Indian Institute of Technology Bhubaneswar
M. Tech (PED) Curriculum

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COMPLIANCE

Category	MTech Curriculum Structure (Requirement)	Proposed MTech Curriculum Structure
Total Credit requirement	82-88	83/85
(i) Theory	32-36	33/35
(ii) Laboratories	6-8	6
(iii) Seminars	4	4
(iv) Thesis	32	32
(v) Research Review papers	8	8

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SUBJECT DETAILS

SEMESTER – I					
Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**	**Syllabus Page No.**
Switched Mode Power Conversion	EE6L051	3-1-0	4	4	5
Theory and Analysis of Electric Drives	EE6L052	3-1-0	4	4	6
Elective I		3-0-0	3	3	
Elective II		3-0-0	3	3	
Elective III		3-0-0 / 3-1-0	3 / 4	3 / 4	
Power Electronics System Simulation Laboratory	EE6P051	0-0-3	2	3	25
Switched Mode Power Conversion Laboratory	EE6P052	0-0-3	2	3	25
Seminar – I	EE6S051	0-0-3	2	3	
		Total	23/ 24	26/27	
SEMESTER – II					
Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**	**Syllabus Page No.**
Advanced Power Electronic Converters	EE6L053	3-0-0	3	3	7
Grid Integration of Renewable Energy Systems	EE6L013	3-0-0	3	3	8
Advanced Machine Drives	EE6L055	3-1-0	4	4	8
Elective IV		3-0-0	3	3	
Elective V		3-0-0 / 3-1-0	3 / 4	3 / 4	
Power Converter and Electric Drives Laboratory	EE6P053	0-0-3	2	3	25
Seminar – II	EE6S052	0-0-3	2	3	
		Total	20/21	22/23	
SEMESTER – Ⅲ					
Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**	**Syllabus Page No.**
Thesis Part I	EE6D051	0-0-0	16	16	
Research Review Paper I	EE6D052	0-0-0	4	4	
		Total	20	20	
SEMESTER – Ⅳ					
Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**	**Syllabus Page No.**
Thesis Part Ⅱ	EE6D053	0-0-0	16	16	
Research Review Paper Ⅱ	EE6D054	0-0-0	4	4	
		Total	20	20	

ELECTIVE Ⅰ to III					
Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**	**Syllabus Page No.**
Dynamics of Linear Systems	EE6L056	3-0-0	3	3	9
Renewable and Distributed Sources	EE6L006	3-0-0	3	3	10
Industrial Instrumentation	EE6L007	3-0-0	3	3	11
Power System Analysis and Operation	EE6L001	3-1-0	4	4	12
High Voltage Engineering	EE6L009	3-0-0	3	3	13
Energy Storage Systems	EE6L011	3-0-0	3	3	14
Electric Power Quality	EE6L002	3-0-0	3	3	14
EHV/UHV Power Transmission Engineering	EE6L012	3-0-0	3	3	15
Statistical Signal Processing	EC6L005	3-0-0	3	3	16
Mathematical Methods	MA6LXXX	3-1-0	4	4	17
ELCTIVES Ⅳ to Ⅴ					
Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**	**Syllabus Page No.**
Power System Dynamics & Control	EE6L003	3-1-0	4	4	18
Smart Grid Technology	EE6L014	3-0-0	3	3	18
Power System Protection	EE6L004	3-1-0	4	4	19
Advanced High Voltage Engineering	EE6L015	3-0-0	3	3	20
Advanced Control	EE6L016	3-0-0	3	3	21
HVDC and Flexible AC Transmission Systems	EE6L005	3-0-0	3	3	22
Advanced Digital Signal Processing	EC6L004	3-1-0	4	4	23
Computational Electromagnetics	EC6L016	3-0-0	3	3	24
Advanced Techniques in Operations Research	MA6LXXX	3-1-0	4	4	24

CORE SUBJECTS

Subject Code: EE6L051	Name: Switched Mode Power Conversion	L-T-P: 3-1-0	Credits: 4

Linear voltage regulators, basic structures, advantages and disadvantages; Steady state analysis of basic DC-DC converters (Buck, boost, buck-boost) Steady state analysis of derived DC-DC (Cuk, SEPIC, Quadratic) converters. Steady state analysis of transformer isolated DC-DC converters (Forward, Flyback, push-pull, bridge) Switched mode voltage regulator specifications, block diagram, Modeling approach, assumptions and approximations. Dynamic models and transfer functions of hard switched converters in CCM and DCM modes. Regulator design example Current Programmed converters, Block diagram, stabilization, modeling and transfer functions. Single phase PFC circuits. Resonant Converters, Soft switching principles: ZVS, ZCS, ZVZCS Resonant Load Converters: Variable frequency series and parallel resonant converters (Resonant Switch Converters (quasi resonant): Half and full wave operations and control. Resonant Transition Phase Modulated Converters, Reduction of VA ratings, fixed frequency operation and advantageous usages of device and transformer non-idealities; Soft Switched Bidirectional DC-DC Converters (Dual Active Bridge): Soft-switching under buck mode and boost mode operations with or without active clamp PWM Converters with Auxiliary Switch, ZVT /ZCT PWM Converters: Isolated and Non-isolated topologies with auxiliary switch; Auxiliary Resonant Commutated Pole Inverters: ZVT and ZCT concepts used for Inverters; Resonant DC Link Inverters: Forced oscillation of DC Link voltage by auxiliary switch.

Pre-requisite: None

Texts/References:

1. M H. Rashed, ‘Power Electronics Circuits, Devices and Applications’, Prentice Hall of India Pvt. Ltd, 2004.
2. R. W. Erickson and D. Maksimovic, ‘Fundamental of Power Electronics’, Springer International Edition, 2005.
3. N. Mohan, T. M. Underland, and W. Robbins, ‘Power Electronics Converters, Applications and Design’, John Wiley and Sons. Inc., 2004.

Subject Code: EE6L052	Name: Theory and Analysis of Electric Drives	L-T-P: 3-1-0	Credits: 4

Introduction and review of electrical machines; Principles of electromagnetic energy conversion: General expression of stored magnetic energy, co-energy and force/torque, example using single and doubly excited system. Calculation of air gap mmf and per phase machine inductance using physical machine data; Voltage and torque equation of dc machine, three phase symmetrical induction machine and salient pole synchronous machines in phase variable form. Introduction to reference frame theory: static and rotating reference frames, transformation relationships, examples using static symmetrical three phase passive circuits. Generalized theory of rotating electrical machine and Krons primitive machine; Modelling of D.C and 3- phase symmetrical induction and synchronous machines; voltage and torque equations, derivation of steady state phasor relationship from dynamic model. Analysis and dynamic modelling of two phase asymmetrical induction machine and single phase induction machine.

Introduction to Electric Drives – Need of electric drives, basic parts, present scenario of electric drives Mechanical Dynamics in an Electric Drive - Speed-torque characteristics of some common motors and loads, multi quadrant operation, equivalent values of drive parameters, stability of an electric drive General Block Diagram of a Closed Loop Drive System – Speed, torque and position control Selection of Motor Power Rating – Thermal model of motor for heating and cooling, classes of motor duty, determination of motor rating Chopper Controlled DC Motor Drive – Different types of choppers and their quadrants of operations, PWM strategies for different choppers, chopper control of series DC motor. Power Semiconductor Switches Used in an Electric Drive System - Basic structure, V-I characteristics and switching characteristics of thyristors and IGBTs, gate drive and protection circuits of thyristors and IGBTs. DC Motor Drive Using Phase Controlled Rectifier – DC motor drive using half controlled and fully controlled single phase and three phase rectifiers, continuous and discontinuous conduction modes of operation, 4-quadrant operation using dual converter. Closed Loop Control of DC Motor – Operating limits of a separately excited DC motor drive, dynamic model of DC motor, dynamic model of chopper and phase controlled rectifier, design of single loop speed controller, cascaded controller design for DC motor using inner current control loop and outer speed control loop, field weakening operation.

Pre-requisite: None

Texts/References:

1. P. C. Krause, O. Wasynczuk and S. D. Sudhoff,‘ Analysis of Electric Machinery and Drive Systems’, John Wiley & Sons, New York, 2006.
2. Chee-Mun Ong, ‘Dynamic Simulation of Electric Machinery using MATLAB’, Prentice Hall PTR, 1998.
3. P. S. Bimbhra ‘Generalized theory of electrical machines’, Khanna Publishers Delhi, 1995.
4. G. K. Dubey, ‘Fundamentals of Electrical Drives’, CRC Press, 2002.

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Subject Code: EE6L053	Name: Advanced Power Electronic Converters	L-T-P: 3-0-0	Credits: 3

High-Power Semiconductor Devices, Diodes, SCR, GTO, GCT, IGBT. Operation of series connected devices: main cause of unbalance, voltage equalizations for GCTs, IGBTs. Multi-pulse Diode and SCR Rectifiers, Definition of THD and PF, THD and PF of six-pulse diode rectifier, 12, 18, 24- pulse series-type and separate-type diode rectifiers, Six-pulse and 12-pulse SCR rectifier, Effect of line and leakage inductances, and Phase-Shifting Transformers, Harmonic current cancellation. Cascaded H-Bridge Multilevel Inverters, Introduction, Sinusoidal PWM, Space Vector PWM in two level voltage source inverters; H-bridge inverter, multilevel inverter topologies: CHB Inverter with equal dc voltages, H-bridges with unequal dc voltages, Carrier based PWM schemes: Phase shifted multi-carrier modulation, Level shifted multi-carrier modulation, overmodulation of cascaded H-bridges, Control of dc bus voltages of the H-bridges. Diode-Clamped Multilevel Inverters, Three level inverter: Converter configuration, switching states, Carrier based PWM: Naturally sampled PD PWM, APOD and POD PWM; Space vector modulation: Optimized space vector sequences, modulator for selecting switching states, decomposition method, hexagonal co-ordinate system, optimal space vector position within a switching period; Neutral point voltage control, over modulation of three-level inverter, High-level diode clamped inverters. Hybrid Multilevel Inverters: Hybridization of Fundamental frequency switching (FFS) and PWM switching inverters: inverter topologies with isolation transformer, PWM switching strategy; Transformerless hybrid inverter: Binary H-bridge multilevel converter, Control of dc bus voltages of different modules. Multilevel Flying Capacitor Inverters: Inverter configuration, Modulation scheme. PWM Current Source Rectifiers and Inverters: Trapezoidal modulation, Selective harmonic Elimination, Space vector modulation, Parallel current source inverters, Single-bridge current source rectifier, Dual-bridge current source rectifier, Power factor control, Active Damping Control. Wide Band-gap devices and Performance and Design of Converters using Wide Band-gap devices.

Pre-requisite: None

Texts/References:

1. L. Umanand ‘Power Electronics – Essentials and Applications’, Wiley India Pvt. Ltd., 2009.
2. B. Wu, ‘High Power Converter and AC Drives’, IEEE Press Wiley Interscience, 2006.
3. M. P. Kazmierkowski, R. Krishnan and F. Blaabjerg ‘Control in Power Electronics - Selected Problems’, Academic Press Series in Engineering, 2002.

Subject Code: EE6L013	Name: Grid Integration of Renewable Energy Systems	L-T-P: 3-0-0	Credits: 3

Control of frequency and voltage of distributed generation in Stand-alone and Grid-connected mode, use of energy storage and power electronics interfaces for the connection to grid and loads. Design and optimization of size of renewable sources and storages.
Concept of microgrid, operation of microgrid in grid-connected as well as isolated mode, power quality problems and fault-ride through capability of microgrid.
Integration of large capacity renewable sources to grid: Operation and control, present trends, challenges, future technological needs viz., advanced characteristics of renewable energy generating units and plants, improved flexibility in conventional generation, transmission technology.

Pre-requisite: None

Texts/References:

1. Math J. Bollen, Fainan Hassan ‘Integration of Distributed Generation in the Power System’, IEEE Press, 2011.
2. S. Heier and R. Waddington ‘Grid Intergration of Wind Energy Conversion Systems’, Wiley, 2006.
3. Loi Lei Lai and Tze Fun Chan ‘Distributed Generation: Induction and Permanent Magnet Generators’, Wiley-IEEE Press, 2007.

Subject Code: EE6L055	Name: Advanced Machine Drives	L-T-P: 3-1-0	Credits: 4

Induction Motor Drives: Field oriented control- Direct and indirect field orientation, stator-flux, rotor-flux and airgap-flux orientation. Flux-torque decoupling, Extended speed operation and Field weakening. Direct torque control of Induction Motor, Flux and speed observers, Induction generators, Doubly Fed Induction Machines (DFIM): Different modes of operation, Equivalent circuit, Active and reactive power control, Vector control of DFIM. Identification of Induction Motor Parameters: Linear Model, Nonlinear least square identification, Parameter error indices. Speed sensor-less control: Signal injection and model based techniques, zero/low speed operation. Synchronous Motor Drives, Vector controlled Cycloconverter fed Drive, Parameter estimation and sensor-less control. Introduction to PM Synchronous Motor, Various rotor configurations of PMSM, Sinusoidal Back-Emf PMSM: Field oriented control, Direct torque control. Interior PM Machine: Maximum torque per ampere control, Field weakening Introduction to Brushless DC Motor: EMF and Torque of BLDC machine, Voltage Source Inverter fed BLDC: Half-wave and Full-wave operation, Speed control, Torque ripple minimization, Sensor-less operation.

Pre-requisite: None

Texts/References:

1. P. C. Krause, O. Wasynczuk and S. D. Sudhoff,‘ Analysis of Electric Machinery and Drive Systems’, John Wiley & Sons, New York, 2006.
2. B. K. Bose, ‘Modern Power Electronics and AC Drives’, Pearson Education, 2005.
3. W. Leonhard, ‘Control of Electric Drives’, Springer International Edition, 2001.

ELECTIVES

Subject Code: EE6L056	**Name: Dynamics of Linear Systems**	**L-T-P: 3-0-0**	**Credits: 3**

Background material on matrix algebra, differential equations, linear operators, Representation of dynamic systems, equilibrium points and linearization of nonlinear systems, Jordan form, functions of matrices, norms of vectors and matrices, Stability of systems, Lyapunov matrix equation, Natural and forced response of state equations, state space descriptions, canonical realizations, Observability and controllability, minimal realization, canonical decomposition, controllability and observability indices in MIMO systems, Linear state variable feedback, stabilization, pole-placement, methods for obtaining feedback gains in MIMO systems, Asymptotic observers, compensator design, and separation principle, reduced order observers, Considerations for system gains, Discretization of CT systems.

Pre-requisite: None

Texts/References:

1. Chi-Tsong Chen, Linear Systems Theory and Design, 2nd edition, HBJ 1984.
2. K. Ogata, Modern Control Engineering, Prentice Hall, 2006.

Subject Code: EE6L006	Name: Renewable and Distributed Energy Sources	L-T-P: 3-0-0	Credits: 3

Brief idea on renewable and distributed sources, their usefulness and advantages.

Wind Energy: Estimates of wind energy potential, wind maps, instrumentation for wind velocity measurements, aerodynamic and mechanical aspects of wind machine design, conversion to electrical energy, aspects of location of wind farms.

Solar Energy: Present and new technological developments in photovoltaic, estimation of solar irradiance, components of solar energy systems, solar-thermal system applications to power generation, heating.

Hydel Power: Water power estimates, use of hydrographs, hydraulic turbine, characteristics and part load performance, design of wheels, draft tubes and penstocks, plant layouts.

Brief idea of other sources viz., tidal, geothermal, gas-based, etc.

Requirements of hybrid/combined use of different renewable and distributed sources, need of energy storage.

Pre-requisite: None

Texts/References:

1. Math J. Bollen, Fainan Hassan 'Integration of Distributed Generation in the Power System', IEEE Press, 2011.
2. Loi Lei Lai and Tze Fun Chan 'Distributed Generation: Induction and Permanent Magnet Generators', Wiley-IEEE Press, 2007.
3. Studies' Craig Anderson and Rudolf I. Howard 'Wind and Hydropower Integration: Concepts, Considerations and Case, Nova Publisher, 2012.
4. Amanda E. Niemi and Cory M. Fincher 'Hydropower from Small and Low-Head Hydro Technologies', Nova Publisher, 2011.
5. D. Yogi Goswami, Frank Kreith and Jan F. Kreider 'Principles of Solar Engineering', Taylor & Francis 2000.
6. G. N. Tiwari 'Solar Energy Technology', Nova Science Publishers, 2005.

Subject Code: EE6L007	Name: Industrial Instrumentation	L-T-P: 3-0-0	Credits: 3

Static and dynamic characteristics of sensors, Resistive, Inductive and Capacitive sensors and signal conditioning circuits. Temperature, pressure, flow and level measurement techniques. pH and conductivity sensors. Piezo-electric and ultrasonic sensors and its application in process and biomedical Instrumentation. Measurement of viscosity, humidity and thermal conductivity. Optical Instrumentation: devices, intensity modulation and interferometric technique. Nucleonic gauges: Sources and Detectors and its application. Interfacing Sensors and actuators using LabVIEW programs. Instrumentation system Design.

Pre-requisite: None

Texts/References:

1. K. Krishnaswamy, S Vijayachitra, ‘Industrial Instrumentation’ New Age International, 2005.
2. William C Dunn, William Dunn ‘Fundamentals of Industrial Instrumentation and Process Control’ McGraw-Hill, 2005.
3. Al Sutko, Adolph A. Sutko, Jerry Faulk ‘Industrial Instrumentation’ Cengage Learning, 2009.

Subject Code: EE6L001	Name: Power System Analysis and Operation	L-T-P: 3-1-0	Credits: 4

Load Flow Studies in power systems, Network model formulation, Bus-Admittance Matrix, Gauss-Siedel, Newton Raphson and decoupled load flow studies, Line Flow and Losses, Load flow with power electronics control, AC-DC analysis.

State estimation: static and dynamic.

Optimal system operation: Optimal operation of generators on bus bar, optimal unit commitment, optimal generation scheduling, Unit commitment and Scheduling of Hydro thermal systems, Power system security: System state classification, security analysis, contingency analysis, sensitivity factors.

State estimation of power system: LSQ, static state estimation and tracking state estimation of power systems, computational considerations, Reliability considerations in power system operation.

Load forecasting : forecasting methodology, time series and Kalman filter based approach, long term load forecasting.

Introduction to power system restructuring, deregulation and market operations.

Pre-requisite: None

Texts/References:

1. D P Kothari, I J Nagrath 'Modern Power System Analysis', Tata McGraw-Hill Education, 2011.
2. Hadi Sadat 'Power system analysis', Tata Mcgraw Hill Education, 2002.
3. Grainmger and Stevenson 'Modern Power system Analysis', Tata McGraw-Hill Education, 1994.
4. Loi Lei Lai, 'Power System Restructuring and Deregulation: Trading, Performance and Information Technology', John Wiley & Sons, 2001.

Subject Code: EE6L009	Name: High Voltage Engineering	L-T-P: 3-0-0	Credits: 3

Generation of High Voltages and Currents: Generation of High Direct Current Voltages, Generation of High alternating voltages, Generation of Impulse Voltages, Generation of Impulse currents, Tripping and control of impulse generators.

Measurement of High Voltages and Currents: Measurement of High Direct Current voltages, Measurement of High Voltages alternating and impulse, Measurement of High Currents-direct, alternating and Impulse, Oscilloscope for impulse voltage and current measurements.

Break Down in Solid Dielectrics: Intrinsic breakdown, electromechanical breakdown, thermal breakdown, breakdown of solid dielectrics in practice, Breakdown in composite dielectrics, solid dielectrics used in practice.

Break Down in Gaseous and Liquid Dielectrics: Gases as insulating media, collision process, Ionization process, Townsend's criteria of breakdown in gases, Paschen's law. Liquid as Insulator, pure and commercial liquids, breakdown in pure and commercial liquids.

High Voltage Testing of Electrical Apparatus: Testing of Insulators and bushings, Testing of Isolators and circuit breakers, Testing of cables, Testing of Transformers, Testing of Surge Arresters, Radio Interference measurements.

Pre-requisite: None

Texts/References:

1. E. Kuffel, and W. S. Zaengl, J. Kuffel 'High Voltage Engineering: Fundamentals', CBS Publishers, 2005.
2. Ravindra Arora, Wolfgang Mosch, 'High Voltage and Electrical Insulation Engineering' John Wiley & Sons, 2011.
3. L L Alston 'High Voltage Technology', Oxford University Press, 2011.
4. Dieter Kind, Kurt Feser, and Y. Narayana Rao 'High-Voltage Test Techniques' Newnes, 2001.
5. W. Peek, and F. W. Peek "Dielectric Phenomena in High Voltage Engineering', Rough Draft Printing, 2008.
6. Research publications that will be suggested during the course.

Subject Code: EE6L011	**Name: Energy Storage Systems**	**L-T-P: 3-0-0**	**Credits: 3**

Energy and economic growth and the environment, implications of the Kyoto Protocol, and structural change in the electricity supply industry, Fundamental concept of batteries, battery performance, charging and discharging of a battery, storage density, energy density, and safety issues. Particularly, we will cover classical batteries, such as (i) Lead-Acid (ii) Nickel-Cadmium, (iii) Zinc Manganese dioxide, and modern batteries: (i) Zinc-Air (ii) Nickel Hydride, (iii) Lithium Battery. Thermo-electricity, Super-capacitor technology, Fuel cell, Use of power electronic converters in energy storage.

Pre-requisite: None

Texts/References:
1. Huggins, Robert 'Energy Storage', Springer, 2010.
2. Ter-Gazarian 'Energy Storage for Power Systems', Institution of Engineering and Technology, 1994.

Subject Code: EE6L002	**Name: Power Quality**	**L-T-P: 3-0-0**	**Credits: 3**

Brief review of various power quality (PQ) problems: Source of generation and their impacts on equipment and systems, need of monitoring, international power quality standards.

Passive Filters: Control of harmonics using passive L-C filters, tuned and de-tuned filters, their design criterion and implementation.

Active Power Filters: Power factor improvement, reactive power compensation, mitigation of harmonics and voltage sag compensation using active power filters. Study of various active power filters viz., static shunt compensators (STATCOM), dynamic voltage restorer (DVR), unified power quality conditioner (UPQC), etc. Suitability of type of active filters for mitigation of various power quality problems, Design of active power filters, various topologies and control schemes.

Pre-requisite: None

Texts/References:
1. Arindam Ghosh and Gerard Ledwich 'Power Quality Enhancement Using Custom Power Devices (Power Electronics and Power Systems)', Springer; 2002.
2. Surya Santoso, H. Wayne Beaty, Roger C. Dugan, and Mark F. McGranaghan, 'Electrical Power Systems Quality', McGraw-Hill Professional, 2002.
3. Math H. Bollen 'Understanding Power Quality Problems: Voltage Sags and Interruptions', Wiley-IEEE Press, 1999.
4. Narain G. Hingorani and Laszlo Gyugy 'Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems', Wiley-IEEE Press, 1999.

Subject Code: EE6L012	Name: EHV/UHV Power Transmission Engineering	L-T-P: 3-0-0	Credits: 3

Electrical power transmission by HVAC and HVDC, overhead transmission lines, bundled conductors, mechanical vibration of conductors, surface voltage gradient on conductors, corona and associated power loss, radio-noise and audio-noise and their measurement, fields under transmission lines, overhead line insulators, insulator performance in polluted environment, EHV cable transmission – underground cables and GIL, high voltage substations – AIS and GIS, grounding of towers and substations, over voltages in power systems, temporary, lightning and switching over voltages, design of line insulation for power frequency voltage, lightning and switching over voltages, insulation co-ordination.

Pre-requisite: None

Texts/References:

1. Begamudre, R.D., Extra High Voltage AC Transmission Engineering, Wiley Eastern Limited, 1990.
2. Transmission line Reference Book 345 kV & above, Electrical Power Research Institute, (EPRI), USA, 1982.

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Subject Code: EC6L005	Name: Statistical Signal Processing	L-T-P: 3-0-0	Credits: 3

Review of Probability and Stochastic Process
Estimation Theory: Minimum-variance unbiased estimator (MVUE), Cramer-Rao Lower bound, Best Linear Unbiased Estimator, Maximum likelihood Estimator, General Bayesian Estimator
Detection Theory: Neyman Pearson Theorem, Receiver Operating Characteristics, Matched Filters, Composite Hypothesis Testing
Nonparametric Spectral Estimation: Estimation of power spectrum of stationary random signal using periodogram-various methods, Joint signal analysis and estimation of cross power spectrum
Linear Signal Model: Synthesis of coloring filter and Analysis of whitening filter, Rational power spectra (AR, MA, ARMA), Relationship between filter parameters and autocorrelation sequences, Lattice-Ladder filter realization
Parametric Spectral Estimation: Order selection criterion of AR model , Minimum-variance, Maximum entropy and Maximum likelihood spectrum estimation Harmonic models and frequency estimation techniques Harmonic Decomposition, MUSIC algorithm, ESPRIT algorithm
Linear Optimum Filter: Optimum FIR Filter, PCA of optimum linear estimator and its frequency domain interpretation, Forward and Backward Linear prediction and optimum reflection coefficients Optimum causal and non-causal IIR Filters, Deconvolution and Signal restoration Algorithms and Structure of Optimum Linear Filters Levinson Recursion for optimum estimate, Order-recursive algorithms for optimum FIR filters and its lattice structures.

Pre-requisite: None

Texts/References Books:

1. Steven Kay, Fundamentals of Statistical Signal Processing, Vol I: EstimationTheory, Vol II: Detection Theory, Prentice Hall, 1993/1998.
2. Harry L. Van Trees, Detection, Estimation, and Modulation Theory, Part I, Wiley-Inter science, 2001
3. Monson H. Hayes, Statistical Digital Signal Processing and Modeling, John Wiley, 1996.

Subject Code: MA6LXXX	Name: Mathematical Methods	L-T-P: 3-1-0	Credits: 4

Probability and Statistics : Random variables (rv) and their properties, some standard discrete and continuous rv, Expectation, Variance, moments, moment generating functions, functions of a rv, their distribution and moments, joint, marginal and conditional distribution and independence of rvs, Hypothesis testing. Numerical solutions of algebraic and transcendental equations: Secant and Newton-Raphson methods, Numerical solutions of systems of linear equations: Gauss elimination, LU decomposition, Gauss-Jacobi and Gauss-Seidel methods. Interpolation: Newton's forward and backward interpolation formulae for equal intervals, Lagrange's and Newton's divided difference formulae for unequal intervals, Differentiation and integration methods, Power method for eigenvalues and eigenvectors. Numerical methods of ODE and PDE: Runge-Kutta and finite difference methods for ODE, Finite difference methods for solving 2-D Laplace's equation, Poisson's equation 1-D wave equation, 1-D heat equation.

Pre-requisite: None

Texts/References:

1. B. S. Grewel, 'Numerical Methods' Khanna Publishers, 2012.
2. K. K. Jain, and S.R.K. Iyengar and R.K. Jain, 'Numerical Methods-problem and solutions', Wiley Eastern Limited, 2001.
3. S. M. Ross, 'Introduction to Probability Models', Academic Press, 2004.
4. A. M. Gun, M.K. Gupta, and B.S. Gupta, 'Fundamentals of Statistics', World Press Private Ltd, 2005.
5. A. J. Hayter, 'Probability and Statistics for Engineers and Scientists', Duxbury Resource Center, 2012
6. J. B. Scarborough, 'Numerical mathematical analysis', Oxford & IBH Publishing Co.Pvt., 2000.
7. R. W. Hamming, 'Numerical Methods for Scientist and Engineers', McGraw Hill, 1998
8. J. H. Mathews and K. D. Fink, 'Numerical Methods using MATLAB', Pearson Education, 2004

Subject Code: EE6L003	Name: Power System Dynamics & Control	L-T-P: 3-1-0	Credits: 4

Basic Ideas of Modeling of Synchronous machines, excitation systems and Governors-Steady state, Dynamic and Transient stability. State space formulation of single and multi-machine models with control equipment. Damping effects of FACTS devices.

Sub-synchronous Resonance: Modal Analysis, Torsional Oscillations, induction generator effect, Torsional interaction effect, countermeasure.

Application of numerical techniques to multi-machine dynamic and transient stability studies. Generation/Frequency Characteristics and load frequency characteristics, tie-line bias control, Automatic Generation Control, Alert and emergency system operation control. Control of reactive power flow: AVR, OLTC Transformers, FACTS, Static VAR compensators, system loss minimization, Emergency control, Reliability and security, Protective relaying.

Pre-requisite: None

Texts/References:

1. Yao-Nan Yu 'Electric Power System Dynamics', Academic Press, 1983.
2. Olle I. Elgerd 'Electric Energy Systems Theory: An Introduction', Tata McGraw Hill, 2001.
3. K. R. Padiyar 'Power System Dynamics: Stability and Control', B P B Publications, 2002

Subject Code: EE6L014	Name: Smart Grid Technology	L-T-P: 3-0-0	Credits: 3

Review of basic elements of electrical power systems, desirable traits of a modern grid, principal characteristics of the smart grid, key technology areas.
Smart grid communication: Two way digital communication paradigm, network architectures, IP-based systems, Power line communications, advanced metering infrastructure.
Renewable Generation: Renewable Resources: Wind and Solar, Microgrid Architecture, Tackling Intermittency, Distributed Storage and Reserves.
Wide Area Measurement: Sensor Networks, Phasor Measurement Units, Communications Infrastructure, Fault Detection and Self-Healing Systems, Application and Challenges.
Security and Privacy: Cyber Security Challenges in Smart Grid, Defense Mechanism, Privacy Challenges.

Pre-requisite: None

Texts/References:

1. James Momoh 'Smart Grid: Fundamentals of Design and Analysis' Wiley-IEEE Press, 2012.
2. Philllip F. Schewe 'The Grid: A Journey through the Heart of our Electrified World' Joseph Henry Press, 2006.

Subject Code: EE6L004	Name: Power System Protection	L-T-P: 3-1-0	Credits: 4

Generation, propagation and interaction of electrical transients in electric power systems. Analysis of single and multiple transients including three phase and switching transients. Mathematical modelling of transmission lines and other power equipment in the presence of surge phenomena. Evolution in Protection systems, Characteristic of protective relays, Basic elements of Digital protection, signal conditioning and conversion, Fourier analysis and least square based techniques, Differential equation based techniques for transmission line applications, Fundamentals of travelling wave based techniques, Digital differential protection of transformers and transmission systems. Intelligent protection using ANN and Fuzzy systems, Application of advanced DSP in numerical relaying.

Pre-requisite: None

Texts/References:

1. A T Johns and S Kalman 'Digital Protection for Power Systems', IET, 1997.
2. A G Phadke and J. Thorp 'Computer Relaying for Power Systems', Wiley, 2009.
3. Allen Greenwood 'Electrical Transient in Power Systems', McGraw Hill, 1990.

Subject Code: EE6L015	Name: Advanced High Voltage Engg.	L-T-P: 3-0-0	Credits: 3

Electrostatic applications: Electrostatic separation, electro-static coating of materials, electro-static precipitation, electro-static copying.

Plasma-based applications: Ion Beam accelerators, Ion nitriding for surface hardening of materials, Ion thrusters for space applications. Nuclear Electro-magnetic Pulse simulation.

Pulsed Power Engineering: Capacitive and inductive energy storage, pulse forming lines, switches for pulsed power. High voltage sources for Cathode ray oscilloscopes and electron microscopes

Non Thermal Atmospheric Pressure Plasma: Non-thermal plasma stabilization at high pressure, Townsend and spark breakdown mechanisms, corona discharge, pulse corona discharge, dielectric barrier discharge, spark discharge, atmospheric pressure glows, micro-plasmas, plasma discharge in water.

Pre-requisite: None

Texts/References:

1. David A. Lloyd ‘Electrostatic Precipitator Handbook’, Institute Of Physics Publishing, 1988.
2. M. Haddad and D. Warne ‘Advances in High Voltage Engineering’ IET, 2009.
3. John Ernest Harry ‘Introduction to Plasma Technology’ Wiley-vch Verlag Gmbh, 2010.
4. J. Reece Roth, J. Reece Roth, and Roth J. Reece ‘Industrial Plasma Engineering – Volume-2’ Taylor & Francis Group, 2001.
5. Bernie M. Penetrante, ‘Non-Thermal Plasma Techniques for Pollution Control: Part B: Electron Beam and Electrical Discharge Processing’ Springer, 2012.
6. Research publications that will be suggested during the course.

Subject Code: EE6L016	Name: Advanced Control	L-T-P: 3-0-0	Credits: 3

State-space representation; Different canonical forms: Controller canonical form, Observer canonical form, Diagonal canonical form, Jordan canonical form, Controllable canonical form, Observable canonical form; Decomposition of transfer functions into different canonical forms; Controllability and Observability; Stabilizability and Detectability; State feedback control; Full and reduced order observers: observer based state feedback control, Separation principle; Optimal control: Linear Quadratic control, Linear Quadratic Gaussian control, Loop transfer recovery control; Internal stability, Well-posedness; Concept of uncertainties and robustness: Structured uncertainties, Unstructured uncertainties, Sensitivity, Complementary Sensitivity and their significance for robustness study, Robust stability of $M-\Delta$ structure; H_∞ control: Two block frame work, Four block frame work, mu-synthesis; Approximate linearization; Feedback linearization: Input to state exact linearization, input to output exact linearization; Sliding mode control.

Pre-requisite: None

Texts/References:

1. R. C. Dorf and R. H. Bishop ‘Modern Control Systems’, Pearson Education, Inc, 2008.
2. R. T Stefani ‘Design of Feedback Control Systems’, Oxford University Press, 2002.
3. S. Skogestad and I. Postlethwaite ‘Multivariable Feedback Control’, John Wiley, 2005.

Subject Code: EE6L005	Name: HVDC and Flexible AC Transmission Systems	L-T-P: 3-0-0	Credits: 3

HVDC transmission- introduction- comparison of ac and HVDC- HVDC transmission analysis of HVDC converters - pulse number- analysis with and without overlap- converter bridge characteristics- converter and HVDC system control- principles of DC link control- starting and stopping of DC link, power control- harmonics & filters– introduction- generation of harmonics- types of ac filters. power flow analysis in AC/DC systems - general modelling of dc links, solutions of AC-DC power flow- flexible ac transmission systems(FACTS)- concept of FACTS - flow of power in an ac system- dynamic stability consideration- basic types of FACTS controllers- static shunt compensators - SVC & STATCOM - objectives of shunt compensation- methods of controllable var generation- switching converter type var generators-basic operating principle and control approaches- static series compensators – GCSC, TSSC, TCSC & SSSC - objectives of series compensator, variable impedance type series compensators:- basic operating control schemes- power angle characteristics- control range and VA rating- external control- combined compensators.

Pre-requisite: None

Texts/References:

1. K.R. Padiyar, ‘HVDC Power Transmission System’, New Age Intl. Co, 2002.
2. N.G Hingorani, and L. Gyugyi ‘Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems’, IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.
3. R. Streeram Kumar, ‘Lecture Notes on Flexible AC Transmission Systems (FACTS)’, Institution of Engineers (India), Calicut Local Centre, 2003.
4. K.S. Sureshkumar, and S. Ashok, ‘FACTS Controllers & Applications’, E-book edition, Nalanda Digital Library, NIT Calicut, 2003.
5. T. J. E Miller, ‘Reactive Power Control in Electric Systems’, John Wiley & Sons, 2010.

Subject Code: EC6L004	Name: Advanced Digital Signal Processing	L-T-P: 3-1-0	Credits: 4

Power spectrum analysis, filter banks, multirate digital signal processing, higher order statistics, 1D & 2D DFT, properties and applications, short time Fourier transform, spectrograms, discrete cosine transform, discrete Wavelet transform, S-transform

Adaptive filters: Least mean square (LMS) algorithm and its variants, Recursive least square algorithm and its variants, block adaptive filtering; transform domain filtering, adaptive filters as estimator, classifier, forecaster, and equalizer.

Application of adaptive signal processing to telecommunication, instrumentation, power system & control and biomedical engineering.

Pre-requisite: None

Texts/References:

1. P. Stoica, and R. Moses, ‘Spectral Analysis of Signals`, Prentice Hall, 2008.
2. J. G. Proakis, and D. G. Manolakis, ‘Digital Signal Processing’, Pearson, 2009.
3. S. Mallat, ‘A wavelet tour of signal processing: the sparse way’, Academic Press, 2010.
4. S.O. Haykin, ‘Adaptive filter theory’, Prentice Hall, 2001.
5. G.Strang, and T. Nguyen, ‘Wavelets and filter banks’, Wellesley-Cambridge Press, 1996.
6. Research publications that will be suggested during the course.

Subject Code: EC6L016	**Name: Computational Electromagnetics**	**L-T-P: 3-0-0**	**Credits: 3**

Applications of electromagnetics in the 21st century. Numerical Methods: ODE solvers, Euler, Runge-Kutta. Review of Basic Electromagnetics: Electrostatics, Magnetostatics, Wave Equations. Numerical Techniques: Method of Moements, Finite Difference Method, Finite Element method, Charge Simulation Method, Monte carlo method. Time Varying Electromagnetic Fiels: Eddy currents & skin depth, introduction to wavelets, families of wavelets. Microwaves, Optics, Micromagnetics, Bio-electromagnetics. Tutorials and demonstration on PC, programming assignments.

Pre-requisite: None

Text/ Reference Books:

1. Numerical Techniques in Electromagnetic, 2nd edition, M.N.O. sadiku, CRC Press.
2. Weber, E., Electromagnetic Fields, Dover 1951
3. Silvester, P. P. and Ferrari, R. L., Finite Elements for Electrical Engineers, Cambridge University Press 1996.
4. Numerical Methods in Engineering with Python, Jaan Kiusalaas, Cambridge.
5. Selected journal papers

Subject Code: MA6LXXX	**Name: Advanced Techniques in Operations Research**	**L-T-P: 3-1-0**	**Credits: 4**

Non--Linear Programming Problems: One variable unconstrained optimization, multivariable unconstrained optimisation, Karush-Kuhn-Tucker (KKT) conditions for constrained optimization, quadratic programming, separable programming, convex and non-convex programming, teepest and Quasi-Newton method. Dynamic Programming: Characteristics of dynamic problems, deterministic dynamic programming and probabilistic dynamic programming, Network analysis, Shortest path problems, minimum spanning tree problem, maximum flow problem, minimum cost flow problem, network simplex, interior point methods, stochastic programming, Nonlinear goal programming applications, Geometric Programming. Multi-objective Optimization Problems: Linear and non-linear programming problems, Weighting and Epsilon method, P-norm methods, Gradient Projection Method, STEM method, Convex Optimization.

Pre-requisite: None

Texts/References:

1. S.S. Rao, ‘Engineering Optimization Theory and Practices’, John Wiley and Sons, 2009
2. M. Ehrgott, ‘Multi-criteria Optimization’, Springer 2006
3. K.M, Miettien, ‘Non-linear multi-objective optimization’, Kluwers International Series, 2004
4. K. Deb, ‘Multi-objective evolutionary optimization for product design and manufacturing’, Springer, 2011.

LABORATORIES

Subject Code: EE6P051	Name: Power Electronics System Simulation Laboratory	L-T-P: 0-0-3	Credits: 2
Introduction to schematic design, Design of power PCB, Design of sandwiched Bus-bar, Introduction to DSP/FPGA programming for power application, PWM generation exercise, Simulation of DC-DC converter, Grid connected Inverter, Loss estimation techniques, Power Quality improvement studies, Input Filter design and noise reduction. **Pre-requisite:** None			
Subject Code: EE6P052	**Name: Switched Mode Power Conversion Laboratory**	**L-T-P: 0-0-3**	**Credits: 2**
Constant current Load, 15V Voltage regulator with current limit, Constant current-constant voltage regulator, Non-isolated Boost converter, Non-isolated Fly-back converter, Non - isolated Forward converter, Current mode control of Boost Converter, Current mode control of Forward Converter, soft-switched converter. **Pre-requisite:** None			
Subject Code: EE6P053	**Name: Power Converter and Electric Drives Laboratory**	**L-T-P: 0-0-3**	**Credits: 2**
Active Power Factor control, Parameterization of Industrial Drive, Converter Drive with Universal motors, Self-Commutated Four quadrant converter, Slip control of asynchronous motor, Frequency converter with three phase asynchronous motor, Electronically commutated Synchronous machine, Smooth starting of Three phase machine, PLC controlled Drive system. **Pre-requisite:** None			