms
CO4: Apply the knowledge of Soft Computing Techniques in engineering problems
CO5: Simulate intelligent control systems to evaluate the performance

Module 1: (9 hours)

Introduction Neural Networks, Biological Neuron, Biological and Artificial Neuron Models, types of Neuron Activation function, ANN Architectures, supervised, and unsupervised learning, Perceptron Models, training Algorithms, Limitations of the Perceptron Model and Applications, Computer based simulation

Module 2: (11 hours)

Multilayer Feed forward Neural Networks - Back propagation Algorithm, Limitations of Back propagation Algorithm, Radial Basis Function network structure - covers theorem and the separability of patterns - RBF learning strategies, Applications in forecasting and pattern recognition and other engineering problems, Computer based simulation

Module 3: (11 hours)

Introduction to classical sets - properties, Operations and relations; Fuzzy sets, Membership, Uncertainty, Operations, properties, fuzzy relations, cardinalities, membership functions., Fuzzification, Membership value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods - Mamdani Fuzzy Models, Sugeno Fuzzy Models - engineering applications

Module 4: (8 hours)

Introduction to Optimization, types of optimization problem, optimization algorithms, classification, History of evolutionary, Advantages of evolutionary computation, Introduction to genetic algorithms, The genetic computation process-natural evolution-parent selection-crossover-mutation-properties - classification - Application to engineering problems, Computer simulation practices.

References:

1. B.Yegnanarayana, *Artificial Neural Networks,* PHI, India, 2006.
2. Limin Fu, *Neural Networks in Computer Intelligence,* McGraw Hill, 2003.
3. N. Yadaiah and S. Bapi Raju, *Neural and Fuzzy Systems: Foundation, Architectures and Applications,* Pearson Education
4. Goldberg D.E., *Genetic Algorithms in Search Optimization and Machine Learning,* Addison Wesley,1989

EE6303D DYNAMICS OF ELECTRICAL MACHINES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Formulate electrodynamic equations for the electrical machines.

CO2: Analyse the performance of the electrical machines using the electrodynamic equations.

CO3: Develop power invariant transformations for the dynamic analysis of electrical machines.

CO4: Carry out stability analysis of the electrical machines under small signal and transient conditions.

Module 1: (12 hours)

Electrodynamic equations and their solution - a spring and plunger system - rotational motion system - mutually coupled coils - lagrange's equation - application of lagrange's equation to electromechanical systems - solution of electrodynamic equations by euler's and runge-kutta methods - linearisation of the dynamic equations and the small signal stability - differential equations and solutions - a smooth air-gap two winding machine - a two phase machine with current excitation - interpretation of the average power conversion conditions in terms of air-gap magnetic fields - primitive 4 winding commutator machine - commutator primitive machine - brush axis and its significance - self and mutually induced voltages in the stationary and commutator windings - speed emf induced in commutator winding - rotational inductance coefficients - sign of speed emf terms in the voltage equation - complete voltage equation of primitive 4 winding commutator machine - torque equation - analysis of dc machine using the primitive machine equations.

Module 2: (9 hours)

Three phase induction motor - equivalent two phase machine by mmf equivalence - equivalent two phase machine currents from three phase machine currents - power invariant phase transformation - voltage transformation - voltage and torque equations of the equivalent two phase machine - commutator transformation and its interpretation - transformed equations - different reference frames for induction motor analysis - nonlinearities in machine equations - equations under steady state - linearised equations of induction machine - small signal and transient stability analysis - eigen values - transfer function formulation.

Module 3: (9 hours)

Three phase salient pole synchronous machine - three phase to two phase transformation - voltage and torque equations in various reference frames - commutator transformation and transformed equations - parks transformation - suitability of reference frame - steady state analysis - large signal transient analysis - eigen values - general equations for small oscillations - small oscillation equations in state variable form - damping and synchronizing torques - small oscillation stability analysis - application of small oscillation models in power system dynamics.

Module 4: (9 hours)

Dynamic analysis of interconnected machines - machine interconnection matrices - transformation of voltage and torque equations using interconnection matrices - large signal transient analysis using transformed equations - small signal model using transformed equations - dc generator-motor system - synchronous generator-motor system -ward-leonard system - hunting analysis of interconnected machines - selection of proper reference frame for individual machines in an interconnected system.

References:

1. D P Sengupta & J.B. Lynn, *Electrical Machine Dynamics*, The Macmillan Press Ltd. 1980.
2. R Krishnan, *Electric Motor Drives, Modeling, Analysis and Control*, Pearson Education, 2001.
3. P.C. Kraus, *Analysis of Electrical Machines*, McGraw Hill Book Company,1987.
4. I. Boldia & S A Nasar, *Electrical Machine Dynamics*, The Macmillan Press Ltd. 1992.
5. C.V. Jones, *The Unified Theory of Electrical Machines*, Butterworth, London. 1967.

EE6304D MODERN DIGITAL SIGNAL PROCESSORS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Design a system using digital signal processors
CO2: Analyse and understand digital signal processors architectures.
CO3: Program various DSP processors using IDEs.
CO4: Utilise the advantages of modern digital signal processors for power electronics applications.

Module 1: Introduction to Digital Signal Processors (DSP) (12 hours)

Features of Digital Signal Processors, Modern trends in DSP: Von Newmann versus Harvard architecture, Architectures of superscalar and VLIW fixed and floating point processors, New Digital Signal Processing hardware trends, Selection of DS processors.
Internal details of DSP using Texas Instruments DSP (TMS330C6000 Series) as a tool: DSP Architecture, CPU Data Paths and Control, Internal Data/Program Memory. On chip peripherals and its programming details: Timers - Multi channel buffered serial ports - Extended Direct Memory Access, Interrupts, Pipelining.

Module 2: Programming the DSP (14 hours)

Texas Instruments IDE - C C Studio - Introduction to the C6713 DSK- Review of FIR filtering: FIR filter design techniques and tools, Review of IIR filtering: IIR filter design techniques and tools, Sampling, quantization and working with the AIC23 codec, Writing efficient code: optimizing compiler - effect of data types and memory map. TMS320C6713 Assembly language Programming: Instructions Set and Addressing Modes – Linear Assembly. Interfacing CC Studio with Matlab.

Module 3: Current trend in Digital Signal Processors (13 hours)

Motor Control Digital Signal Processing Solutions Using the TMS320F240DSP-Controller. Architecture of TMS320C2XX series DSP and its applications. Architecture trends of other DSP processors, Analog Devices DS processors: ADSP-2105 digital signal processor for motor control applications, Microchip dsPIC controllers for power electronics applications. Other major vendors in the DSP market and the latest trends.

References:

1. On-line TI materials for the TI C6713 DSK board: *http://www.ti.com*
2. Naim Dahnoun, *Digital Signal Processing Implementation using the TMS320C6000 DSP Platform*, 1st ed., Prentice Hall, 2000.
3. R. Chassaing, *Digital Signal Processing and Applications with the C6713 and C6416 DSK*, John Wiley and Sons, Inc., New York, 2004
4. Sen M. Kuo and Woon-Seng Gan, *Digital Signal Processors: Architectures, Implementations, and Applications*, Pearson Prentice Hall, 2005.
5. David J Defatta J, Lucas Joseph G & Hodgkiss William S, *Digital Signal Processing: A System Design Approach*, 1st ed., John Wiley, 1988.
6. A.V. Oppenheim and R.W. Schafer, *Discrete-Time Signal Processing*, 2nd ed., Prentice-Hall,Upper Saddle River, NJ, 1989
7. John G Proakis, Dimitris G Manolakis, *Introduction to Digital Signal Processing*, 1st ed.
8. On-line Microchip materials: *http://www.microchip.com/design-centers/intelligent-power*

EE6306D POWER ELECTRONIC DRIVES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Choose a suitable Motor and Power Electronic Converter system from a description of drive requirement – involving load estimation, load cycle considerations, thermal aspects and motor-converter matching.

CO2: Design various DC and AC machines used in drives.

CO3: Demonstrate Electrical Motor operation using Generalized machine theory.

CO4: Explain the working and design of various converters used in Electrical Drives.

Module 1: (10 hours)

Introduction to Motor Drives - Components of Power Electronic Drives – Criteria for selection of Drive components - Match between the motor and the load - Thermal consideration - Match between the motor and the Power Electronics converter - Characteristics of mechanical systems - stability criteria

Module 2: (10hours)

D.C Motor Drives - System model motor rating - Motor-mechanism dynamics - Drive transfer function – Drives control-speed controller design-Effect of armature current waveform - Torque pulsations –Adjustable speed dc drives - Chopper fed and 1-phase converter fed drives - Effect of field weakening.

Module 3: (11 hours)

Induction Motor Drives - Basic Principle of operation of 3 phase motor - Equivalent circuit – MMF Space harmonics due to fundamental current - Fundamental spatial mmf distributions due to time harmonics -Simultaneous effect of time and space harmonics - Speed control by varying stator frequency and voltage -Impact of non-sinusoidal excitation on induction motors - Variable frequency converter classifications -Variable frequency PWM-VSI drives - Variable frequency square wave VSI drives - Variable frequency CSI drives - Comparison of variable frequency drives - Line frequency variable voltage drives - Soft start of induction motors - Speed control by static slip power recovery. - Vector control of 3 phase squirrel cage motors - Principle of operation of vector control

Module 4: (8 hours)

Synchronous Motor Drives - Introduction - Basic principles of synchronous motor operation methods of control - operation with field weakening - load commutated inverter drives. PMSM Drives, Switched reluctance Drive.

References:

1. Ned Mohan, *Power Electronics*, Wiley 2006
2. R Krishnan, *Electric Motor Drives, Modeling, Analysis, and Control*, Pearson Education, 2001
3. G.K.Dubey & C.R.Kasaravada, *Power Electronics & Drives*, Tata McGraw Hill, 1993.
4. W.Shephered, L N HulleyCambride, *Power Electronics & Control of Motor*, University Press, 2005.
5. Dubey,*Power Electronics Drives* ,Wiley Eastern,1993.
6. Chilikin ,M ,*Electric drives*, 2nd ed., Mir publications,1976.

EE6322D STATIC VAR CONTROLLERS AND HARMONIC FILTERING

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.

CO2: Illustrate various single phase and three-phase Static VAr Compensation Schemes and their controls.

CO3: Develop analytical modeling skills needed for modeling and analysis of such Static VAr systems with a view towards Control Design

CO4: Demonstrate the fundamental principles of Passive and Active Harmonic Filtering in Power Systems.

CO5: Analyse various single-phase and three-phase active harmonic filtering systems employing Current-regulated PWM VSI and their control.

CO6: Analyse and Model Active Harmonic Filtering systems with a vision towards Controller Design

Module 1: (10 hours)

Fundamentals of Load Compensation, Steady-State Reactive Power Control in Electric Transmission Systems , Reactive Power Compensation and Dynamic Performance of Transmission Systems . Power Quality Issues. Sags, Sweels, Unbalance, Flicker, Distortion, Current Harmonics - Sources of Harmonics in Distribution Systems and Ill Effects.

Module 2: (10hours)

Static Reactive Power Compensators and their control. Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems.

Module 3: (10 hours)

Converters for Static Compensation. Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM) . GTO Inverters . Multi-Pulse Converters and Interface Magnetics . Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies (includes SVM) . Multi-level inverters of Cascade Type and their modulation. Current Control of Inverters.

Module 4: (9 hours)

Passive Harmonic Filtering. Single Phase Shunt Current Injection Type Filter and its Control, Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modelling . Three-phase four wire shunt active filters . Hybrid Filtering using Shunt Active Filters . Series Active Filtering in Harmonic Cancellation Mode . Series Active Filtering in Harmonic Isolation Mode. Dynamic Voltage Restorer and its control, Power Quality Conditioner.

References:

1. T.J.E Miller, *Reactive Power Control in Electric Systems*, John Wiley & Sons,1982.
2. N.G. Hingorani& L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems,* IEEE Press, 2000.
3. Ned Mohan, *Power Electronics,* John Wiley and Sons, 2006

EE6323D DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Develop mathematical model of power electronic switches and electrical machines.
CO2: Model and simulate Power Electronic Systems using software packages such as PSpice, MATLAB -Simulink & Saber
CO3: Design and simulate power electronic systems using PSpice.
CO4: Illustrate power electronic system design and simulation using MATLAB- Simulink.
CO5: Analyse and design power electronic systems and simulate using Saber

Module 1: (10 hours)

Principles of Modeling Power Semiconductor Devices – Macro models versus Micro models– Thyristor model - Semiconductor Device modelled as Resistance, Resistance-Inductance and Inductance-Resistance-Capacitance combination - Modelling of Electrical Machines - Modelling of Control Circuits for Power Electronic Switches. Computer Formulation of Equations for Power Electronic Systems - Review of Graph Theory as applied to Electrical Networks - Systematic method of Formulating State. Equations – Computer Solution of State Equations - Explicit Integration method - Implicit Integration method.

Module 2: (9 hours)

Circuit Analysis Software Micro SimPSpice A/D - Simulation Overview - Creating and Preparing a Circuit for Simulation - Simulating a Circuit with PSpice A/D - Displaying Simulation Results - PSpice A/D Analyses - Simple Multi-run Analyses - Statistical Analyses - Simulation Examples of Power Electronic systems.

Module 3: (9 hours)

MicroSimPSpice A/D - Preparing a Schematic for Simulation - Creating Symbols - Creating - Models - Analog Behavioral Modeling - Setting Up and Running analyses - Viewing Results - Examples of PowerElectronic Systems. MATLAB SIMULINK in Power system.

Module 4: (11 hours)

Design Creation and Simulation with Saber Designer - Placing the Parts - Editing the Symbol - Properties -Wiring the Schematic - Modifying Wire Attributes - Performing a Transient and DC Analysis – Placing Probes in the Design - Performing AC Analysis and Invoking Saber Scope - Analysing waveforms with Saber Scope - Performing Measurements on a waveform - Varying a Parameter - Displaying the Parameter Sweep Results - Measuring a Multi-Member Waveform - Simulation Examples of Power Electronic Systems.

References:

1. V.Rajagopalan, *Computer Aided Analysis of Power Electronic Systems,* Marcel Dekker Inc,1987.
2. *Micro Sim PSpice A/D and Basics+: Circuit Analysis Software, User's Guide,* Micro Sim Corporation
3. *Micro Sim Schematics: Schematic Capture Software, User's Guide*, Micro Sim Corporation.
4. *Getting Started with Saber Designer (Release 5.1)*, An Analogy Inc.
5. *Guide to Writing MAST Template (Release 5-1)*, Analogy Inc.

EE6327D IMPLEMENTATION OF DSP ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Illustrate the architecture of DSP systems, various transforms and algorithms in DSP.
CO2: Analyse and design digital filters and implement them.
CO3: Explain about Quantization Noise, and significance of Sampling rate and its conversion.
CO4: Design DSP algorithms and implement in PDSP / FPGA systems.

Module 1: Introduction and Transforms (13 hours)

Overview of Digital Signal Processing, Introduction to MATLAB , Applications of Digital Signal Processing; DISCRETE-TIME SIGNALS AND SYSTEMS - Discrete-time Signals, Discrete Systems, Convolution, Difference Equations; THE DISCRETE-TIME FOURIER ANALYSIS - The Discrete-time Fourier Transform (DTFT), The Properties of the DTFT, The Frequency Domain Representation of LTI Systems, Sampling and Reconstruction of Analog Signals; THE *z*-TRANSFORM - The Bilateral *z*-Transform, Important Properties of the *z*-Transform, Inversion of the *z*-Transform, System Representation in the *z*-Domain, Solutions of the Difference Equations; THE DISCRETE FOURIER TRANSFORM - The Discrete Fourier Series, Sampling and Reconstruction in the *z*-Domain, The Discrete Fourier Transform, Properties of the Discrete Fourier Transform, Linear Convolution Using the DFT, The Fast Fourier Transform.

Module 2: Digital Filter Implementation (14 hours)

IMPLEMENTATION OF DISCRETE-TIME FILTERS - Basic Elements, IIR Filter Structures, FIR Filter Structures, Lattice Filter Structures, Overview of Finite-Precision Numerical Effects, Representation of Numbers, The Process of Quantization and Error Characterizations, Quantization of Filter Coefficients; FIR FILTER DESIGN - Preliminaries, Properties of Linear-phase FIR Filters, Window Design techniques, Frequency Sampling Design Techniques, Optimal Equiripple Design Technique, IIR FILTER DESIGN, Some Preliminaries, Some Special Filter Types, Characteristics of Prototype Analog Filters, Analog-to-Digital Filter Transformations, Lowpass Filter Design, Frequency-band Transformations.

Module 3: Sampling Rate Conversion (12 hours)

Introduction, Decimation by a Factor *D,* Interpolation by a Factor *I,* Sampling Rate Conversion by a Rational Factor *I/D,* FIR Filter Designs for Sampling Rate Conversion, FIR Filter Structures for Sampling Rate Conversion; ROUND-OFF EFFECTS IN DIGITAL FILTERS - Analysis of A/D Quantization Noise, Round-off Effects in IIR Digital Filters, Round-off Effects in FIR Digital Filters; APPLICATIONS IN ADAPTIVE FILTERING - LMS Algorithm for Coefficient Adjustment, System Identification or System Modeling, Suppression of Narrowband Interference in a Wideband Signal, Adaptive Line Enhancement, Adaptive Channel Equalization.

Note: Use MATLAB as a tool to implement all these DSP concepts and obtain the resulting plots. Convert this Matlab code and implement in PDSP and / or FPGA systems.

References:

1. Vinay K. Ingle ,John G. Proakis, *Digital Signal Processing Using MATLAB®*, 3rd ed., Cengage Learning, ISBN-13: 978-1-111-42737-5.

2. Dimitris G Manolakis, John G. Proakis, *Digital Signal Processing : Principles, Algorithms, and Applications*, 4th ed., Pearson, 2007, ISBN: 9788131710005, 8131710009.
3. Hazarathaiah Malepati, *Digital Media Processing: DSP Algorithms Using C*, Elsevier Science Publisher, ISBN: 9781856176781, 1856176789.
4. Sanjit K Mitra, Digital Signal Processing, *A computer-based approach*, Tata McGraw-Hill, 1998.
5. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, *Statistical and Adaptive Signal Processing*, McGraw Hill international, 2000
6. Alan V. Oppenheim, Ronald W. Schafer, *Discrete-Time Signal Processing*, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997
7. John G. Proakis, and Dimitris G. Manolakis, *Digital Signal Processing*, 3rd ed., Prentice-Hall ofIndia Pvt. Ltd, New Delhi, 1997
8. Emmanuel C. Ifeachor, Barrie W. Jervis , *Digital Signal Processing-A practical Approach*, Addison Wesley,1993
9. Abraham Peled and Bede Liu, *Digital Signal Processing - Theory, Design and Implementation*, John Wiley and Sons, 1976

EE6329D ADVANCED MICROPROCESSOR BASED SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Illustrate the working of advanced microprocessors/controllers.
CO2: Program a processor in assembly language and develop an advanced processor based system.
CO3: Configure and use different peripherals in a digital system.
CO4: Explain how to compile, debug and execute Programs.

Module 1: Introduction (8 hours)

Technology trend in microprocessors - performance measurement –Comparing and summarizing performance - quantitative principles of computer design – Amdahl's law - Case studies.

History of the x86 family - Instruction Set architecture of a typical advanced x86 processor – using MASM32 for 32 bit assembly programming of x86 architectures

Module 2: 80386 to Pentium (8 hours)

Enhancements of 80386, Hardware Features, Protected virtual addressing mode -Virtual Memory, Memory Management Unit, Converting a Logical Address to a Physical Address, Calculating the size of the Logical Address Space, Protection, Multi Tasking, Interrupts of 80386, Privileged Instructions, The Enhanced Features of 80486, Data Alignment, The Pentium Processor, Pentium Pro, Pentium-II And Pentium-III, Pentium-IV, Latest Trends in Microprocessor Design

Module 3: ARM Introduction and Pipeline structures (13 hours)

Instruction Set Architecture (ISA) and ARM History, ARM architecture, Stack implementation in ARM, Endians, ARM organization and Implementation, Different Types of Instructions, ARM Instruction Set and Thumb Instruction set. Thumb state, Thumb Programmers model, Thumb Implementation, Thumb Applications. Thumb Instructions, Assembly Language Programming, condition codes, Data processing Instructions, High- Level Language Programming, System Development using ARM. Pipeline Hazards Interrupts and Exceptions, Exception Handlers, Reset Handling. Aborts, software Interrupt Instruction, undefined instruction exception. Interrupt Handling schemes, Interrupt Latency.

Module 4: ARM Memory and Hardware interfacing (10 hours)

Memory Hierarchy, Cache and Memory Management and Protection, Digital Signal Processing on ARM, Peripheral Programming and system design for a specific ARM processor (ARM7/9), PWM generation and Motor control using ARM processor board. .

References:

1. Lyla B.Das, *The x86 Microprocessors –Architecture Programming and Interfacing -8086 to Pentium*, Pearson Education, 2010.
2. Daniel W. Lewis , *Fundamentals of Embedded Software with the ARM Cortex-M3*, 1st ed., PEARSON, 2015, ISBN: 9789332549937, 9332549931
2. Jonathan W Valvano, *Embedded Systems: Introduction to Arm® Cortex(TM)-M3 Microcontrollers* , 2012.

3. Vincent Mahout, *Assembly Language Programming: ARM Cortex-M3* , Wiley , 2012
4. Jurij Silc, Borut Rob c, Theo Ungerer, *Processor Architecture – From Dataflow to Superscalar and Beyond* , Springer. 1999.
5. Shibu K.V, *Introduction to Embedded Systems*, Tata McGraw Hill, 2009
6. Robert Ashby *Designer's Guide to the Cypress PSoC Newnes*, (An imprint of Elsevier), 2006
7. Sloss, Symes, Wright, *ARM System Developer’s Guide*, Elsevier, 2014, ISBN: 9781493303748.
8. Oliver H. Bailey, *The Beginner's Guide to PSoC Express*, Timelines Industries Inc., 2007
9. Van Ess, Currie and Doboli, *Laboratory Manual for Introduction to Mixed-Signal, Embedded Design, Alphagraphics*, USA, ISBN: 978-0-9814679-1-7, 2008.
10. Steve Furber, *ARM System-on-chip Architecture* ,2nd ed., Pearson Education,2007
11. William Hohl, *ARM Assembly Language Programming*, CRC Press,2009
12. Andrew Sloss, Dominic Symes, Christ Wright, *ARM System Developer’s guide –Designing and optimizing software*, Elseiver Publishers ,2008
13. Andrew N. Sloss, Dominic Symes and Chris Wright, *ARM System Developers Guide: Designing And Optimizing System Software,* Elsevier, 2004
14. Steve Furber, *ARM System-on-Chip Architecture*, 2nd ed., Pearson, 2013
15. *Manuals and Technical Documents* from the ARM Inc, web site.
16. Hennesy J. L. & Pattersen D. A., *Computer Architecture: A Quantitative approach*, 4th ed., Elseiver Publications, 2007

EE6401D ENERGY AUDITING & MANAGEMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Recognize the role of energy managers and use the skills and techniques required to implement energy management.

CO2: Identify and quantify the energy intensive business activities in an organization.

CO3: Describe the standard methodologies for measuring energy in the workplace and energy audit Instruments

CO4: Analyze energy efficient control scheme for electric motors and perform case study on load matching and selection of motors.

CO5: Explain the energy conservation methods in motors, pumps, fans, compressors, transformers, geysers, lighting schemes, air conditioning, refrigeration, cool storage.

CO6: Conduct a walkthrough audit in various industries.

Module 1: (9 hours)

System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments- ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study.

Module 2: (10 hours)

Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis- Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors.

Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing -Optimal operation and Storage; Case study

Module 3: (10 hours)

Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study.

Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study.

Peak Demand controls- Methodologies-Types of Industrial loads-Optimal Load scheduling-case study.

Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

Module 4: (10 hours)

Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study;
Electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating-Gysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS

References

1. Y P Abbi and Shashank Jain, *Handbook on Energy Audit and Environment Management* , TERI, 2006
2. Albert Thumann, William J. Younger, Terry Niehus , *Handbook of Energy Audits*, 2009
3. Giovanni Petrecca, *Industrial Energy Management: Principles and Applications*, The Kluwer international series -207,1999
4. Anthony J. Pansini, Kenneth D. Smalling, *Guide to Electric Load Management*, Pennwell Pub; 1998
5. Howard E. Jordan, Energy-*Efficient Electric Motors and Their Applications*, 2nd ed., Plenum Pub Corp, 1994
6. Turner, Wayne C, *Energy Management Handbook*, Lilburn, The Fairmont Press, 2001
7. Albert Thumann, *Handbook of Energy Audits*, 5th ed., Fairmont Pr; 1998
8. IEEE Bronze Book, *Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities*, IEEE Inc, USA. 2008
9. Albert Thumann, P.W, *Plant Engineers and Managers Guide to Energy Conservation,* Seventh Edition,TWI Press Inc, Terre Haute, 2007
10. Donald R. W., *Energy Efficiency Manual,* Energy Institute Press, 1986
11. Partab H., *Art and Science of Utilisation of Electrical Energy*, Dhanpat Rai and Sons, New Delhi. 1975
12. Tripathy S.C, *Electric Energy Utilization And Conservation*, Tata McGraw Hill, 1991
13. NESCAP Guide Book on Promotion of Sustainable Energy Consumption, 2004
14. IEEE Bronze Book, IEEE STD 739
15. IEEE Recommended Practices for Energy Management in Industrial and Commercial Facilities
16. Barney L. Capehart, Wayne C. Turner , William J. Kennedy, Guide *to Energy Management*, 6th ed., Fairmont Press, April 23, 2008.
17. Donald R. Wulfinghoff*, Energy Efficiency Manual: for everyone who uses energy, pays for utilities, designs and builds, is interested in energy conservation and the environment*, Energy Institute Press March 2000.
18. Albert Thumann., William J. Younger, *Handbook of Energy Audits*, 7th ed., Fairmont Press, November 12, 2007.
19. *Certified Energy Manager Exam Secrets Study Guide: CEM Test Review for the Certified Energy Manager Exam*, CEM Exam Secrets Test Prep Team Mometrix Media LLC , 2009
20. Albert Thuman, D. Paul Mehta, *Handbook of Energy Engineering*, 6th ed., Fairmont Press, June 24, 2008.

EE6403D COMPUTER CONTROLLED SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Identify the scientific and mathematical principles and methodologies relevant to computer control of systems.
CO2: Describe the fundamentals of PLC and its architecture.
CO3: Explain the PLC programming fundamentals, process logic and human machine interface.
CO4: Describe DCS architecture and configuration.
CO5: Analyze in detail the case studies of PLC, SCADA and DCS.
CO6: Perform inter task communication, synchronization and real time memory management.

Module 1: Multivariable Control (11 hours)

Multivariable control- Basic expressions for MIMO systems- Singular values- Stability norms- Calculation of system norms- Robustness- Robust stability- H2 / H∞ Theory- Solution for design using H2 / H∞ - Case studies. Interaction and decoupling- Relative gain analysis- Effects of interaction- Response to disturbances- Decoupling- Introduction to batch process control.

Module 2: Programmable Logic Controllers (9 hours)

Programmable logic controllers- Organisation- Hardware details- I/O- Power supply- CPU- Standards- Programming aspects- Ladder programming- Sequential function charts- Man- machine interface- Detailed study of one model- Case studies.

Module 3: Large Scale Control System (11 hours)

SCADA: Introduction, SCADA Architecture, Different Commnication Protocols, Common System Components, Supervision and Control, HMI, RTU and Supervisory Stations, Trends in SCADA, Security Issues

DCS: Introduction, DCS Architecture, Local Control (LCU) architecture, LCU languages, LCU - Process interfacing issues, communication facilities, configuration of DCS, displays, redundancy concept - case studies in DCS.

Module 4: Real Time Systems (8 hours)

Real time systems- Real time specifications and design techniques- Real time kernels- Inter task communication and synchronization- Real time memory management- Supervisory control- direct digital control- Distributed control- PC based automation.

References:

1. Shinskey F.G., *Process control systems: application, Design and Tuning*, McGraw Hill International Edition ,Singapore,1988.
2. Be.langer P.R., *Control Engineering: A Modern Approach, Saunders College Publishing*, USA, 1995.
3. Dorf, R.C. and Bishop R. T , *Modern Control Systems*, Addison Wesley Longman Inc., 1999

4. Laplante P.A., *Real Time Systems: An Engineers Handbook*, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
5. Constantin H. Houpis and Gary B. Lamont, *Digital Control systems*, McGraw Hill Book Company, Singapore, 1985.
6. Stuart A. Boyer, *SCADA-Supervisory Control and Data Acquisition*, Instrument Society of America Publications, USA, 1999
7. Gordon Clarke, Deon Reynders, *Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems*, Newnes Publications, Oxford, UK,2004
8. Efim Rosenwasser, Bernhard P. Lampe, *Multivariable Computer-Controlled Systems: A Transfer Function Approach*, Springer, 2006

EE6405D ARTIFICIAL INTELLIGENCE & AUTOMATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Identify potential areas for automation and justify need for automation
CO2: Select suitable major control components required to automate a process or an activity
CO3: Identify suitable automation hardware for the given application
CO4: Explain "Artificial" Intelligence and how to identify systems with Artificial Intelligence.
CO5: Implement classical Artificial Intelligence techniques, such as search algorithms, minimax algorithm, neural networks, tracking, robot localization.

Module 1: (10 hours)

Introduction: Overview and Historical Perspective, Turing test, Physical Symbol Systems and the scope of Symbolic AI, Agents. State Space Search: Depth First Search, Breadth First Search, DFID. Heuristic Search: Best First Search, Hill Climbing, Beam Search, Tabu Search. Randomized Search: Simulated Annealing, Genetic Algorithms, Ant Colony Optimization. Finding Optimal Paths: Branch and Bound, A*, IDA*, Divide and Conquer approaches, Beam Stack Search.

Module 2: (9 hours)

Problem Decomposition: Goal Trees, AO*, Rule Based Systems, Rete Net. Game Playing: Minimax Algorithm, AlphaBeta Algorithm, SSS*. Planning and Constraint Satisfaction: Domains, Forward and Backward Search, Goal Stack Planning, Plan Space Planning, Graphplan, Constraint Propagation. Logic and Inferences: Propositional Logic, First Order Logic, Soundness and Completeness, Forward and Backward chaining.

Module 3: (10 hours)

Automation – Introduction - Automation in Production System, Principles and Strategies of Automation, Basic elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines. (SLE: Analysis of Transfer Lines). Automated Manufacturing Systems: Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation.

Module 4: (10 hours)

Control Technologies in Automation: Industrial Control Systems, Process Industries VS Discrete Manufacturing Industries, Continuous VS Discrete Control, Computer Process and its Forms. (SLE: Sensors, Actuators and other Control System Components). Computer Based Industrial Control: Introduction & Automatic Process Control, Building Blocks of Automation Systems: LAN, Analog & Digital I/O Modules, SCADA Systems & RTU. Distributed Control System - functional requirements, configurations & some popular Distributed Control Systems.

References:

1. M.P.Groover , Automation*, Production Systems and Computer Integrated Manufacturing*, 5th ed., Pearson Education, 2009.
2. Krishna Kant, *Computer Based Industrial Control*, 2nd ed., EEE-PHI, 2010
3. Tiess Chiu Chang & Richard A. Wysk , *An Introduction to Automated Process Planning Systems*.

4. Viswanandham, *Performance Modeling of Automated Manufacturing Systems*, 1st ed., PHI, 2009.
5. Deepak Khemani, *A First Course in Artificial Intelligence*, McGraw Hill Education (India), 2013
6. Stefan Edelkamp and Stefan Schroedl. *Heuristic Search: Theory and Applications*, Morgan Kaufmann, 2011.
7. John Haugeland, *Artificial Intelligence: The Very Idea*, A Bradford Book, The MIT Press, 1985.
8. Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence,* 2nd ed., A K Peters/CRC Press; 2004.
9. Zbigniew Michalewicz and David B. Fogel, *How to Solve It: Modern Heuristics*, 2nd ed., Springer, 2004.
10. Judea Pearl, Heuristics: *Intelligent Search Strategies for Computer Problem Solving*, Addison-Wesley, 1984.
11. Elaine Rich and Kevin Knight., *Artificial Intelligence*, Tata McGraw Hill, 1991.
12. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd ed., Prentice Hall, 2009.
13. Eugene Charniak, Drew McDermott, *Introduction to Artificial Intelligence*, Addison-Wesley, 1985.
14. Patrick Henry Winston, *Artificial Intelligence*, Addison-Wesley, 1992.

EE6421D SMART GRID TECHNOLOGIES AND APPLICATIONS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Get acquainted with the smart resources, smart meters and other smart devices.
CO2: Describe how modern power distribution system functions.
CO3: Identify suitable communication networks for smart grid applications

Module 1: (8 hours)

Introduction - Evolution of Electric Grid, Smart Grid Concept - Definitions and Need for Smart Grid – Functions – Opportunities – Benefits and challenges, Difference between conventional & Smart Grid,Technology Drivers.

Module 2: (11 hours)

Energy Management System (EMS) - Smart substations - Substation Automation - Feeder Automation, SCADA – Remote Terminal Unit – Intelligent Electronic Devices – Protocols, Phasor Measurement Unit – Wide area monitoring protection and control, Smart integration of energy resources – Renewable, intermittent power sources – Energy Storage.

Distribution Management System (DMS) – Volt / VAR control – Fault Detection, Isolation and Service Restoration, Network Reconfiguration, Outage management System, Customer Information System, Geographical Information System, Effect of Plug in Hybrid Electric Vehicles.

Module 3: (9 hours)

Introduction to Smart Meters – Advanced Metering infrastructure (AMI), AMI protocols – Standards and initiatives, Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.

Module 4: (11 hours)

Elements of communication and networking – architectures, standards, PLC, Zigbee, GSM, BPL, Local Area Network (LAN) - House Area Network (HAN) - Wide Area Network (WAN) - Broadband over Powerline (BPL) - IP based Protocols - Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid

References:

1. Stuart Borlase , *Smart Grid: Infrastructure, Technology and Solutions*, CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, *Smart Grid: Technology and Applications*, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, *Power System SCADA and Smart Grids*, CRC Press, 2015
4. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, *Communication Networks for Smart Grids*, Springer, 2014.

EE6422D ENGINEERING OPTIMIZATION AND ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply mathematical and numerical techniques of optimization theory to concrete Engineering problems.
CO2: Create, solve and analyze the optimization problems.
CO3: Describe the mathematical properties of general linear programming problems and obtain the solution of linear programming problems using appropriate techniques.
CO4: Formulate real-world problems as Linear Programming models, apply the simplex method and dual simplex algorithms in solving the standard LP problem and interpret the results obtained.
CO5: Apply linear programming in various engineering applications.
CO6: Identify solution algorithms to find the best possible solution in nonlinear decision models.

Module 1: (10 hours)

Concepts of optimization: Engineering applications-Statement of optimization problem-Classification - type and size of the problem.

Classical Optimization Techniques: Single and multi variable problems-Types of Constraints .Semi definite case-saddle point.

Linear programming: Standard form-Geometry of LP problems-Theorem of LP-Relation to convexity - formulation of LP problems - simplex method and algorithm -Matrix form- two phase method.

Duality-dual simplex method- LU Decomposition. Sensitivity analysis .Artificial variables and complementary solutions-QP.

Engineering Applications: Minimum cost flow problem, Network problems-transportation, assignment & allocation, scheduling. Karmarkar method-unbalanced and routing problems

Module 2: (10 hours)

Nonlinear programming: Non linearity concepts-convex and concave functions- non-linear programming - gradient and Hessian.

Unconstrained optimization: First & Second order necessary conditions-Minimisation & Maximisation-Local & Global convergence-Speed of convergence.

Basic decent methods: Fibonacci & Golden section search - Gradient methods - Newton Method-Lagrange multiplier method - Kuhn-tucker conditions . Quasi-Newton method- separable convex programming - Frank and Wolfe method, Engineering Applications.

Module 3: (9 hours)

Nonlinear programming- Constrained optimization: Characteristics of constraints-Direct methods-SLP,SQP-Indirect methods-Transformation techniques-penalty function-Langrange multiplier methods-checking convergence- Engineering applications

Module 4: (10 hours)

Dynamic programming: Multistage decision process- Concept of sub optimization and principle of optimality- Computational procedure- Engineering applications.

Genetic algorithms- Simulated Annealing Methods-Optimization programming, tools and Software packages.

References:

1. David G Luenberger, *Linear and Non Linear Programming*, 2nd ed., Addison-Wesley Pub.Co.,Massachusetts, 2003.
2. W.L.Winston, *Operation Research-Applications & Algorithms*, 2nd ed., PWS-KENT Pub.Co., Boston, 2007.
3. S.S.Rao, *Engineering Optimization*, 3rd ed., New Age International (P) Ltd, New Delhi, 2007
4. W.F.Stocker, *Design of Thermal Systems*, 3rd ed., McGraw Hill, New York. 1990
5. G.B.Dantzig, *Linear Programming and Extensions,* Princeton University Press, N.J., 1963.
6. L.C.W.Dixton,. *Non Linear Optimisation: Theory and algorithms,* Birkhauser, Boston, 1980
7. Bazarra M.S., Sherali H.D. & Shetty C.M., *Nonlinear Programming Theory and Algorithms*, John Wiley, New York,1979.
8. A. Ravindran, K. M. Ragsdell, G. V. Reklaitis, *Engineering Optimization: Methods And Applications*, Wiley, 2008.
9. Godfrey C. Onwubolu, B. V. Babu, *New Optimization Techniques in Engineering*, Springer, 2004
10. Kalyanmoy Deb, *Optimisation for Engineering Design-Algorithms and Examples*, Prentice Hall India, 1998.

EE6428D SCADA SYSTEMS & APPLICATIONS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the basic tasks of Supervisory Control Systems (SCADA) as well as their typical applications

CO2: Explain SCADA architecture and SCADA system components.

CO3: Describe single unified standard architecture IEC 61850

CO4: Explain SCADA communication system, various industrial communication technologies and open standard communication protocols

CO5: Apply SCADA systems in transmission and distribution sectors and industries.

Module 1: (10 hours)

Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries

Module 2: (10 hours)

SCADA System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems

Module 3: (10 hours)

SCADA Architecture: Various SCADA architectures, advantages and disadvantages of each system - single unified standard architecture - IEC 61850. SCADA Communication: various industrial communication technologies -wired and wireless methods and fiber optics. Open standard communication protocols

Module 4: (9 hours)

SCADA Applications: Utility applications- Transmission and Distribution sector -operations, monitoring, analysis and improvement. Industries - oil, gas and water. Case studies, Implementation, Simulation Exercises

References:

1. Stuart A. Boyer, *SCADA-Supervisory Control and Data Acquisition*, Instrument Society of America Publications,USA,2004.
2. Gordon Clarke, Deon Reynders, *Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems*, Newnes Publications, Oxford, UK,2004.
3. William T. Shaw, *Cybersecurity for SCADA systems*, Penn Well Books, 2006
4. David Bailey, Edwin Wright, *Practical SCADA for industry*, Newnes, 2003
5. Michael Wiebe, *A guide to utility automation: AMR, SCADA, and IT systems for electric power*, Penn Well 1999.

EE6429D WIRELESS & SENSOR NETWORKS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply knowledge of wireless sensor networks(WSN) to various application areas.
CO2: Design and implement WSN.
CO3: Conduct performance analysis of WSN and manage WSN.
CO4: Formulate and solve problems creatively in the area of WSN.

Module 1: (11 hours)

Introduction: Introduction to Sensor Networks, unique constraints and challenges, Advantage of Sensor Networks, Applications of Sensor Networks, Mobile Adhoc NETworks (MANETs) and Wireless Sensor Networks, Enabling technologies for Wireless Sensor Networks. Sensor Node Hardware and Network Architecture: Single-node architecture, Hardware components & design constraints, Operating systems and execution environments

Module 2: (10 hours)

Introduction to TinyOS and nesC - Network architecture, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts. Deployment and Configuration: Localization and positioning, Coverage and connectivity, Single-hop and multi-hop localization, self configuring localization systems, sensor management

Module 3: (10 hours)

Network Protocols: Issues in designing MAC protocol for WSNs, Classification of MAC Protocols, S-MAC Protocol, B-MAC protocol, IEEE 802.15.4 standard and Zig Bee, Dissemination protocol for large sensor network. Routing protocols: Issues in designing routing protocols, Classification of routing protocols, Energy-efficient routing, Unicast, Broadcast and multicast, Geographic routing.

Module 4: (8 hours)

Data Storage and Manipulation: Data centric and content based routing, storage and retrieval in network, compression technologies for WSN, Data aggregation technique. Applications: Detecting unauthorized activity using a sensor network, WSN for Habitat Monitoring.

References

1. Holger Kerl, Andreas Willig, *Protocols and Architectures for Wireless Sensor Network*, John Wiley and Sons, 2005 (ISBN: 978-0-470-09511-9).
2. Raghavendra, Cauligi S, Sivalingam, Krishna M., Zanti Taieb, *Wireless Sensor Network*, Springer 1st ed., 2004 (ISBN: 978-4020-7883-5).
3. Feng Zhao, Leonidas Guibas, *Wireless Sensor Network* , 1st ed., Elsevier, 2004 (ISBN: 13- 978-1-55860-914-3)
4. Kazem, Sohraby, Daniel Minoli, Taieb Zanti, *Wireless Sensor Network: Technology, Protocols and Application*, 1st ed., John Wiley and Sons, 2007 (ISBN: 978-0-471-74300-2).
5. B. Krishnamachari, *Networking Wireless Sensors*, Cambridge University Press, 2005.
6. N. P. Mahalik, *Sensor Networks and Configuration: Fundamentals, Standards, Platforms, and Applications*, Springer Verlag, 2007.

EE6430D NETWORK & DATA SECURITY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Discuss about information security governance, and related legal and regulatory issues
CO2: Identify external and internal security threats to an organization
CO3: To be familiar with information security awareness and a clear understanding of its importance
CO4: Discover and analyze the threats to an organization and select suitable solution strategies.

Module 1: (10 hours)

Introduction: Basic objectives of cryptography, secret-key and public-key cryptography, Block ciphers: Modes of operation, DES and its variants, AES, linear and differential cryptanalysis, stream ciphers, message digest algorithms: properties of hash functions, MD5 and SHA-1, keyed hash functions, attacks on hash functions.

Module 2: (11 hours)

Modular arithmetic, gcd, primality testing, Chinese remainder theorem, finite fields. Intractable problems: Integer factorization problem, RSA problem, discrete logarithm problem, DiffieHellman problem, Publickey encryption: RSA, Elliptic curve cryptography. Key exchange: Diffie-Hellman algorithms. Digital signatures: RSA, DSS, DSA, ECDSA, blind signatures, threshold cryptography, key management.

Module 3: (13 hours)

Network Security – Electronic Mail Security- Pretty Good Privacy – S/MIME – IP security – overview and architecture – authentication header – encapsulating security payload – combing security associations – web security requirements Secure Socket Layer and Transport Layer Security – secure electronic transactions, Authentication applications: X-509, Kerberos, RADIUS.

Module 4: (5 hours)

Wireless network security - WEP, WPA2 (802.11i), security in Bluetooth.

References:

1. Stallings, W., *Cryptography And Network Security: Principles and Practice,* 4^{th} ed., Upper Saddle River: Prentice Hall, 2006. ISBN 0-13-187316-4.
2. Stallings, *Network Security Essentials Applications and Standards*, Pearson education, 1999.
3. Menezes, A. J., Van Oorschot, P. C.; Vanstone, S. A., *Handbook of Applied Cryptography* , Boca Ratón [etc.]: CRC Press, 1997. ISBN 0-8493-8523-7.
4. Stajano, F*., Security for Ubiquitous Computing*, Chichester: John Wiley and Sons, 2002. ISBN 0-470- 84493-0.

EE6432D ADVANCED ALGORITHMS & DATA STRUCTURE ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain algorithmic techniques such as brute force, greedy, and divide and conquer.
CO2: Apply advanced abstract data type (ADT) and data structures in solving real world problems.
CO3: Devise complete algorithmic solution to a given problem effectively combining the fundamental data structures and algorithmic techniques.

Module 1: (9 hours)

Review of order notation & growth of functions, recurrences, probability distributions, Average case analysis of algorithms, Basic data structures such as stacks, queues, trees, graphs linked lists, and applications, priority queues.

Module 2: (8 hours)

Direct access tables and hash tables, hash functions and relates analysis, Binary Search trees and Operations, AVL Trees and balancing operations, R B Trees, properties, operations. Dynamic Graphs, Strings, Succinct. Dynamic optimality, Memory hierarchy.

Module 3: (11 hours)

Quick sort randomized version, searching in linear time, More graph algorithms – maximal independent sets, colouring vertex cover, introduction to perfect graphs.

Module 4: (11 hours)

Algorithmic paradigms Greedy Strategy, Dynamic programming, Backtracking, Branch-and-Bound, Randomized algorithms. Generic programming methodology and algorithm design – microprogramming - ADC, Quantization, word length issues, floating point numbers, etc

References:

1. H. S. Wilf, *Algorithms and complexity*, Prentice hall, 2002.
2. T. H. Cormen, C. E. Leiserson, R. L. Rivest, *Introduction to Algorithms*, Prentice hall, 2009.

EE6434D INTERNET OF THINGS AND APPLICATIONS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Discover the application areas of IOT ·
CO2: Realize the revolution of Internet in Mobile Devices, Cloud & Sensor Networks ·
CO3: Describe the building blocks of Internet of Things and characteristics
CO4: Explain cloud based sensor data analysis

Module 1: (10 hours)

Elements of an IoT ecosystem. Technology drivers, Business drivers. Typical IoT applications. Trends and implications. Overview of IoT supported Hardware platforms such as: Raspberry pi, ARM Cortex Processors, Arduino and Intel Galileo boards. IoT architecture: History of IoT, M2M - Machine toMachine, Web of Things, IoT protocols. Internet of Things (IoT) and Web of Things (WoT). Internet and Web Layering Business aspects of the Internet of Things. Representational State Transfer (REST) and Activity Streams, Business Cases & Concepts Persuasive Technologies & Behavioral Change IoT Communication Protocols Big Data and Semantic Technologies

Module 2: (10 hours)

Overview and working principle of Wired Networking equipment - Router, Switches, Overview and working principle of Wireless Networking equipment – Access Points, Hubs, etc. Linux Network configuration concepts: Networking configurations in Linux Accessing Hardware & Device Files interactions.

Module 3: (12 hours)

Network Fundamentals: Anatomy of a Sensor Network, Examples of Sensor Networks, Topology of a Sensor Network Communication Media. Wired Networks, Wireless Networks, Hybrid Networks. Types of Sensor Nodes, How Sensors Measure Storing Sensor Data. XBee Primer, Building an XBee-ZB Mesh Network, Arduino-Based Sensor Nodes, Hosting Sensors with Raspberry Pi

Module 4: IoT Tutorial and Mini-Project (7 hours)

Storing Sensor Data, Storage Methods - Local Storage Options for the Arduino, Local Storage Options for the Raspberry Pi, Remote Storage Options, MySQL
Local processing on the sensor nodes.

- Connecting devices at the edge and to the cloud.
- Processing data offline and in the cloud.
- Mini-project: Designing an IoT system

References:

1. J. Biron and J. Follett, *Foundational Elements of an IoT Solution* , O'Reilly Media, 2016.
2. Keysight Technologies, *The Internet of Things: Enabling Technologies and Solutions for Design and Test*, Application Note, 2016.
3. Charles Bell, *Beginning Sensor Networks with Arduino and Raspberry Pi* , Apress, 2013.
4. D. Evans, *The Internet of Things: How the Next Evolution of the Internet Is Changing Everything* , Cisco Internet Business Solutions Group, 2011
5. McKinsey&Company, *The Internet of Things: Mapping the value beyond the hype* , McKinsey Global Institute, 2015

6. European Alliance for Innovation (EAI), *Internet of Things: Exploring the potential* , Innovation Academy Magazine, Issue No. 03, 2015
7. Digital Greenwich, *Greenwich Smart City Strategy* , 2015
8. ITU and Cisco, *Harnessing the Internet of Things for Global Development* , *A contribution to the UN broadband commission for sustainable development*

EE6501D HIGH VOLTAGE ENGINEERING

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the need for the generation of high AC, DC and impulse voltage
CO2: Describe the principles behind generation of high DC, AC and impulse voltages
CO3: Develop equivalent circuit models of the different high voltage generators
CO4: Understand the principle of high voltage measurement systems.
CO5: Identify the insulation used in power equipment and their classification based on temperature.
CO6: Compute the breakdown strength of gas-filled insulation systems with simple geometries
CO7: Estimate the breakdown strength of contaminated liquids and solids.

Module 1: (11 hours)

Requirements of HV generation in laboratory, Generation of High voltages, AC voltages: Testing transformers-Series resonance circuits; DC voltages: symmetric and asymmetric voltage doubler circuits-electrostatic machines.
Generation of Impulse voltages and currents: single stage and multistage circuits- wave shaping-modeling of impulse generator circuit-triggering and control of impulse generators. Generation of switching surge voltage and currents.
Simulation of AC, DC and Impulse Voltage/Current generation circuits.

Module 2: (10 hours)

Measurement of high voltages: Sphere gaps, factors affecting sphere gap measurements, correction factors.
Measurement of high AC voltage: Capacitance voltage dividers, Chubb-Fortescue method, CVT, electrostatic voltmeters.
Measurement of high DC voltage: Resistive voltage dividers, Generating voltmeter.
Measurement of impulse voltage: Capacitance divider, Impedance matching.
Measurement of transient currents: Resistive shunt, Magnetic coupling, Hall Effect current transducers, Integrating and differentiating type Rogowski coils.
Digital techniques in HV measurements, DSO.

Module 3: (8 hours)

Introduction to solid, liquid and gaseous insulators used in power equipment. Classifications of insulation based on temperature withstand limits, dielectric losses, ageing of insulation materials (paper –press board) and remaining life analysis.
Applications of nanofilled materials for outdoor and indoor insulation.

Module 4: (10 hours)

Introduction to solid, liquid and gaseous dielectrics. Breakdown in gas and gas mixtures-breakdown in uniform and non uniform fields-Paschen's law-Townsends criterion-streamer mechanism-corona discharge-breakdown in electro negative gases. Breakdown in liquid dielectrics-suspended particle mechanism. Breakdown in solid dielectrics - intrinsic, streamer and thermal breakdown.

References:

1. Kuffel and Zaengl, *High Voltage Engineering*, 2nd ed., Newnes, 2000.
2. M. S. Naidu, V. Kamaraju, *High Voltage Engineering*, McGraw-Hill, 1995.
3. Subir Ray, *An Introduction to High Voltage Engineering*, 2nd ed., PHI Learning Private Limited, 2013.
4. Kuffel and Abdulla. M., *High Voltage Engineering*, Pergamon press, 1998.
5. Wadhwa C L., *High Voltage Engineering*, Wiley Eastern Limited, NewDelhi, 1994.
6. T. J. Gallagher, A.J Pearmain, *High Voltage- Measurement Testing and Design*, John Wiley & Sons, 1984.

EE6503D POWER SYSTEM TRANSIENTS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcome:

CO1: Understand the source and characteristics of lightning, switching, and temporary overvoltages.
CO2: Understand travelling wave propagation on transmission lines.
CO3: Understand the critical switching transient situations.
CO4: Be able to set up differential equations for RLC circuits and solve it via stationary and transient solutions.
CO5: Select various protective devices and insulation level.

Module 1: (10 hours)

Analysis and modelling of electromagnetic transients in power system: Fundamental circuit analysis of electrical transients -The Laplace Transform method of solving- simple Switching transients -Damping circuits -Abnormal switching transients -Three-phase circuits and transients. Computation of power system transients -Principle of digital computation – Matrix method of solution- Modal analysis- Z transform- Modelling for computation of electromagnetic transients-wavelet technique for determining fault in transformer.

Module 2: (10 hours)

Temporary, Lightning and Switching and overvoltages:
Temporary overvoltages: line dropping, load rejection, over voltages induced by fault, Ferranti effect, Ferromagnetic resonance.
Switching overvoltages: Energizing transients - closing and re-closing of lines –Switching of cables and capacitor banks, Short line or kilometric fault, Switching HVDC lines.
Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Influence of tower footing resistance and earth Resistance- indirect lightning- protection by ground wires.

Module 3: (10 hours)

Travelling waves on transmission line : Circuits with distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion – Multi-conductor system and Velocity wave- Behaviour of transformer windings for surges- Protection of tapping winding of transformer under transmission line fault due to resonance.

Module 4: (9 hours)

Insulation coordination:
Basics of Insulation Coordination • Definitions, principle of insulation coordination, Volt-time curves-Rated withstand voltage levels and clearances, relevant standard. Insulation Coordination as applied to Electrical Installation • Over-voltage protective devices, breakdown consequences, reduction of risks and levels of over-voltage, installation of surge arrestor.

References:

1. Allan Greenwood, *Electrical Transients in Power System*, Wiley & Sons Inc. New York, 1991.
2. Juan A. Matinez-velasco, *Power system Transients- Parameter determination*, CRC press, 2010

3. Philip C. Magnusson, Gerald C. Alexander, Vijai K Tripathi, Andreas Weisshaar, *Transmission lines and wave propagation*, CRC press, 2001.
4. Arieh L. Shenkman, *Transient analysis of Electric power circuits Handbook*, Springer, 2005.

EE6506D EHV POWER TRANSMISSION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcome:

CO1: To understand the need of EHV and UHV systems.

CO2: To know methods of governance on the line conductor design, line height and phase.

CO3: To know the different types of substation earthing schemes

CO4: To know the fundamentals of a GIS and GIL

Module 1: (10 hours)

Overview of Electrical power transmission at high voltages. Overhead transmission lines: Bundled conductors, Resistance, Inductance and capacitance calculations of EHV line and multiconductor configurations-sequence inductance and capacitance-line parameters for modes of propagation-Temperature rise of conductors and current carrying capacity.

Module 2: (10 hours)

Computation of surface voltage gradient on conductors, Corona: Power loss due to corona, Radio noise and Audible noise and their measurement as well as computation. Electric Field under transmission lines and its computation Effect of ES fields of humans, Animals and plants.

Module 3: (9 hours)

Functional Requirements of Earthing System, Equipment Earthing, Neutral Point Earthing, Substation Earthing System, Dimensioning of Earth Conductors, Step Potential and Touch Potential, Earth Mat, Resistance of Earthing System, Values of Soil Resistivity, Fencing, Procedure of Laying Earthing ,Shielding by wires and masts.

Module 4: (2 hours)

HVDC Transmission: HVDC transmission, kind of dc links, Comparison between AC and DC transmissions Applications of HVDC transmission. Power modulation and power control of HVDC lines.

Module 5: (8 hours)

Gas Insulated Substation: Evolution of GIS, Basics of GIS technology, Key design features, SF6 volume reduction, Reliability of GIS, Design tests, Gas tightness and monitoring, Global status of GIS.
Gas Insulated Transmission Line: Why GIL, Historical development of GIL, Applications of GIL, Basic units of GIL, Basic insulation level and current carrying capacity of GIL, Gas mixture as insulation, Installation of GIL, Comparison of GIL with cables and overhead lines.

References:

1. Hermann Koch, *Gas Insulated Substations*, Wiley, 2014.
2. R.D. Begamudre, *EHV AC transmission engineering*, New age international, 2006.
3. Kimbark E.W., *HVDC transmission*, Wiley, 1965.
4. Arrilaga J, *High voltage Direct Current Transmission*, Peter Peregrinus, London, 2007

EE6521D HVDC TRANSMISSION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Identify significance of DC over AC transmission system, types and application of HVDC links in practical power systems.
CO2: Analyze different converters viz.3, 6 and 12 pulse converters.
CO3: Analyze AC/DC system interactions and know the operation and control of various MTDC systems.
CO4: Model AC/DC system and apply protection for HVDC system against transient overvoltage and over currents

Module 1: (10 hours)

Introduction – Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system – Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables – VSC based HVDC.

Module 2: (10 hours)

Pulse number – Choice of converter configuration – Simplified analysis of Graetz circuit – Converter bridge characteristics – Detailed analysis of converters - General principles of DC link control –Converter control – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering, Filter design.

Module 3: (9 hours)

Introduction – Potential applications of MTDC systems – Types of MTDC systems – Control and protection of MTDC systems – Study of MTDC systems.

Module 4: (10 hours)

Introduction – System simulation: Philosophy and tools – HVDC system simulation –Modeling of HVDC systems for digital dynamic simulation – Dynamic interaction between DC and AC systems. Power flow analysis of AC-DC systems. Transient stability analysis.

References

1. Kimabrk E.W., *HVDC Transmission*, 1st ed., Wiley,1965.
2. Arrillaga J., *High Voltage Direct Current Transmission*, Peter Peregrinus, London, 2007.
3. Kundur P., *Power System Stability and Control*, Tata McGraw-Hill, 1993.
4. Erich Uhlmann, *Power Transmission by Direct Current*, BS Publications, 2004.
5. Sood V.K., *HVDC and FACTS controllers – Applications of Static Converters in Power System*, Kluwer Academic Publishers, April 2004.

EE6522D HIGH VOLTAGE POWER TRANSFORMERS AND CIRCUIT BREAKERS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Acquire knowledge about the build-up, modeling, and protection system of power transformers.

CO2: Accomplish insight regarding detailed power transformer features as loss phenomena, stray fields, impedance characteristics, insulation design etc.

CO3: Assess the condition of the transformer by performing various tests.

CO4: Acquire knowledge about the different types of circuit breakers for protecting power system equipment.

CO5: Understand the testing of circuit breakers

Module 1: (8 hours)

HV power transformers, principle and equivalent circuit, Magnetic characteristics-Excitation characteristics, over excitation performance, Inrush current.
Impedance characteristics, Reactance calculation, Losses in transformers-eddy current loss, hysteresis loss and stray loss in power transformers.

Module 2: (11 hours)

Short circuit forces, failure mode due to radial and axial forces, Short circuit test, Effect of inrush current. Sweep frequency response of power transformer.
Surge phenomenon-initial voltage distribution-ground capacitance calculations-capacitance of winding, inductance calculation- standing and traveling wave theory, Method for analysis of impulse distribution.

Module 3: (10 hours)

Impulse testing, diagnostics and condition monitoring of transformers, Conventional tests, Dissolved Gas Analysis, Partial Discharge Diagnostics, Degree of Polymerization and Furan Analysis, Time domain and frequency domain dielectric response method. Impulse testing of power transformer for winding of low inductance

Module 4: (10 hours)

Introduction to HV switching devices, electric arcs, short circuit currents, TRV, CB types, air, oil and SF_6 CB, short circuit testing.

References

1. S.V. Kulkarni, S.A. Khaparde, *Transformer Engineering: Design, Technology, and Diagnostics*, 2nd ed., CRC Press Taylor and Francis Group, 2012.
2. Sivaji Chakravorti, Debangshu Dey, Biswendu Chatterjee, *Recent trends in the condition monitoring of transformers, Theory, Implementation and Analysis*, Springer Verlag London 2013.
3. Bernard Hochart, *Power Transformer Handbook*, Butterworth, 1987.
4. M J Heathcote, Newnes*, The J & P Transformer Book*, 12th ed., 1998.
5. *Transformers, Bharat Heavy Electricals Limited*, Tata McGraw Hill, 2001.
6. Blume, L.F., and BoyaJian, *Transformer Engineering*, John Wiley and Sons, 1951.

7. Garzon, R.D., *HV Circuit Breakers – Design and Applications*, Marcel and Dekker NY, 1996.
8. Flurscheim, C.H., *Power Circuit Breaker: Theory and Design*, Peter Peregrinus Ltd., 1975.
9. Ryan, H.M., and Jones G.R., *SF_6 Circuit Breaker*, Peter Peregrinus Ltd., 1989.

EC6302D COMMUNICATION NETWORKS

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total hours: 39L + 26P

Course Outcomes:

CO1: Describe the basic building blocks of a computer network and understand the architecture of the global Internet

CO2: Describe, analyze and compare a number of datalink, network, and transport layer protocols

CO3: Develop a strong theoretical foundation on performance analysis of various queueing models with applications to Internet

CO4: Develop the ability to explore the design and development of more resource efficient and eco-friendly networking technologies

Module 1: (12 hours)

Introduction: General issues in networking - Circuit switching, packet switching and virtual circuit switching - Layered architecture for Internet -Performance metrics for networks - Data link layer –Framing- Error detection- Reliable Transmission – Automatic repeat request (ARQ) schemes and performance analysis- Medium access control (MAC) protocols- Direct Link Networks- -Ethernet and multiple access networks - IEEE 802.11 wireless LANs: Distributed coordination function

Module 2: (12 hours)

Internetworking :IPV4 and IPV6 - Addressing in internet – Subnetting and supernetting– Routing in Internet –Routing protocols for Internet – Datagram forwarding in Internet - Address resolution protocol (ARQ) – Dynamic host configuration protocol (DHCP) – Mobile IP Transport layer protocol - TCP and UDP - End-to-end reliability in Internet – Time out computation in TCP - TCP flow control and congestion control

Module 3: (15 hours)

Broadband services and QOS issues: Quality of Service issues in networks- Integrated service architecture- Queuing Disciplines- Weighted Fair Queuing- Random Early Detection- Differentiated Services- Protocols for QOS support- Resource reservation-RSVP- Multi protocol Label switching- Real Time transport protocol. Performance analysis: Introduction to Queuing theory: Markov chain- Discrete time and continuous time Markov chains- Poisson process- Queuing models for Datagram networks- Little's theorem- M/M/1 queuing systems- M/M/m/m queuing models- M/G/1 queue- Mean value analysis- Time reversibility- Closed queuing networks- Jackson's Networks.

References:

1. Peterson L.L. and Davie B.S., *Computer Networks: A System Approach*, 5th ed.,Elsevier, 2012
2. James. F. Kurose and Keith.W. Ross, *Computer Networks, A top-down approach featuring the Internet*, 5th ed., Pearson Education, 2015
3. D. Bertsekas and R. Gallager, *Data Networks*, 2nd ed., PHI, 2000
4. S. Keshav, *An Engineering Approach to Computer Networking*, Pearson Education, 2005

EC6434D LINEAR & NONLINEAR OPTIMIZATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Outline an adequate mathematical background on optimization theory.
CO2: Analyze the basic techniques commonly used in linear programming problems.
CO3: Develop the basic skill to address the nonlinear programming problems.
CO4: Obtain the fundamental knowledge to oversee the constrained and unconstrained optimization problems.

Module 1: (10 hours)

Mathematical background: sequences and subsequences, mapping and functions, continuous functions infimum and supremum of functions minima and maxima of functions, differentiable functions. Vectors and vector spaces, matrices, linear transformation, quadratic forms, gradient and Hessian-Linear equations, solution of a set of linear equations, basic solution and degeneracy, convex sets and convex cones, convex hulls, extreme point, convex and concave functions, differentiable convex functions.

Module 2: (13 hours)

Linear Programming: introduction, optimization model, formulation and applications, classical optimization techniques: single and multi variable problems, types of constraints, graphical method, linear optimization algorithms: simplex method, basic solution and extreme point, degeneracy, primal simplex method, dual linear programs, primal, dual, and duality theory, dual simplex method, primal-dual algorithm. Post optimization problems: sensitivity analysis and parametric programming.

Module 3: (16 hours)

Nonlinear Programming: minimization and maximization of convex functions, local & global optimum, convergence. Unconstrained optimization: one dimensional minimization, elimination methods: Fibonacci & Golden section search, gradient methods. Constrained optimization: Lagrangian method, Kuhn-Tucker optimality conditions, convex programming problems. augmentedLagrangian method (ALM)
Applications of optimization theory in signal processing: signal processing via convex optimization, applications in weight design, linearizing pre-equalization, robust Kalman filtering, online array weight design, basic pursuit denoising (BPDN), compressing sensing and orthogonal matching pursuit (OMP).

References:

1. David G Luenberger, *Linear and Non Linear Programming*., Addison-Wesley, 2ndEdn., 2001
2. S.S.Rao, *Engineering Optimization.; Theory and Practice,* 4th ed., John Wiley, 2013,
3. S.M. Sinha, *Mathematical programming: Theory and Methods*, Elsevier, 2006.
4. Hillier and Lieberman Introduction to Operations Research, 8th ed., McGraw-Hill, 2005.
5. Kalyanmoy Deb, Optimization for Engineering: Design Algorithms and Examples, Prentice Hall, 1998.
6. Igor Griva, ArielaSofer, Stephen G. Nash: *Linear and Nonlinear Optimization*, SIAM, 2009.

MA8154D WAVELET THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Review fundamental concepts of linear algebra and understand the theory of Fourier transform.
CO2: Acquire knowledge about construction of discrete wavelets.
CO3: Learn the construction of continuous wavelets through iteration and their implementation.
CO4: Study about multi resolution analysis and construction.

Module 1: (10 hours)

Vector spaces and Bases, Linear transformation, Matrices and change of basis, Inner products, Hilbert Space, Fourier transforms, Parseval identity and Plancherel theorem, Basic Properties of Discrete Fourier Transforms , Translation invariant Linear Transforms ,The Fast Fourier Transforms.

Module 2: (18 hours)

Construction of wavelets on ZN ,The Haar system, Shannon Wavelets, Real Shannon wavelets,Daubechie's D6 wavelets on ZN., Examples and applications.

Wavelets on Z:l2 (Z), Complete orthonormal sets in Hilbert spaces,L2 (−π,π) and Fourier series, The Fourier Transform and convolution on l2 (Z), First stage Wavelets on Z , Implementation and Examples.

Module 3: (11 hours)

Wavelets on *R* : L^2 (*R*) and approximate identities, The Fourier transform on *R* , Multiresolution analysis, Construction of MRA .

References:

1. Michael. W. Frazier, *An Introduction to Wavelets through Linear Algebra*, Springer, Newyork, 1999.
2. Jaideva. C. Goswami, Andrew K Chan, *Fundamentals of Wavelets Theory Algorithms and Applications*, John Wiley and Sons, Newyork. , 1999.
3. Yves Nievergelt, *Wavelets made easy*, Birkhauser, Boston,1999.
4. G. Bachman, L.Narici and E. Beckenstein , *Fourier and wavelet analysis*, Springer, 2006.