# Course Syllabi
# Department of Electrical Engineering

## EEL101 ELEMENTARY ELECTRICAL ENGINEERING (3-0-2-8)

### Contents:

Electrical circuit, circuit elements resistance, inductance & capacitance, Kirchhoff's laws, voltage source & current source, superposition theorem, Thevenin's theorem, Norton's theorem, duality, star-delta transformation.

AC circuits, periodic function, average & r.m.s. values, steady state behavior with sinusoidal excitation, phase representation, reactance & impedance, power and power factor, series & parallel circuit, resonance and quality factor, principle of generation of single phase & three phase voltages, power in balanced three phase ac system.

Power systems: elementary idea about bulk power generation, long distance transmission and distribution, industrial and residential distribution, safety & legal standards.

Magnetic circuit, flux, mmf, reluctance, analogy with electric circuits.Simple calculations for composite magnetic circuits.

Measurement of electrical current, voltage and energy in ac & dc systems.

Transformer: introduction, basic principles, construction, phasor diagram for transformer under no load condition, transformer on load, balance of mmf on both sides, phasor diagram, equivalent circuit, open circuit & short circuit test.

Electric Machines:

a) DC shunt and series motor: construction, principle of working and applications, need of starters, torque and speed control.

b) Induction motors: construction, principle of working of single phase and 3-phase motors, torque-slip characteristics.

### Text Books:

1. Hughes, E., Electrical and Electronics Technology, 10th ed., Pearson Education, 2013.
2. Kulshreshtha, D.C., Basic Electrical Engineering, Tata McGraw Hill, 2013.

### Reference Books:

1. Toro,V.D., Electrical Engineering Fundamentals, 2nd ed., Prentice Hall of India, 2012.
2. Kothari D.P., Nagrath I.J, Theory and Problems of Basic Electrical Engineering, Prentice Hall India 2011.

## EEL202 BASIC ELECTRICAL CIRCUITS (3-0-2-8)

### Contents:

Classification of elements of an electrical circuit, resistors, inductors, capacitors, controlled sources, diodes and ideal transformers. Basic circuit analysis methods nodal, mesh and modified nodal-analysis. Transient analysis of RL, RC and RLC circuits.

Network theorems: Tellegen's theorem, superposition theorem, Thevenin theorem, Norton theorem, substitution theorem, reciprocity theorem, maximum power transfer theorem, network analysis methods, poly-phase circuits. Circuits with ideal transformers, Laplace transforms and their adaptation to networks. Two-port networks, two-port parameters, interconnection of two ports and their effect on the parameters. Tellegen's generalized reciprocity theorem, multiport and multiterminal networks, their representations and interconnections.

### Text Books:

1. Hayt, W.H. and Kemmerley, J.E. and Durbin, S.N., Engineering Circuit Analysis, 7th ed., McGraw Hill, 2013.
2. Choudhury, D.R., Networks and Systems, 2nd ed., New Age Publication, 2014.

### Reference Books:

1. Murthy, K.V.V.and Kamath M.S, Basic Circuit Analysis, 8th ed., Jaico Publishing House, 2010.
2. Valkenburg, M. E. Van, Network Analysis, 3rd Ed. Prentice Hall India, 2011.

## EEL203 ELECTRICAL MACHINES (3-0-2-8)

### Contents:

DC machines: concept of induced emf, armature winding and field winding, mmf of armature and field winding.

DC motor: basic principle and operation, classification, torque, power, losses and efficiency, characteristics.

DC generator: emf equation, shunt and compound generator, characteristics & applications.

Three phase transformer: connection and phasor groups, effect of phase sequence, inrush current & harmonics, tertiary winding, open delta connection, Scott connection, applications.

Three phase induction motor: principle and operation, types of motors, starting against load, star delta starter, soft starting, matching with load torque-speed characteristics, determination of equivalent circuit parameter, motor faults, single phasing & protection.

Single phase induction motor: principle and two phase operation, types, equivalent circuit, characteristics, motors for special operation.

Three phase alternator: constructional features of cylindrical and salient pole rotor machines, steady state operation of three phase synchronous generators, phasor diagram, regulation & efficiency, parallel operation, transient & sub transient reactances and their measurement, short circuit fault currents. Effects of variable excitation and mechanical power input on generator operation.

Three phase synchronous motor: methods of starting, performance and leading power factor operation due to effect of variable excitation and load on motor operation.

### Text Books:

1. Fitzgerald, A.E., Kingsley, C. and Umans, S.D., Electric Machinery,6th ed., Tata McGraw Hill, 2014.
2. Bhattacharya, S.K., Electrical Machines, 3rd ed., McGraw Hill Education (India) Private Limited, 2013.

### Reference Books:

1. Bhimbhra, P.S., Electrical Machinery, Khanna Publishers, Delhi, 2003.
2. Nagrath, I. J. and Kothari, D. P., Electric Machines, Tata McGraw Hill, 2006.
3. Toro, V.D., Electric Machines and Power Systems, Prentice Hall, 1985.

## EEL204 NETWORK THEORY (3-2-0-8)

### Contents:

Graphs: paths, connectedness, circuits, cutsets, trees, matrix representation of directed graphs, incidence and circuit matrices, methods of analysis of linear networks, nodal, mesh and loop analysis.

Trigonometric and exponential Fourier series, discrete spectra and symmetry of waveform, steady state response of a network to non-sinusoidal periodic inputs, power factor, effective values, Fourier transform and continuous spectra, three phase unbalance circuit and power calculation. Frequency domain approaches to electrical networks.

Driving points and transfer functions poles and zeros of immittance function, their properties, sinusoidal response from pole-zero locations, convolution theorem and integral solutions.

Elements of filter theory: introduction, classification of filters, introduction of windows, butter worth filter challenge filter equation of ideal filter, image parameters and characteristics impedance, passive and active filter of various filter, low pass, high pass, constant K type, M derived filters and their design.

Transmission line parameters and performance, operation for maximum power transfer, characteristic impedance.

### Text Books:

1. Hayt, W.H. and Kemmerley, J.E. and Durbin, S.N., Engineering Circuit Analysis, 7th ed., McGraw Hill, 2013.
2. Choudhury, D.R., Networks and Systems, 2nd ed., New Age Publication, 2014.

### Reference Books:

1. Chua , L.O., Desoer, C.A. and Kuh, E.S., Linear and Nonlinear Circuits, McGraw Hill, 1991.
2. Murthy, K.V.V. and Kamath M.S, Basic Circuit Analysis, 8th ed., Jaico Publishing House, 2010.
3. Valkenburg, M. E.V., Network Analysis, 3rd ed., Prentice Hall of India, 2011.

## EEL205 MEASUREMENT AND INSTRUMENTATION (3-0-2-8)

### Contents:

Classification of measuring instruments, comparison of analog and digital instruments, advantages of digital instruments, classification of analog instruments, absolute and secondary instruments, indicating type, recording type and integrating type instruments, loading effect of instruments.

Measurement of resistance: classification, measurement of low resistance by Kelvins' double bridge, measurement of medium resistance by voltmeter-ammeter method, Wheatstone bridge. Measurement of high resistance by ohmmeter, Megger and loss of charge method, general theory of AC bridges, study of Maxwell, Hay's, Owen's, De Sauty's, Wien and Schering bridges, detectors for AC bridges. Principles and use of D.C. potentiometer for calibration purposes, principle and applications of A.C. potentiometer.

Ammeter, voltmeter, principles of moving coil, moving iron and dynamometer type instruments, extension of range using series and shunts, error due to extension of range.

Digital voltmeter : types of DVM, integrating type DVM.
Measurement of active and reactive power in polyphase circuits using dynamometer type instruments, measurement of energy in single and polyphase circuits using induction type instruments. Errors in power and energy measurements, class of accuracy, maximum demand indicator, trivector meter.
General theory of extension of range using CT and PT, errors in instrument transformers, applications of instrument transformers.
Special instruments: power factor meter, frequency meter, tachometer, synchroscope, rectifier type instruments, measurement of non-electrical quantities, digital frequency meter.

### Text Books:


1. Sawhney, A.K., A Course in Electrical and Electronics Measurements and Instrumentation, Dhanpat Rai and Sons, 2013.
2. Cooper, W.D. and Helfrick, A.D.,Modern Electronic Instrumentation and Measurement Techniques, 3rd ed., PHI Learning Private Limited, 2012.


### Reference Book:


1. Golding, E. W. andWiddis, F. C., Electrical Measurements and Measuring Instruments, 5th ed.,Wheeler Publishing, New Delhi,, 1998.


## EEL301 POWER SYSTEM (3-2-0-8)

### Contents:

General structure of electrical power system.Basic concept of inductance and capacitance of transmission lines.Per unit system and single line diagram representation.
Models of short, medium, long transmission lines. A, B, C, D parameters. Introduction to load flow analysis, Y bus formation, types of overhead line insulators, string efficiency.
Stability of power system: introduction, dynamics of synchronous machine. Swing equation, swing equation for multi machine system. power angle equation, steady state stability studies.
Transient stability studies : swing curve, equal area criterion for transient stability, application of equal area criterion for different disturbances. Solution of swing equation point by point methods of improving transient stability.
Introduction of HVDC transmission, line insulators, power cables, sag and tension, corona and its effects.

### Text Books:


1. Grainger, J.J., Stevenson, W.D., Power System Analysis, 22th ed., McGraw Hill Education (India) Private Limited, New Delhi, 2014.
2. Nagrath, I. J. andKothari, D.P., Power System Engineering, 2nd ed., Tata McGraw Hill Publications, 2013.


### Reference Books:


1. Elgerd, O.I., Electric Energy Systems Theory : An Introduction, 2nd ed., Tata Mc-Graw Hill Education , 2012.
2. Saadat, H., Power System Analysis, 3rd ed., PSA Publishing, 2010.


## EEL302 CONTROL SYSTEM (3-0-2-8)

### Contents:

Introduction to need for automation and automatic control.Use of feedback, broad spectrum of system application.
Mathematical modeling, differential equations, transfer functions, block diagram, signal flow graphs, application to elementary system simplifications, effect of feedback on parameter variation, disturbance signal servomechanisms and regulators.
Control system components, electrical, electromechanical, and other components. Their functional analysis and input output representation.
Time response of first order and second order system, standard inputs, concept of gain and time constants. Steady state error, type of control system, approximate methods for higher order system.
Stability of control systems, conditions of stability characteristic equation, Routh-Hurwitz criterion, special cases for determining relative stability.
Root location and its effect on time response, elementary idea of root locus, effect of adding pole and zero and proximity of imaginary axis.
Frequency response method of analyzing linear system, Nyquist and Bode plots, stability and accuracy analysis from frequency responses, open loop and close loop frequency response. Nyquist criterion, effect of variation of gain and addition of pole and zero on response plot, stability margins in frequency response.
State variable method of analysis, characteristic of system, state, choice of state representation of vector matrix differential equation standard form, relation between transfer function and state variable.

### Text Books:


1. Ogata, K., Modern Control Engineering,5th ed., Prentice Hall of India, 2012.
2. Nagrath, I.J. and Gopal, M., Control System Engineering, 5th ed., New Age International, 2012.


### Reference Books:


1. Dorf R. C. and Bishop R. H., Modern Control Systems, 12th ed., Pearson Education, 2013.
2. D'Azzo J. J., Houpis, C.H. and Sheldon, S.N., Linear Control System Analysis and Design with MATLAB, 6th ed., CRC Press, 2014.
3. Kuo, B.C. and Golnaraghi F., Automatic Control Systems, 8th ed., Wiley India, 2011.
4. Nise, N.S., Control Systems Engineering, 6th ed., Wiley, 2013.
5. Gopal, M., Control Systems: Principles and Design, 3rd ed., Tata McGraw Hill Education, 2010.


## EEL303 POWER ELECTRONICS (3-0-2-8)

### Contents:

Power semiconductors devices and switching circuits: SCR and its characteristics, SCR ratings , series and parallel operations of SCRs, triggering circuits, commutating circuits, protection of SCR. gate circuit protection, over voltage and over current protection, snubber circuit design, converter circuit faults and their protection, uni-junction transistor (UJT).
Static controllable switches: characteristics and working of MOSFET, gate turn off thyristor and insulated gate bipolar transistor.
Phase controlled rectifiers: working of single pulse and two pulse converters. Three pulse midpoint converter and 3 phase six pulse bridge converter. Effect of source inductance in converters, effect of freewheeling diode. Speed control of DC motor using converter.
D.C choppers: classification, principles of step down chopper and step up chopper, thyristor chopper circuit, multiphase choppers and application of low power circuits.
DC to AC converters: single phase and three phase bridge inverters, output voltage control, harmonics in output voltage waveform, harmonics attenuation by filters. Harmonic reduction by pulse width modulation techniques, analysis for single pulse width modulation, working of current source inverters, applications of inverters.
Voltage regulators: operation & analysis of single phase integral cycle and phase controlled converters, configuration of three phase controllers.
Cycloconverters: single phase and three phase configurations and operating principle.

### Text Books:


1. Dubey, G.K., Fundamentals of Electrical Drives, 2nd ed., Narosa Publication, 2013.
2. Mohan, Ned, Undeland, T.M. and Robbins, W.P., Power Electronics, 3rd ed., Wiley India,2014.


### Reference Books:


1. Singh, M.D. and Khanchandani K.B., Power Electronics, 2nd ed., Tata McGraw Hill Education, 2012.
2. Rashid, M.H., Power Electronics: Circuits Devices & Applications, 3rd ed., Pearson Education, 2012.
3. Bose, B.K., Modern Power Electronics and AC Drives, PHI Learning, New Delhi, 2012.
4. Lander, C.W., Power Electronics, 3rd ed., McGraw Hill, 1993.
5. Bimbhra, P.S., Power Electronics, Khanna Publishers, 2012.


## EEL304 SWITCHED MODE POWER CONVERTERS (3-2-0-8)

### Contents:

The ideal switch, basic switch cell, basic topology rules, possible basic converter topologies, buck, boost, buck-boost, steady state analysis, dc transformer equivalent.
Switch characteristics of common switches: power diodes, SCRs, power BJTs, GTOs, power MOSFETs, IGBTs, conduction and switching loss, V-I plane representation of switches, switch realization from basic switch cell, drive requirements for switches, drive circuits, switching aid networks, designing with real switches, switch selection, loss calculation, basics of thermal design.
Effect of non-idealities on converter performance, efficiency, steady-state voltage gain, state space averaging, basics of small signal analysis, ac equivalent circuit.
Control of converters, voltage mode control, review of bode plots, design of converter controls.
Resonant converters, Parallel loaded and series loaded resonant converters, transfer characteristics, design.
Inverters: basic two-level inverters, topology derivation and switching schemes, PWM methods, sine-triangle and space-phasor methods.
Multi-level inverters: basic topology derivation and introduction to PWM schemes for multi-level inverters.

### Text Books:


1. Mohan, Ned, Undeland, T.M. and Robbins, W.P., Power Electronics, 3rd ed., Wiley India, 2014.
2. Vithayathil, J., Power Electronics: Principles and Applications, Tata Mc Graw Hill, 2013.


### Reference Book:


1. Ericksson, R., and Maksimovic D., Fundamentals of Power Electronics, 2nd ed., Springer, 2013.


## EEL305 SOFT COMPUTING TECHNIQUES (3-0-2-8)

### Contents:

Introduction, brief history of artificial intelligence, comparison with deterministic methods, aims, objectives of artificial intelligence and current state of the art.

Expert systems: introduction to knowledge based systems structure and definitions knowledge acquisition inference engine, forward and backward chaining.
Fuzzy logic: introduction to concepts, fuzzy reasoning, defuzzification,adaptive fuzzy systems.
Artificial neural networks: basic concepts, back-propagation, multi-layer networks, introduction to various paradigms, learning in neural networks.
Evolutionary computing (genetic algorithms): basic concepts, applications of AI to power systems like alarm processing, condition monitoring, protective relaying etc.

### Text Books:


1. Zurada, J.M., Introduction to Artificial Neural Systems, Jaico Publication House, 2006.
2. Haykin, S.S., Neural Networks and Learning Machines, 3rd ed., PHI Learning, 2013.


### Reference Books:


1. Deb, K., Multi-Objective Optimization Using Evolutionary Algorithms, John Wiley and Sons, 2009.
2. Hagan, M.T., Demuth, H.B. and Beale, M.H., Neural Network Design, Vikas Publishing House, New Delhi, 2004.


## EEL306 POWER QUALITY ISSUES AND SOLUTIONS (3-0-0-6)

### Contents:

Power system components: single line diagram of power system. Transmission lines: configurations, types of conductors, resistance of line, skin effect, Kelvin's law, proximity effect.Voltage sags and interruptions: sources of sags and interruptions, end user issues, Ferro resonant transformer, on-line UPS, hybrid UPS, motor generator set, SMES etc., motor starting sags, utility system fault clearing issues.
Transient over voltage: sources of transient over voltages, principles of over voltage protection, devices for over voltage protection, utility capacitor switching transients, utility lightning protection, load-switching transient problems.
Harmonics: voltage and current harmonics distortions, harmonics of single-phase power supplies, effects of harmonics distortion, system response characteristics, locating sources of harmonics, peripherals for controlling harmonics, devices for filtering harmonics distortion, harmonics study procedure, symmetrical components, modeling harmonics sources, harmonic filter design, telecommunication interferences, computer tools for harmonic analysis.

### Text Books:


1. Kennedy, B.W., Power Quality Primer,Mc-Graw Hill, 2000.
2. Dugan, R.C. and et.al.,Electrical Power Systems Quality, 3rd ed., Tata McGraw Hill, 2012.


### Reference Book:


1. Kazibwe, W.E. and Sendaula, M.H., Electric Power Quality Control Techniques, Van Nostrand Reinhold, 1993.


## EEL307 ELECTRICAL AND INDUSTRIAL SAFETY (3-0-0-6)

### Contents:

Review of electrical concept, working principle of major electrical equipment, typical supply situation, standards and statutory requirements, Indian electricity acts and rules, Indian boiler acts and regulations statutory requirements from electrical inspectorate. International standards of electrical safety, first aid-cardio pulmonary resuscitation (CPR).
Electrical hazards, effect of electrical shock of human being, effect of lightening current on installation and buildings, energy leakage, clearance and insulation, excess energy, current, surges, electrical causes of fire and explosion, importance of earthing in installation.
National electrical safety code. General safety rules, principles, maintenance, inspections.

### Text Books:


1. Krishnan, N.V., Safety Management in Industry, Jaico Publishing House, 1997.
2. Cooper W.F., Electrical Safety Engineering,3rd ed., Newnes, 2002.


### Reference Books:


1. Cadick, J., et. al., Electrical Safety Handbook, 4th ed, McGraw Hill, 2013.
2. Bureau of Indian Standards, National Electrical Code 2011, Bureau of Indian Standards, New Delhi, 2011.
3. Manchanda, S.C., Manchanda's the Indian Boilers Regulations, 1950 and the Indian Boilers Act, 1923 (Act No. V of 1923), 2nd ed., Delhi Law House, Delhi, 2009.


## EEL308 INDUSTRIAL INSTRUMENTATION (3-0-2-8)

### Contents:

**Measurement of force torque, velocity**: electric balance, different types of load cells, magnets, elastics load cell, strain gauge load cell, different methods of torque measurement, strain gauge, relative regular twist, speed measurement, revaluation counter, capacitive tacho-drag up type tacho D.C and A.C tacho generators, stroboscope.

**Measurement of acceleration, vibration and density**: accelerometers,

LVDT, piezo-electric, strain gauge and variable reluctance type accelerometers, mechanical type vibration instruments, seismic instrument as an accelerometer and vibrometer, calibration of vibration pickups, units of density, specific gravity and viscosity used in industries, Baume scale, API scale, pressure head type densitometer, float type densitometer, ultrasonic densitometer bridge type gas densitometer.

**Pressure measurement**: units of pressure, manometers, different types, elastic type pressure gauges, Bourde type bellows, diaphragms, electrical methods, elastic elements with LVDT and strain gauges, capacitive type pressure gauge, piezo resistive pressure sensor, resonator pressure sensor, measurement of vacuum, McLeod gauge, thermal conductivity gauges, ionization gauge cold cathode and hot cathode types, testing and calibration of pressure gauges, dead weight tester.

**Temperature measurement**: definitions and standards, primary and secondary fixed points, calibration of thermometers different types of filled in system thermometer, sources of errors in filled in systems and their compensation, bimetallic thermometers, electrical methods of temperature measurement signal conditioning of industrial RTDs and their characteristics, 3 lead and 4 lead RTDs.

**Thermocouples and pyrometers:** thermocouples, law of thermocouple, fabrication of industrial thermocouples, signal conditioning of thermocouple output, thermal block references functions, commercial circuits for cold junction compensation, response of thermocouple, special techniques for measuring high temperature using thermocouples, radiation methods of temperature measurement, radiation fundamentals, total radiation and selective radiation pyrometers, optical pyrometer, two colour radiation pyrometer.
Introduction to sequence control, PLCs and relay ladder logic.

### Text Books:


1. Doebelin, E.O. and Dhanesh, N.M, Measurement Systems,6th ed., Tata McGraw Hill Education Private Limited, 2012.
2. Krishnaswamy, K. and Vijayachitra, S., Industrial Instrumentation, 2nd ed., New Age International Publication, 2013.


### Reference Books:


1. Rangan, C.S., Sarma, G.R. and Mani, V.S.V., Instrumentation: Devices and Systems, 2nd ed., Tata McGraw Hill, 1997.
2. Cooper, W.D. and Helfrick, A.D., Modern Electronic Instrumentation and Measurement Techniques, 3rd ed., PHI Learning Private Limited, 2012.


## EEL309 ELECTRIC DRIVES (3-0-2-8)

### Contents:

Definitions, classification and speed torque characteristics of common industrial loads & drive motors and their characteristics under starting, running, braking and speed control.
Rating & service Capacity: selection of motor, power capacity for continuous and intermittent periodic duties.
Load equalization: flywheel effect, speed-time relations.
Programmable logic controllers: basic construction, operation block diagram arrangement, its elementary programming and applications in electric drives.
AC and DC contactors and relays: magnetic structure, operation, arc interruption contactor rating, H.V. contactors, control circuits for automatic starting and braking of DC motor and three phase induction motor, control panel design.
Traction motors: motor used in AC/DC traction, their performance and desirable characteristics, requirements and suitability of motor for traction duty. Control of D.C. traction motor, series parallel control. Starting and braking of traction motor.

### Text Books:


1. Dubey, G.K., Fundamentals of Electrical Drives, 2nd ed., Narosa Publication, 2013.
2. Partab H., Modern Electrical Traction; Dhanpat Rai and Co. Pvt. Ltd, 2014.


### Reference Books:


1. Subrahmanyam, V., Electric Drives: Concepts and Applications, 2nd ed., Tata McGraw Hill Education, New Delhi, 2011.
2. Soni, M.L., Gupta, P.V. and Bhatnagar, U.S., A Course in Electrical Power, Dhanpat Rai & Sons, New Delhi, 1987.


## EEL310 CONTROL SYSTEM DESIGN (3-2-0-8)

### Contents:

Introduction to design: state-space models, performance measures like ISE, ITAE, quadratic indices, controllability and observability. Linear quadratic regulator (LQR), performance index, optimal control law, algebraic Riccati equation, frequency-domain interpretation. Linear quadratic Gaussian (LQG): statistical descriptions of noise, Kalman filter, stability margins. H design, uncertainty descriptions, robustness measures, formulation for control synthesis, Riccati equation, and model-order reduction. Case studies, inverted pendulum, missile guidance, process control. Software based design of industrial controllers.

### Text Books:

1. Dorf, R.C., Modern Control System, 11th ed., Pearson Education, 2013.
2. Nise, N., Control System Engineering, 6th ed., John Wiley & Sons, 2013.

### Reference Books:

1. Anderson, B.D.O. and Moore, J.B., Optimal Control: Linear Quadratic Methods, Dover Publications, 2007.
2. Friedland, B., Control System Design: An Introduction to State-Space Methods, Dover Publications, 2012.
3. Doyle, J.C., Francis, B.A. and Tannenbaum, A.R., Feedback Control Theory, Dover Publications, 2009.

## EEL312 ELECTRICAL ENERGY SYSTEM (3-0-0-6)

### Contents:

**Introduction**, fossil fuel based systems, impact of fossil fuel based systems, non-conventional energy, seasonal variations and availability, renewable energy, sources and features, hybrid energy systems, distributed energy systems and dispersed generation (DG)

**Solar thermal systems**: solar radiation spectrum, radiation measurement, technologies, applications, heating, cooling, drying, distillation, power generation.

**Solar photovoltaic systems:** operating principle, photovoltaic cell concepts, cell, module, array, series and parallel connections, maximum power point tracking, applications, battery charging, pumping, lighting, peltier cooling.

**Microhydel**: operating principle, components of a microhydel power plant, types and characteristics of turbines, selection and modification, load balancing.

**Wind**: wind patterns and wind data, site selection, types of wind mills, characteristics of wind generators, load matching.

**Hybrid systems:** need for hybrid systems, range and type of hybrid systems, case studies of diesel-PV, wind-PV, microhydel-PV, electric and hybrid electric vehicles.

Tariffs and cost of energy under regulated and de-regulated environment, energy audit and its methodologies.

### Text Books:

1. Rai, G.D., Non-Conventional Energy Sources, 5th ed., New Age International, 2013.
2. Ramesh, R., Renewable Energy Technologies: Ocean Thermal Energy Conversion and other Sustainable Energy Options, Narosa, New Delhi, 1997.

### Reference Book:

1. Vanek, F.M., Albright, L.D. and Angenent, L.T., Energy Systems Engineering: Evaluation and Implementation, 2nd ed., Tata McGraw Hill, 2012.

## EEL313 ELECTRICAL DISTRIBUTION SYSTEM (3-0-0-6)

### Contents:

General concepts: introduction to distribution systems, load modelling and characteristics. Coincidence factor, contribution factor loss factor-relationship between the load factor and loss factor.Classification of loads (residential, commercial, agricultural and industrial) and their characteristics. Distribution feeders: design consideration of distribution feeders: radial and loop types of primary feeders, voltage levels, feeder loading; basic design practice of the secondary distribution system. Substations: location of substation, rating of distribution substation, service area within primary feeders. Benefits derived through optimal location of substations. System Analysis: voltage drop and power-loss calculations, derivation for voltage drop and power loss in lines, manual methods of solution for radial networks, three phase balanced primary lines. Protection: objectives of distribution system protection, types of common faults and procedure for fault calculations. Protective devices: principle of operation of fuses, circuit re-closures, line sectionalizes, and circuit breakers. Coordination: coordination of protective devices: general coordination procedure. Compensation for power factor improvement, capacitive compensation for power-factor control. Different types of power capacitors, shunt and series capacitors, effect of shunt capacitors (fixed and switched), power factor correction, capacitor allocation- economic justification, procedure to determine the best capacitor location. Voltage control: equipment for voltage control, effect of series capacitors, effect of AVB/AVR, line drop compensation.

### Text Books:

1. Gonen, T., Electric Power Distribution System Engineering, 3rd ed.,CRC Press 2014.
2. Pabla, A.S., Electric Power Distribution, 6th ed., Tata McGraw Hill, 2012.

### Reference Books:

1. Sivanagaraju, S. and Sankar, V., Electrical Power Distribution and Automation, Dhanpat Rai & Co, 2006.
2. Kamaraju, V., Electrical Power Distribution Systems, Tata McGraw Hill Education, New Delhi, 2011.

## EEL314 HIGH VOLTAGE ENGINEERING (3-0-0-6)

### Contents:

Levels of high voltage, votage levels, electrical insulation and dielectrics, importance of electric field intensity in the dielectrics, types of electric fields and degree of uniformity of fields, utilization of dielectric properties and stress control. Properties of atmospheric air, SF6 and vacuum, relate deionization process, properties in vacuum, related ionization process, development of electron Avalanche, breakdown mechanisms, Townsend's mechanism, breakdown mechanisms, streamer mechanism, breakdown in uniform fields (Paschen's law), breakdown of gaseous dielectrics in weakly non-uniform and the limiting value of Î, development of PB in extremely non-uniform fields, breakdown characteristics in air with stable PB (corona). Classification and properties of liquid dielectrics, classification and properties of solid dielectrics, classification and properties of liquid dielectrics, classification and properties of solid dielectrics, insulation resistance, conductivity and losses in dielectrics, partial breakdown phenomenon in dielectrics, partial breakdown phenomenon on the surfaces of solid and liquid dielectrics and degradation due to PB. Definition and measurements of intrinsic and practical breakdown strengths of liquid dielectrics, measurement of intrinsic breakdown in solid dielectrics, thermal and other breakdown mechanisms in extremely non-uniform fields, comparison of the development of breakdown in extremely and weakly non-uniform fields and the requirement of time for breakdown in solid dielectrics. methods of generation of power frequency highest voltage, transformers in cascade, resonance transformers, generation of high DC voltage, voltage multiplier circuits and ripple minimization, sources of overvoltage and standard lightning and switching wave shapes, impulse voltage generator, analysis of single stage circuit, multistage impulse generator and their triggering methods. Peak high voltage measurement techniques, sphere gap, construction, effects of earthed objects and atmospheric conditions, electrostatic voltmeters, principle and construction.Potential dividers, their types and applications. Measurable properties of dielectrics, measurement of dielectric properties with Schering Bridge and Mega ohm meter, partial breakdown (PB), measurement techniques in dielectrics/equipment. Over voltages and basic insulation level design systems.

### Text Books:

1. Kimbark, E.W., Direct Current Transmission, Wiley-Interscience, New York, 1971.
2. Padiyar, K.R., HVDC Power Transmission Systems, 2nd ed., New Age International, 2013.

### Reference Book:

1. Arrillaga, J., Liu, Y.H. and Watson, N.R., Flexible Power Transmission: The HVDC Options, Wiley, 2007.

## EEL315 ELECTRICAL UTILIZATION AND TRACTION (3-0-0-6)

### Contents:

Electric traction: features of an ideal traction system, systems of electric traction, mechanism of train movement, speed-time curve, traction supply system, transmission line to substation, feeding and distributing system on an ac traction, system of current collection, traction motors, tractive effort and horse power, speed control schemes, electric braking.

Electric heating: classification, heating element, losses in oven and efficiency, resistance furnace, radiant heating, induction heating, high frequency eddy current heating, dielectric heating, arc furnace, heating of buildings.

Electric welding: methods and equipment, electrolysis and electroplating applications.

Illumination: radiant energy, terms and definitions, laws of illumination, polar curves, photometry, MSCP, integrating sphere, luminous efficacy, electrical lamps, design of interior and exterior lighting systems, illumination levels for various purposes, light fittings, factory lighting, flood lighting,street lighting, energy conservation in lighting. Air conditioning and refrigeration: control of temperature, protection of motors, simple heat load and motor calculations. Air-conditioning, function of complete air conditioning system, type of compressor motor. Cool storage, estimation of tonnage capacity and motor power. Technology of electric and hybrid electric vehicles.

### Text Books:

1. Openshaw, T.E., Utilisation of Electric Energy, Orient Longman, 2007.
2. Gupta, J.B., Utilization of Electric Power and Electric Traction, S.K. Kataria and Sons, 2013.

### Reference Book:

1. Arrillaga, J., Liu, Y.H. and Watson, N.R., Flexible Power Transmission: The HVDC Options, Wiley, 2007.

## EEL401 SWITCHGEAR AND PROTECTION (3-0-2-8)

### Contents:

Faults in power supply system: symmetrical component transformation. Three phase power in unbalanced circuit in terms of symmetrical component. Sequence impedance of generator, transformer transmission line & passive loads. Phase shift in star/delta three phase transformer (Yd1, Yd11 connection), symmetrical fault analysis without & with prefault load currents, selection of circuit breakers ratings, current limiting reactors.

Unsymmetrical fault analysis, L-G, L-L-G-, L-L, open conductors fault using symmetrical components.

General philosophy of protective relaying: protective zones. Primary protection, back up protection, remote and local back up, selectivity

Medium voltage line protection: overcurrent relaying directional over current relays.

High voltage line protection: distance relays, carrier distance schemes. Unit carrier schemes.

Equipment protection: principles of differential relaying, protection of generator, transformers and busbars by differential relaying and other relays. Protection of induction motor's against overload, short-circuits, thermal release, miniature circuit breaker.

Introduction to numerical relays: comparison of static and electro-mechanical relays, two input amplitude and phase comparators and their duality. Generation of various distance relay characteristics using above comparators.

Switchgear: circuit breakers, arc interruption theory, recovery and restriking voltages, RRRV, breaking of inductive and capacitive current, C.B. ratio, different media of arc interruption, SF6 and vacuum breakers.

### Text Books:


1. Ram, B. and Vishwakarma, D.N. Power System Protection & Switchgear, 2nd ed., Tata McGraw Hill, 2013.
2. Paithankar, Y.G. and Bhide, S.R., Fundamentals of Power System Protection, 2nd ed.,PHI Learning, 2013.


### Reference Books:


1. Elmore, W.A, Protective Relaying Theory and Applications, 2nd ed., Marcel Dekker, New York, 2004.
2. Mason, C.R., Art and Science of Protective Relaying, Wiley, New York, 1968.
3. Warrington, A.R.V., Protective Relays: Their Theory and Practice (Vol. I & Vol. II), 3rd ed., Chapman and Hall, London, 1978.


## EEL402 SPECIAL ELECTRICAL MACHINES DESIGN (2-0-2-6)

### Contents:

Review of material used in construction of electrical machines. Classification of insulating materials depending upon permissible temperature rise, properties of transformer oil, standard specifications, C.M.R. and short time rating of machines. Heating and cooling characteristics.

Transformer design: specific loading, equation for voltage per turn for power and distribution transformer output equation.

Principle of electric and magnetic circuits, design, method of cooling and cooling circuit design.Estimation of performance characteristics from the design data.

Inductor motor: main dimensions, output equation, loading constants, estimation of axial lengths, air gap diameter, winding design. Air gap length, slot dimension for stator and rotor I.M., cage rotor and wound rotor design, calculation of no load current and other performance on characteristics for design data.

Synchronous machines: air gap length, methods of obtaining sinusoidal output voltage, field coil design for salient pole machine and for turbo generator rotor. Ventilation of synchronous generator, cooling air circuits, closed ventilation, quantity of cooling medium, hydrogen and water as cooling media.

### Text Books:


1. Sawhney, A.K, Electrical Machine Design, Dhanpat Rai and Sons, Delhi, 2013.
2. Singh, B., Electrical Machine Design, Vikas Publishing House Private Limited, New Delhi, 1982


### Reference Books:


1. Say, M.G., Performance and Design of AC Machines, 3rd ed., CBS Publishers and Distributors, 2008.
2. Pyrhonen, J., Jokinen, T. and Hrabovcova, V., Design of Rotating Electrical Machines, 2nd ed., Wiley, 2014.


## EEL403 OPTIMAL CONTROL THEORY (3-2-0-8)

### Contents:

Basic mathematical concepts, conditions for optimality, static and dynamic optimization.Parameter optimization. Calculus of variations: problems of Lagrange. Mayer and Bolza.Euler-Language equation and transversality conditions, Lagrange's multipiliers.

Pontryagin's maximum principle: theory, application to minimum time, energy and control effort problems, and terminal control problem.

Dynamic programming : Belaman's principle of optimality, multistage decision processes. Application to optimal control.

Linear regulator problem : matrix Riccati equation and its solution, tracking problem, brief introduction to H-2 and H-infinity optimal control problem.

### Text Books:


1. Kirk, D. E., Optimal Control Theory: An Introduction, Dover Publications, 2004.
2. Kwakernaak, H. and Sivan, R., Linear Optimal Control Systems, Wiley-Interscience, 1972.


### Reference Books:


1. Anderson, B.D.O. and Moore, J.B., Optimal Control: Linear Quadratic Methods, Dover Publications, 2007.
2. Sage, A.P. and White, C.C., Optimum Systems Control, 2nd ed., Prentice Hall, 1977.
3. Tabak, D. and Kuo, B.C., Optimal Control by Mathematical Programming, Prentice Hall, 1971.
4. Athans, M. and Falb, P.L., Optimal Control: An Introduction to the Theory and its Applications, Dover Publications, 2007


## EEL404 COMPUTER CONTROL AND AUTOMATION OF POWER SYSTEMS (3-0-0-6)

### Contents:

Energy management systems (EMS): energy management centers and their functions, architectures, recent developments, characteristics of power generating units and economic dispatch, unit commitment (spinning reserve, thermal, hydro and fuel constraints), solution techniques of unit commitment. Generation scheduling with limited energy, energy production cost, cost models, budgeting and planning, practical considerations, interchange evaluation for regional operations, types of interchanges, exchange costing techniques.

Supervisory control and data acquisition (SCADA): introduction to supervisory control and data acquisition. SCADA functional requirements and components, general features, functions and applications, benefits. Configurations of SCADA, RTU (remote terminal units) connections, power systems SCADA and SCADA in power system automation. SCADA communication requirements. SCADA communication protocols: past present and future, structure of a SCADA communications protocol.

### Text Books:


1. Wood, A. J., Wollenberg, B.F. and Sheble, G.B., Power Generation Operation and Control,3rd ed.,Wiley-Interscience, 2014.
2. Green J.N, Wilson, R,Control and Automation of Electric Power Distribution Systems,CRC Press, 2013.


### Reference Books:


1. Handschin E. and Petroianu, A., Energy Management Systems: Operation and Control of Electric Energy Transmission Systems, Springer Verlag, 1991.
2. Handschin, E., Real-Time Control of Electric Power Systems, Elsevier, 1972.
3. McDonald, J.D., Electric Power Substations Engineering, 3rd ed., CRC Press, 2012.


## EEL405 FACTS (3-0-0-6)

### Contents:

Introduction of semiconductor devices, need of FACTS, steady state and dynamic problems in AC systems, power flow, types of conductors in transmission line.

Flexible AC transmission systems (FACTS): basic realities & roles, types of facts controller, principles of series and shunt compensation, thermal ratings.

Description of static VAR compensators (SVC), thyristor controlled series compensators (TCSC), static phase shifters (SPS), static condenser (STATCON), static synchronous series compensator (SSSC) and unified power flow controller (UPFC), IEEE standards, DVR, circuit operation and control.

Modelling and analysis of FACTS controllers, control strategies to improve system stability, harmonics, harmonics creating loads, modeling, harmonic power flow, mitigation of harmonics, filters, passive filters, location of FACTS devices, real life examples, BEP.

### Text Books:


1. Hingorani, N. G. and Gyugi, L., Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, IEEE Press, Delhi, 2001,
2. Padiyar, K.R., FACTS Controllers in Power Transmission and Distribution, New Age International Publisher, 2013.


### Reference Book:


1. Ghosh, A. and Ledwich, G., Power Quality Enhancement Using Custom Power Devices, Springer Verlag, 2012.


## EEL406 DISCRETE DATA AND DIGITAL CONTROL (3-2-0-8)

### Contents:

Sampling and data reconstruction processes: sampled, data control systems, ideal sampler, sampling theorem, sample and hold operations, frequency domain considerations.

Z-transforms: properties inverse, applications to solution of difference equations, convolution sums.

Stability of discrete systems: location of poles, jury's stability criterion, stability analysis through bilinear transforms.

Design of digital control systems: PID controllers and frequency domain compensation design.

State variable methods and the discrete linear regulator problem.

### Text Books:

1. Ogata, K., Discrete Time Control System, 2nd ed., Prentice Hall of India, 2011.
2. Gopal, M., Digital Control Engineering and State Variable Methods: Conventional and Intelligent Control Systems, 4th ed., Tata McGrawHill,2012.

### Reference Books:

1. Isermann, R., Digital Control Systems, 2nd ed., Springer, 1997.
2. Landau, Y.D. and Zito, G., Digital Control Systems: Design, Identification and Implementation, Springer, 2006

## EEL407 POWER PLANT ENGINEERING (3-0-0-6)

### Contents:

Conventional Sources of electrical energy: Steam, hydro, nuclear, diesel and gas, their scope and potentialities for energy conversion.

Generation: different factors connected with a generating station, load curve, load duration curve, energy load curve, base load and peak load plants.

Thermal stations: selection of site, size and no. of units, general layout, major parts, auxiliaries, generation costs of steam stations.

Hydro stations: Selection of site, mass curve, flow duration curve, hydrograph, classification of hydro plants, types of hydro turbines, pumped storage plants.

Nuclear stations: main parts, location, principle of nuclear energy, types of nuclear reactors, reactor control, nuclear waste disposal.

Power station control and interconnection: excitation systems, excitation control, automatic voltage regulator action, advantage of interconnection.

Economic operation of power system: introduction, distribution of load between units within the plant, optimum generation scheduling considering transmission losses.

Alternate energy sources: solar, wind, geo-thermal, ocean-thermal, tidal wave, MHD and biomass.

### Text Books:

1. Deshpande, M.V., Elements of Electrical Power Station Design, 5th ed.,PHI, 2013.
2. Gupta, B.R.,Generation of Electrical Energy,S. Chand, New Delhi, 2013.

### Reference Books:

1. Nag, P.K., Power Plant Engineering, 3rd ed., Tata Mc-Graw Hill Education, 2013.
2. Raja, A.K., Srivastava, A.P. and Dwivedi, M., Power Plant Engineering, New Age International Private Limited, New Delhi, 2006.

## EEL409 PROCESS CONTROL AND INSTRUMENTATION (3-0-2-8)

### Contents:

An introduction to automatic process control, basic concepts and techniques, selection of controlled variables & manipulated variables, controller selection and tuning procedures, dynamic behavior of process model, special feedback techniques, direct synthesis and adaptive control, decoupling and feed-forward methods, various multiple loop feedback control strategies widely used in in dustries, such as cascade, ratio, split-range, selective, feed-forward compensation, sensors, transmitters, transducers and actuators, final control elements, selection of a controller's action and direction, basics of industrial automation systems: PLCs and distributed control systems (DCS), their features and applications.

Types of processes: dead time signal and multi-capacity, self and non-self-regulating , interaction and non-interaction, linear and non-linear, process gain , process reaction curve, process time constant and constant step analysis method for finding time constant, dead time, dynamic element in control loop, PID control of processes, tuning of PID controllers, basic idea of MPC.

### Text Books:

1. Shinskey, F.G., Process Control Systems: Application, Design and Tuning, 4th ed., McGraw Hill, 1996.
2. Chaudhuri, U.R. and Chaudhuri, U.R., Fundamentals of Automatic Process Control, CRC Press/Taylor and Francis, 2013.

### Reference Books:

1. Rao, A.R., Process Control Engineering, Gordon and Breach Science Publishers, 1993.
2. Bequette, B.W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2010.

## EEL410 HVDC (3-0-0-6)

### Contents:

Evolution of HVDC transmission, comparison of HVAC and HVDC systems, type of HVDC transmission systems, components of HVDC transmission systems, analysis of simple rectifier circuits, required features of rectification circuits for HVDC transmission, analysis of HVDC converter, different modes of converter operation, output voltage waveforms and DC voltage in rectification, output voltage waveforms and DC in inverter operation, thyristor voltages, equivalent electrical circuit, HVDC system control features, control modes, control schemes, control comparisons.

Converter mal-operations, commutation failure, starting and shutting down the converter bridge, converter protection, smoothing reactor and DC Lines, reactive power requirements, harmonic analysis, filter design.

Component models for the analysis of AC DC systems, power flow analysis of AC-DC systems, transient stability analysis, dynamic stability analysis.

Multi terminal HVDC system, advances in HVDC transmission, HVDC system application in wind power generation.

### Text Books:

1. Padiyar, K.R., HVDC Power Transmission Systems, 2nd ed., New Age International, 2013.
2. Kimbark, E.W., Direct Current Transmission, Wiley-Interscience, New York, 1971.

### Reference Books:

1. Singh, S.N., Electric Power Generation, Transmission and Distribution, 2nd ed., PHI Learning, New Delhi, 2010.
2. Arrillaga, J., High Voltage Direct Current Transmission, 2nd ed., Institution of Engineering and Technology, London, 2008.

## EEL411 POWER SYSTEM ECONOMICS AND MANAGEMENT (3-0-0-6)

### Contents:

Economic operation of power systems: optimal operation of generators in thermal power stations, heat rate curve, cost curve, incremental fuel and production costs, input-output characteristics, optimum generation allocation with line losses neglected.

Optimum generation allocation including the effect of transmission line losses, loss coefficients, general transmission line loss formula.

Hydrothermal scheduling: optimal scheduling of hydrothermal system, hydroelectric power plant models, scheduling problems-short term, hydrothermal scheduling problem.

Modeling of turbine, generator and automatic controllers, modelling of turbine, first order turbine, model, block diagram representation of steam turbines and approximate linear models.

Modelling of generator (steady state and transient models), description of simplified network model of a synchronous machine (classical model), description of swing equation (no derivation) and state-space II-order mathematical model of synchronous machine.

Modelling of governor: mathematical modelling of speed governing system, derivation of small signal transfer function.

Modelling of excitation System: fundamental characteristics of an excitation system, transfer function, block diagram representation of IEEE type-1 model.

Single area load frequency control: necessity of keeping frequency constant, definitions of control area, single area control, block diagram representation of an isolated power system, steady state analysis, dynamic response, uncontrolled case.

Two-area load frequency control: load frequency control of 2-area system, uncontrolled case and controlled case, tie-line bias control.

Load Frequency Controllers: proportional plus Integral control of single area and its block diagram representation, steady state response, load frequency control and economic dispatch control.

Reactive power control: overview of reactive power control, reactive power compensation in transmission systems, advantages and disadvantages of different types of compensating equipment for transmission systems, load compensation, specifications of load compensator, uncompensated and compensated transmission lines, shunt and series compensation.

### Text Books:

1. Shinskey, F.G., Process Control Systems: Application, Design and Tuning, 4th ed., McGraw Hill, 1996.
2. Chaudhuri, U.R. and Chaudhuri, U.R., Fundamentals of Automatic Process Control, CRC Press/Taylor and Francis, 2013.

### Reference Books:

1. Rao, A.R., Process Control Engineering, Gordon and Breach Science Publishers, 1993.
2. Bequette, B.W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2010.