B. Tech. (Electrical and Electronics Engineering)

OVERALL CREDIT STRUCTURE

Undergraduate Core (UC)		Undergraduate Elective (UE)	
Category	*Credit*	*Category*	*Credit*
DC	67	**DE**	23 (minimum)
BS	19	**HM**	06 (minimum)
ES	22	**OC**	18 (Balance)
HM	05	**UN**	0 (03 Courses)
Total	113	**Total**	47
Grand Total (UC + UE)			**160**

Basic Science (BS)			
Course Code	**Course**	**L-T-P**	**Credit**
SCL152	Applied Mathematics-I	3-2-0	04
SCL153	Applied Mathematics-II	3-2-0	04
SCL251	Applied Mathematics-III*	3-0-0	03
SCL154	Applied Physics	3-0-0	03
SCP154	Applied Physics Lab	0-0-2	01
SCL155	Applied Chemistry	3-0-0	03
SCP155	Applied Chemistry Lab	0-0-2	01
Total			**19**

Humanities and Management (Core) (HM)			
Course Code	**Course**	**L-T-P**	**Credit**
HMP152	Technical Communication	2-0-2	03
HML151	Social Science	2-0-0	02
Total			**05**

Engineering Arts and Science (ES)			
Course Code	**Course**	**L-T-P**	**Credit**
MEL152	Elementary Mechanical Engineering	3-0-0	03
EEL151	Elementary Electrical Engineering	3-0-0	03
EEP151	Elementary Electrical Engineering Lab	0-0-2	01
MEL151	Basic Electronics Engineering	3-0-0	03
MEP151	Basic Electronics Engineering Lab	0-0-2	01
MEL151	Engineering Drawing	3-0-0	03
MEP151	Engineering Drawing Lab	0-0-2	01
CSL151	Computer Programming and Problem Solving	3-0-0	03
CSP151	Computer Programming Lab	0-0-2	01
MEP152	Mechanical Workshop	0-0-2	01
CEL151	Environmental Science	2-0-0	02
Total			**22**

Non Credit Requirement (UN)			
Course Code	**Course**	**L-T-P**	**Credit**
NCN151	NCC#	-	0
NCN152	NSS#	-	0
NCN153	NSO#	-	0
SPB151	Sports-I#	0-0-4	0
SPB152	Sports-II#	0-0-4	0
HMD251	Community Project	-	0
EET251	Practical Training	-	0

#A student has to opt at least one from NCC, NSS, NSO and Sports (I & II both).

Departmental Core (DC)			
Course Code	**Course**	**L-T-P**	**Credit**
EEL251	Basic Electrical Circuits	3-0-0	03
EEP251	Basic Electrical Circuits Lab	0-0-2	01
EEL252	Measurement & Instrumentation	3-0-0	03
EEP252	Measurement & Instrumentation Lab	0-0-2	01
EEL253	Electrical Machines I	3-0-0	03
EEP253	Electrical Machines I Lab	0-0-2	01
EEL254	Control System	3-0-0	03
EEP254	Control System Lab	0-0-2	01
EEL255	Power Electronics	3-0-0	03
EEL256	Power System I	3-0-0	03
ECL251	Signals and Systems	3-2-0	04
ECL252	Analog Circuits	3-0-0	03
ECP252	Analog Circuit Lab	0-0-2	01
ECL254	Engineering Electromagnetics	3-0-0	03
ECL256	Digital Circuits	3-0-0	03
ECP256	Digital Circuits Lab	0-0-2	01
EEL351	Electrical Machines II	3-0-0	03
EEP351	Electrical Machines II Lab	0-0-2	01
EEL352	Electric Drives	3-0-0	03
EEP352	Electric Drives Lab	0-0-2	01
EEL353	Power System II	3-0-0	03
EEL354	Advanced Power Electronics	3-0-0	03
EEP354	Power Electronics Lab	0-0-2	01
EEL355	Switchgear & Protection	3-0-0	03
EEP355	Switchgear & Protection Lab	0-0-2	01
ECL351	Linear Integrated Circuits	3-0-0	03
ECP351	Linear Integrated Circuits Lab	0-0-2	01
ECL353	Microcontroller & Interfacing	3-0-0	03
ECP353	Microcontroller & Interfacing Lab	0-0-2	01
EED 351	Minor Project	-	01
EED 451	Major Project	-	02

Departmental Elective (DE)			
Course Code	**Course**	**L-T-P**	**Credit**
EEL 451	Computer Control and Automation of Power Systems	3-0-0	03
EEL 452	Discrete Data and Digital Control	3-2-0	04
EEL 453	Power Plant Engineering	3-0-0	03
EEL 454	HVDC	3-0-0	03
EEL 455	Power System Economics and Management	3-0-0	03
EEL 456	System Engineering	3-2-0	04
EEL 457	Pulse Width Modulation for Power Converters	3-0-0	03
EEL 458	Soft Computing Techniques	3-0-0	03
EEL 459	Commissioning and Testing of Electrical Systems	3-0-0	03
EEL 460	Control System Design	3-2-0	04
EEL 461	Electrical Energy System	3-0-0	03
EEL 462	Electrical Distribution System	3-0-0	03
EEL 463	High Voltage Engineering	3-0-0	03
EEL 464	Power Quality Issues & Solutions	3-0-0	03
EEL 465	Electrical Engineering Material	3-0-0	03
EEL 466	Power System Operation and Control	3-0-0	03
EEP 467	Soft Computing Techniques Lab	0-0-2	01
ECL352	Digital Signal Processing	3-0-0	03
ECP352	Digital Signal Processing Lab	0-0-2	01
ECL469	Hardware Description Language	3-0-0	03
ECP469	Hardware Description Language Lab	0-0-2	01
SCL452	Linear Algebra	3-0-0	03
SCL453	Probability Theory & Statistics	3-0-0	03
MEL461	Robotics	3-0-0	03
MEP461	Robotics Lab	0-0-2	01
CSL253	Object Oriented Design	3-0-0	03
CSL251	Data Structures	3-0-0	03
CSP251	Data Structures Lab	0-0-2	01
CSL359	Neuro-Fuzzy Techniques	3-0-0	03

Course Code: EEL151
Course Title: ELEMENTARY ELECTRICAL ENGINEERING
Structure (L-T-P): 3-0-0
Prerequisite: NIL
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. *DC Transients*
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. *Magnetic Coupling Coefficient*
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:
1. DC shunt and series motor – construction, principle of working and applications, need of starters, torque and speed control.
2. 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. Toro,V.D., Electrical Engineering Fundamentals, 2nd ed., Prentice Hall of India, 2012.

Reference Books:
1. Kothari D.P., Nagrath I.J, Theory and Problems of Basic Electrical Engineering, Prentice Hall India 2011.
2. Kulshreshtha, D.C., Basic Electrical Engineering, Tata McGraw Hill, 2013.

Course Code: EEL251
Course Title: BASIC ELECTRICAL CIRCUITS
Structure (L-T-P): 3-0-0
Prerequisite: EEL151
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 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.
Graphs: paths, connectedness, circuits, cutsets, trees, matrix representation of directed graphs, incidence, cutset and circuit matrices, methods of analysis of linear networks, nodal, cutset, 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. Pole-zero concept, network synthesis: Hurwitz polynomial, Properties of Hurwitz polynomial, Positive real functions and their properties, Concepts of network synthesis, Realization of simple R-L, R-C and L-C functions in Cauer-I, Cauer-II, Foster-I and Foster-II forms.
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. Valkenburg, M. E. Van, Network Analysis, 3rd ed. Prentice Hall India, 2011.
3. Hayt, W.H. and Kemmerley, J.E. and Durbin, S.N., Engineering Circuit Analysis, 7th ed., McGraw Hill, 2013.
4. M. E. Van Valkenburg: Network Analysis, 3rd ed., Prentice Hall of India.
5. 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. Choudhury, D.R., Networks and Systems, 2nd ed., New Age Publication, 2014.
3. Chua , L.O., Desoer, C.A. and Kuh, E.S., Linear and Nonlinear Circuits, McGraw Hill, 1991
4. Murthy, K.V.V. and Kamath M.S, Basic Circuit Analysis, 8th ed., Jaico Publishing House, 2010.

Course Code: EEL252
Course Title: MEASUREMENT & INSTRUMENTATION
Structure (L-T-P): 3-0-0
Prerequisite: EEL151, EEL 251
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. Oscilloscope, working principle and its operations. 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, synchroscope, rectifier type instrument, 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. E.W. Golding & F.C. Widdis, "Electrical Measurement and Measuring Instruments", A.W. Wheeler and Co.Pvt. Ltd. India.

Reference Book:

1. E.O. Doebelin and D. N. Manik, "Measurement systems application and design", TMH, New Delhi.
2. Cooper, W.D. and Helfrick, A.D.,Modern Electronic Instrumentation and Measurement Techniques, 3rd ed., PHI Learning Private Limited, 2012.

Course Code: **EEL253**
Course Title: **ELECTRICAL MACHINES-I**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL151**
Contents: Transformer: **Single phase transformer** : Phasor diagram for transformer for different loading conditions, equivalent circuit, open circuit & short circuit test , Back to back Test. Voltage regulation, efficiency calculation, parallel operation of transformer, Auto transformer, conversion of two winding transformer to auto transformer.

Three Phase Transformer: Connection and phasor groups, effect of phase sequence, inrush current & harmonics, tertiary winding, open delta connection, Scott connection, Applications.

Basic of Rotating Machines: Rotating magnetic field, Induced EMF, Torque developed

DC Machines: Concept of induced emf, Armature winding and field winding, mmf of armature and field winding. Armature reaction, its bad effects and steps to limit the effects of armature reaction, Staring of Motor

DC Motor: Basic principle and operation, classification, torque, power, losses and efficiency, characteristics. Speed control of DC motor, Braking.

DC Generator: Emf equation, shunt and compound generator, losses and efficiency , characteristics & Applications.

Text Books:

1. Fitzgerald, A.E., Kingsley, C. and Umans, S.D., Electric Machinery,6th ed., Tata McGraw Hill, 2014
2. Bhimbhra, P.S., Electrical Machinery, Khanna Publishers, Delhi, 2003.
3. Nagrath, I. J. and Kothari, D. P., Electric Machines, Tata McGraw Hill, 2006.

Reference Books:

1. Bhattacharya, S.K., Electrical Machines, 3rd ed., McGraw Hill Education (India) Private Limited, 2013.

Course Code: **EEL256**
Course Title: **POWER SYSTEM-I**
Structure (L-T-P): **3-2-0**
Prerequisite: **EEL151, EEL251**
Contents: **Power system introduction**: Introduction, comparison of AC and DC systems, overhead versus underground systems, choice of working voltages for transmission and distribution, cost comparison of overhead and underground systems, Classification of Voltage levels, Introduction to HVDC & basic configuration.

Power factor improvement: Necessity of power factor improvement, techniques for power factor improvement, Synchronous condenser, economics

Line parameters: Inductance and Capacitance, skin effect, proximity effect, Graphical method for performance of overhead transmission line.

Transmission line modeling: Characterization of transmission line on basis of length, modeling of long, short and medium transmission line, ABCD parameters. Derivation for voltage drop and power loss in lines efficiency of short, medium and long transmission lines, Surge impedance, SIL.

Mechanical design: Sag and tention calculation in hilly and plain area, Sag and tension calculation with wind and ice effect. Line support, types of conductors; Overhead line insulators, types of insulator spin, suspension and strain insulators, insulator materials, insulator string;

Voltage regulation: Calculation of voltage distribution and string efficiency, methods of equalizing voltages, use of guard rings, sag calculation, factors affecting sag. power-loss calculations, Manual methods of solution for radial networks,

Corona: Corona formation, factors affecting corona, calculation of potential gradient, disruptive critical voltage and visual critical voltage, corona power loss, minimizing corona, merits and demerits of corona, skin effect.

Travelling Waves: Introduction and mechanism of traveling waves, wave equation, characteristic impedance of a line, incident and reflected waves, transmission and refraction of waves, velocity of traveling waves, behavior of traveling waves for different terminations: inductor, capacitor, open-end, short-end and over the junction of dissimilar lines, attenuation of traveling waves, lattice diagrams.

Surge Performance and Protection: Switching surges, origin and mechanism of lightening strokes, direct and induced strokes, protection from surges- lightning arrestors (rod gap, horn gap, multigap and expulsion type) and surge diverters, evaluation of surge impedance, energy and power of a surge.

Introduction to cables: Introduction, sheath, amour and covering, Classification of cables, Grading of cables, Underground HVDC cables.

Text Books:

1. Nagrath, I. J. andKothari, D.P., Power System Engineering, 2nd ed., Tata McGraw Hill Publications, 2013.
2. C.L Wadhwa, Electrical Power Systems, 6th ed., New Age international publications.

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.
3. Grainger, J.J., Stevenson, W.D., Power System Analysis, 22th ed., McGraw Hill Education (India) Private Limited, New Delhi, 2014.

Course Code: **EEL254**
Course Title: **CONTROL SYSTEM**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL151, EEL251**
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. Controllability and Observability.

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.

Root location and its effect on time response, elementary idea of root locus, effect of adding pole and zero and proximity of imaginary axis.

Stability of control systems, conditions of stability characteristic equation, Routh-Hurwitz criterion, special cases for determining relative stability.

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.
3. Kuo, B.C. and Golnaraghi F., Automatic Control Systems, 8th ed., Wiley India, 2011.
4. Abbas Emami-Naeini J. Da Powell Gene F. Franklin, Feedback Control of Dynamic Systems, Global Edition 7th Edition.

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. Nise, N.S., Control Systems Engineering, 6th ed., Wiley, 2013.
4. Gopal, M., Control Systems: Principles and Design, 3rd ed., Tata McGraw Hill Education, 2010.

Course Code: **EEL255**
Course Title: **POWER ELECTRONICS**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL151, EEL251**
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), Self Commutating Device: characteristics and working of MOSFET. Gate turn off thyristor and insulated gate bipolar transistor.
AC to DC Converters: 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.
DC to DC Converters: Classification, principles of step down chopper and step up chopper, Buck, Boost, Buck-Boost converter and application to 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.
AC to AC Converters: 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, AC voltage controller Introduction of matrix converter.
Text Books:
1. Mohan, Ned, Undeland, T.M. and Robbins, W.P., Power Electronics, 3rd ed., Wiley India, 2014
2. Rashid, M.H., Power Electronics: Circuits Devices & Applications, 3rd ed., Pearson Education, 2012.
3. Joseph Vithayathil, Power Electronics: Principles and Applications, Tata McGraw-Hill Education.
Reference Books:
1. Singh, M.D. and Khanchandani K.B., Power Electronics, 2nd ed., Tata McGraw Hill Education, 2012.
2. Bose, B.K., Modern Power Electronics and AC Drives, PHI Learning, New Delhi, 2012.
3. Lander, C.W., Power Electronics, 3rd ed., McGraw Hill, 1993.
4. Bimbhra, P.S., Power Electronics, Khanna Publishers, 2012.
5. Dubey, G.K., Fundamentals of Electrical Drives, 2nd ed., Narosa Publication, 2013.

Course Code: **EEL352**
Course Title: **ELECTRIC DRIVES**
Structure (L-T-P): **3-0-2**
Prerequisite: **EEL253, EEL255**
Contents: Definitions, classification and speed torque characteristics of common industrial loads & drive motors and their characteristics under starting, running, braking and speed control.
Introduction:
Review of power converters used in drives, multi-quadrant operation of electric drive, example of hoist operation in four quadrant.
DC Drives:
Single-phase half controlled and fully controlled converter fed dc motor drives, operation of dc drives with continuous armature current, voltage and current waveforms; Concept of energy utilization and effect of free-wheeling diode;
Operation of drive under discontinuous current, expression for speed-torque characteristic.
Chopper fed DC Drives:
Principle of operation and control techniques, chopper circuit configurations used in dc drives: Type A, B, C, D and E; Motoring operation of chopper fed separately excited dc motor, steady state analysis of drive with time-ratio control.
Closed Loop Control of DC Drives:
Drives with current limit control, single-quadrant closed loop drive with inner current control loop, advantage of inner current control loop in drives.
AC Drives:
Variable voltage, rotor resistance and slip power recovery control of induction motors, torque-speed characteristics under different control schemes; Variable frequency control of induction motor, analysis of induction machine under constant V/f operation, constant flux operation and controlled current operation.
Estimation of Drive Motor Rating:
Selection of motor power capacity for continuous duty at constant load and variable loads; Selection of motor capacity for short time and intermittent periodic
duty, permissible frequency of starting of squirrel cage motor for different duty cycles.
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.
3. J. M. D. Murphy & F. G. Turnbull, "Power Electric Control of AC Motors", Pergamon Press.
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
3. Bimal K. Bose, "Power Electronics and Variable Frequency Drives: Technology and Applications".

Course Code: **EEL353**
Course Title: **POWER SYSTEM-II**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL151, EEL251, EEL256**
Contents: General concept: Introduction of bus matrix, Ybus formulation, Tap changing transformer formulation in Ybus, Zbus formulation, Single line representation, per unit calculations of parameters.
Load Flow Analysis: Formation of static load flow equations, solution of decoupled load flow problem by Gauss-Seidel, Newton-Rapson (polar and rectangular) and fast decoupled techniques
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 analysis: Swing curve, Swing equations solutions using Runga Kutta method (4th order). Equal area criteria, for transient stability, application of equal area for different disturbance, solution of swing equation point by point methods.
Power System Control: Elementary idea of single area load-frequency control, automatic generation control, Necessity of keeping frequency control, Block diagram representation of an isolated power system, steady state analysis, dynamic response
Voltage control: Equipment for voltage control, Effect of series capacitors, Effect of AVB/AVR, Line drop compensation.
Active power and frequency control: fundamentals of speed governing, control of generating unit power output, composite regulating characteristics of power systems, response rates of turbine governing systems, fundamental of automatic generation control, Implementation of AGC, underfrequency load shedding.
Reactive power and voltage control: Production and absorption of reactive power, method of voltage control,shunt reactors, shunt capacitors, series capacitors, synchronous condensers, static Var system, principle of transmission system compensation, Modelling of reactive compensating devices, Application of tap changing transformers to transmission systems, ULTC control system.
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.

Course Code: EEL355
Course Title: SWITCHGEAR AND PROTECTION
Structure (L-T-P): 3-0-0
Prerequisite: EEL256, EEL253, EEL351

Contents: Faults in Power Supply System: Symmetrical component transformation. **Classification of faults,** Three phase power in unbalanced circuit in terms of symmetrical component. Sequence impedance of generator. Transformer transmission line & passive loads. 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. Medium voltage line protection: overcurrent relay, 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. Phase shift in Y/delta three phase transformer (Yd1, Yd11 connection). 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, different media of arc interruption, SF6 and vacuum breakers. Introduction to Gas Insulated Switchgear and Substation

Text Books:

1. Ram, B. and Vishwakarma, D.N. Power System Protection & Switchgear, 2nded., 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., MarcelDekker, 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.

Course Code: EEL354
Course Title: ADVANCED POWER ELECTRONICS
Structure (L-T-P): 3-2-0
Prerequisite: EEL255

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 Books:

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

Course Code: EEL351
Course Title: ELECTRICAL MACHINES-II
Structure (L-T-P): 3-0-0
Prerequisite: EEL151, EEL253

Contents: **Three Phase Induction Motor:** principle and operation, types of motors, Three phase speed control of induction motor (V/f control etc.) load torque-speed characteristics, determination of equivalent circuit parameter, circle diagram of induction motor , starting against load, star delta starter, soft starting faults on motor , single phasing & protection. Different types of slots of machines (open, closed, semi closed), Crawling, Cogging, Induction Generator,

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 reactance's 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. Study of both cylindrical and salient pole alternator, phasor diagram at various power factor, V curve, capability characteristics etc.

Single phase machines: Induction Motor: principle, equivalent circuit, characteristics, double field revolving theory, staring methods, Repulsion motor, Reluctance motor, Hysteresis motor, Universal motor, Stepper motor.

Text Books:

1. Fitzgerald, A.E., Kingsley, C. and Umans, S.D., Electric Machinery,6th ed., Tata McGraw Hill, 2014
2. Bhimbhra, P.S., Electrical Machinery, Khanna Publishers, Delhi, 2003.
3. Nagrath, I. J. and Kothari, D. P., Electric Machines, Tata McGraw Hill, 2006.

Reference Books:

1. A.S. Langsdorf: Theory of Alternating Current Machinery, Tata Mc-Graw Hill.
2. I.J. Nagrath, D.P. Kothari: Electrical Machines, Tata McGraw Hill.
3. M. G. Say: The Performance and Design of Alternating Current Machines, III Edition, CBS Publishers & Distributers.
4. Toro, V.D., Electric Machines and Power Systems, Prentice Hall, 1985.

Course Code: EEL451
Course Title: COMPUTER CONTROL AND AUTOMATION OF POWER SYSTEMS
Structure (L-T-P): 3-0-0
Prerequisite: EEL256

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.
3. M A Pai, Computer Techniques In Power System Analysis, Mc-Graw Hills
4. G.W. Stagg & A.H. El-Abiad, Computer Methods In Power System Analysis, Mc-Graw Hills

Reference Books:

1. Handschin E. and Petroianu, A., Energy Management Systems: Operationand 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.

Course Code: **EEL452**
Course Title: **DISCRETE DATA AND DIGITAL CONTROL**
Structure (L-T-P): **3-2-0**
Prerequisite: **EEL254**
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.

General procedures for obtaining pulse Transfer functions, Pulse Transfer function of open loop and closed loop systems, Dead beat controller, closed loop digital control systems with time delay systems.

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

State variable methods and the discrete linear regulator problem. Deadbeat observer, The Separation Principle, Reduced order observer, Root locus technique.

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

Course Code: **EEL453**
Course Title: **POWER PLANT ENGINEERING**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL253, EEL256**
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.

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.

Course Code: **EEL454**
Course Title: **HVDC**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL255**
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.

Course Code: **EEL 455**
Course Title: **POWER SYSTEM ECONOMICS & MANAGEMENT**
Structure (L-T-P): **3-0-0**
Prerequisite: **EEL256**
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, Ttransfer 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. Kundur P., Power System Stability and Control, EPRI Series, McGraw-Hill, 1998.
2. Wood A. J. and Wollenberg B. F., Power Generation, Operation and Control, second edition, Willey Publication, 2008.

Reference Books:

1. Nagrath I. J. and Kothari D. P., "Power System Engineering", 2nd edition, Tata Mc-Graw Hill Publishing Company,2008.
2. Saadat H., Power System Analysis, 1st International Edition, Tata McGraw-Hill Publishing Company Limited, 2008

Course Code: EEL456
Course Title: SYSTEM ENGINEERING
Structure (L-T-P): 3-0-0
Prerequisite: NIL

Contents: Introduction to Optimization, Generalized Principles of System Modeling, Engineering Applications of Optimization, Statement of problem, Classification of optimization problem techniques.

Linear programming, introduction, Requirements for a LP Problem, Graphical solution of 2-variable LP problems, Some exceptional cases, General mathematical formulation for LPP, Canonical and standard forms of LP problem, Simplex method, special cases in simplex method, Big-M method, Concept of duality, Dual simplex method and sensitivity analysis.

Transportation problem, Definition and mathematical representation of transportation model, Formulation and solution of transportation models (basic feasible solution by north-west corner method, Inspection method, Vogell's approximation method).

Network models, Scope and definition of network models, Minimal spanning tree algorithm, Shortest-route problem, Maximal flow model.

Goal programming, Formulation of goal programming, Introduction to goal programming algorithms, The weights method, The preemptive method.

Text Book:

1. Hamdy A. Taha, Operations Research: An Introduction, Pearson, 9th Ed., 2014.

Reference Books:

1. S. S. Rao, Engineering Optimization: Theory and Practice, 4th Ed., John Wiley & Sons, 2009.
2. G. Hadley, Linear Algebra, Narosa, 2002.
3. P. K. Gupta and D. S. Hira, Operations Research, S. Chand Publications, 7th Ed., 1976.

Course Code: EEL457
Course Title: Pulse Width Modulation for Power Converters
Structure (L-T-P): 3-0-0
Prerequisite: EEL255

Contents: Introduction: Review of Voltage Source Inverters and Multi-level Inverters.

Harmonic Distortion: Voltage and Current Distortion Factors and Weighted THD calculation by using Fourier series for different level Voltage Source Inverters.

Pulse width modulation (PWM) at low switching frequency: Square wave operation of voltage source inverter; PWM with a few switching angles per quarter cycle; equal voltage contours; selective harmonic elimination.

Triangle-comparison based PWM: Average pole voltages, sinusoidal modulation, third harmonic injection, continuous PWM, bus-clamping or discontinuous PWM; Extensions of sine-triangle PWM to multilevel inverters.

Space Vector Based PWM: Space vector concept and transformation, per-phase methods from a space vector perspective, space vector based modulation, conventional space vector PWM, bus-clamping PWM, advanced PWM, triangle-comparison approach versus space vector approach to PWM, Extensions of space vector based PWM to multilevel inverters.

Inverter loss: Evaluation of conduction loss, Dependence of switching loss on power factor and modulation method, PWM techniques for reduced switching loss.

Effect of inverter dead-time: Effect of dead-time with continuous modulation, Effect of dead-time with discontinuous or bus-clamping PWM.

Text books:

1. Mohan N., Underland T.M., Robbins W.P., "Power Electronics – Converters, Applications and Design", John Wiley & Sons Inc., 2004.
2. Erickson R. W., Maksimovic D., "Fundamentals of Power Electronics", Springer (India) Pvt. Ltd., 2005.
3. Rashid M. H., "Power Electronics: Circuits, Devices and Applications", Third Edition, Pearson, 2009.

Reference books:

1. Choi Byungcho, "Pulsewidth Modulated DC to DC Power Conversion: Circuits, Dynamics and Control Designs", IEEE Press, John Wiley & Sons, Inc., 2013.
2. Holmes D.G., Lipo T.A., "Pulse Width Modulator for Power Converters – Principles and Practice", IEEE Press, John Wiley & Sons, Inc., 2003.

Course Code: EEL458
Course Title: SOFT COMPUTING TECHNIQUES
Structure (L-T-P): 3-0-0
Prerequisite: SCL152, SCL153

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, introduction to various paradigms, learning in neural networks, back-propagation, multi-layer networks,

Evolutionary computing (Genetic algorithms): basic concepts, Genetic algorithms and variants,

Differential evolution, Particle swarm optimization (PSO) and variants, Bacterial foraging optimization (BFO), Ant colony optimization - travelling salesman problem, cat swarm optimization.

Applications of AI in Electrical Engineering like 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.
3. Lotfi A. Zadeh (Advances in Fuzzy Systems: Application and Theory) First Edition,

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.
3. S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Systems and Evolutionary Algorithms: Synthesis and Applications Paperback – Import, 8 May 2017
4. Lefteri H. Tsoukalas, Robert E. Uhrig, Lotfi A. Zadeh, Fuzzy And Neural Approaches in Engineering.

Course Code: EEL459
Course Title: COMMISSIONING AND TESTING OF ELECTRICAL SYSTEMS
Structure (L-T-P): 3-0-0
Prerequisite: EEL151, EEL253, EEL351
Contents: **Installation of Electrical Equipment:** Inspection of Electrical Equipment at site, Storage Electrical Equipment at site, Foundation of Electrical Equipment at site, Alignment of Electrical Machines, Tools/Instruments necessary for installation, Technical report, Inspection, storage and handling of transformer, switchgear and motors.
Testing of Transformer, Plant and Equipment:
General Requirements for Type, Routine and Special Tests, Measurement of winding resistance; Measurement of voltage ratio and check of voltage vector relationship; Measurement of impedance voltage/short-circuit impedance and load loss; Measurement of no-load loss and current; Measurement of insulation resistance; Dielectric tests; Temperature-rise, insulation and HV test, dielectric absorption, switching impulse test. Testing of Current Transformer and Voltage Transformer, power transformer, distribution transformer, CVT and special transformer with reference to Indian Standard (IS). Drying out procedure for transformer. PI index, Commissioning steps for transformer, Troubleshooting &
Maintenance of transformer. [Ref: IS 2026:Part_1-10- Power Transformers: Methods of Test; IS 13956:1994Testing Transformers]
Installation and Commissioning of Rotating Electrical Machines: Degree of protection, cooling system, degree of cooling with IP- IC code (brief discussion), enclosures, rating of industrial rotating electric machine, installation, commissioning and protection of induction motor and rotating electric machine, drying out of electric rotating machine, insulation resistance measurement, site testing and checking, care, services and maintenance of motors, commissioning of synchronous generator, protection and automation of synchronous generator, synchronous motor, D.C. generator and motor with reference to Indian Standard (IS). [Ref: IS 4029:2010-Guide for Testing Three Phase Induction Motors; IS 7132:1973-Guide for Testing Synchronous Machines; IS 9320:1979-Guide for Testing of Direct Current (dc) Machines]
Transmission line:
Commissioning of A.C transmission line and HVDC transmission, galvanize steel structure, towers and insulator for transmission and distribution line, tower footing resistance, substation equipment, bus bar system, power cable, low power control cable, Contactor, GIS (gas insulated substation).
SWITCH GEAR & PROTECTIVE DEVICES
Standards, Classification, specification, rating and duties of CB, installation, commissioning tests, maintenance schedule, type & routine tests. Operation of s/s (steps) for line Circuit breaker maintenance. Location of lightening arrester with reasons
Text books:
1. S. Rao, Testing Commissioning Operation & Maintenance of Electrical Equipments , 6th Ed , Khanna Publishers Delhi, 2010.
2. P. Gill, Electrical Power Equipment Maintenance and Testing, 2nd Ed., CRC Press (Taylor & Francis Group), 2009.

Reference Books:
1. T. Singh, Installation commissioning & Maintenance of Electrical Equipments, S. K. Kataria and Sons, New Delhi, 2013.
2. P. Kiameh, Electrical Equipment Handbook: Troubleshooting & Maintenance, 1st Ed., McGraw-Hill Companies, Inc, 2003.

Course Code: EEL460
Course Title: CONTROL SYSTEM DESIGN
Structure (L-T-P): 3-0-0
Prerequisite: NIL
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.

Course Code: EEL461
Course Title: ELECTRICAL ENERGY SYSTEM
Structure (L-T-P): 3-0-0
Prerequisite: NIL
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.

Course Code: 462
Course Title: ELECTRICAL DISTRIBUTION SYSTEM
Structure (L-T-P): 3-0-0
Prerequisite: EEL256
Contents: General concepts: Introduction to distribution systems, Load modeling 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.
Underground Cables :Introduction, Insulation, Sheath, Armour and Covering, Classification of Cables, Pressurized Cables, Effective Conductor Resistance, Conductor Inductive Reactance, Parameters of Single Core Cables, Grading of Cables, Capacitance of Three Core Belted Cable, Breakdown of Cables, Cable Installation, Current Rating of Cables, System Operating Problems with Underground Cables, HVDC Cables.
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 off uses, 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.

Course Code: EEL463
Course Title: HIGH VOLTAGE ENGINEERING
Structure (L-T-P): 3-0-0
Prerequisite: EEL256, EEL353
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 dionization 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 high test voltage, transformers in cascade, resonance transformers, g generation of high DC voltage, voltage multiplier circuits and ripple minimization, sources of overvoltages 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 Book:

1. Naidu, M. S. and Kamaraju, V., High Voltage Engineering, 4th edition, Tata McGraw-Hill, New Delhi, 2008.

Reference Books:

1. Kuffel J., Kuffel E., and Zaengl W. S., High Voltage Engineering fundamentals, 2nd edition, Newness (Oxford, Boston), 2000.
2. Abdel-salam M., Anis H. and, Abdel-salamani, High Voltage Engineering: Theory and Practice, 2nd edition, CRC Press, 2001.
3. Ray S., An introduction to High Voltage Engineering, Prentice Hall, New Delhi, India, 2004

Course Code: EEL464
Course Title: POWER QUALITY ISSUES AND SOLUTION
Structure (L-T-P): 3-0-0
Prerequisite: EEL151, EEL255
Contents: Definitions of various powers, power factor and other figures of merit under balanced, unbalanced and nonsinusoidal conditions.
Definitions of various powers, power factor, SINGLE PHASE CIRCUITS: Sinusoidal Voltage Source Supplying Non-linear Load Current, Non-sinusoidal Voltage Source Supplying Non-linear Loads.
THREE PHASE CIRCUITS: POWER DEFINITIONS AND VARIOUS COMPONENTS: Three-phase Sinusoidal Balanced System, Instantaneous Active and Reactive Powers for Three-phase Circuits: Three-Phase Balance System, Three-Phase Unbalance System, Three-phase Non-sinusoidal Balanced System, Unbalanced and Non-sinusoidal Three-phase System
FUNDAMENTAL THEORY OF LOAD COMPENSATION, Phase Balancing and Power Factor Correction of Unbalanced Loads, A Generalized Approach for Load Compensation using Symmetrical Components , CONTROL THEORIES FOR LOAD COMPENSATION
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.
Voltage Sag, Compensators to mitigate power quality related Problems, series and shunt compensation, Description of static VAR compensators (SVC), Detailed modeling, analysis and design aspects of custom power devices (DSTATCOM, DVR).

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.

Course Code: EEL 465
Course Title: ELECTRICAL ENGINEERING MATERIAL
Structure (L-T-P): 3-0-0
Prerequisite: NIL
Contents: Introduction to engineering materials, crystal structures and defects, ceramic materials, dielectric properties of insulators in static fields, dielectric properties of insulators in alternating field, insulating materials and their applications, Dielectric breakdown, magnetic materials – basics, properties and applications, ferrites, ferro-magnetic materials and components; basics of solid state physics, conductors, Photo-conductivity, optical properties of materials, Basics of Nano materials and Superconductors

Text books:

1. S.P.Seth, "A Course in Electrical Engineering Materials", Dhanpat Rai Publications, 3rd edition, 2011.
2. N Alagappan, N Kumar, "Electrical Engineering Materials", Tata McGraw Hill, 2017

Reference Book:

1. A.J.Dekker, "Electrical Engineering Materials", Prentice-Hall Of India Pvt Ltd , 2011.

Course Code: EEL466
Course Title: POWER SYSTEM OPERATION AND CONTROL
Structure (L-T-P): 3-2-0
Prerequisite: EEL256, EEL353
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.

Unit commitment, constraints in unit commitment, Solution methods: priority list method, Mixed Integer Linear Programming, Dynamic programming method and Lagrange relaxation methods.

Introduction to Single Area load frequency control

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.

Optimal power flow formulation, gradient and Newton method, linear programming methods.

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. Wood. A. J. and Wollenberg B. F., Power Generation, Operation and Control, 3rd edition, Willey Publication, 2014.
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