1st SEMESTER

MAL 1101	Engineering Mathematics – I	3-1-0-4
As per the syllabus prescribed by the Department of Mathematics		

CHL 1101	Engineering Chemistry	3-0-0-3
As per the syllabus prescribed by the Department of Chemistry		

HUL 1101	Communicative English	2-0-0-2
As per the syllabus prescribed by the Department of English		

MEL 1101	Engineering Mechanics	3-0-0-3
As per the syllabus prescribed by the Department of Mechanical Engineering		

EEL1101: BASIC ELECTRICAL ENGINEERING **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Describe KCL, KVL equation, nodal, mesh analysis and voltage method and explain different network theorems for solving different problems.
- Analyse AC circuits and Magnetic circuits.
- Describe three Phase balanced Supply & Power Measurement.
- Introduce different types of machines and some measuring instruments.

1. **Introduction:** Introduction to electrical equipment, circuit components, Electrical Elements and their classification, KCL, KVL equation, nodal, mesh analysis, voltage method, D.C. circuits steady state analysis with independent and dependent sources, Series and parallel circuits, star-delta conversion, Superposition theorem, Thevenin's theorem, Norton's theorem, Maximum Power Transfer Theorem.

LECTURES: 10

2. **A.C. circuits:** Common signals and their waveform, RMS and Average value, form factor and peak factor of a sinusoidal wave, Impedance of series and parallel circuits, Phasor diagram, Power, Power factor, Power Triangle, coupled circuits, Resonance and Q-factor.

LECTURES: 7

3. **Magnetic circuits:** Introduction, Series & Parallel magnetic circuits, Analysis of Linear and non-linear magnetic circuits, Energy storage, A.C. excitation, Eddy current, and hysteresis losses.

LECTURES: 5

4. **Three Phase Balanced Supply & Power Measurement:** Star-delta connection, Power measurement.

LECTURES: 2

5. **Introduction of Electrical Machines:** Transformer, DC machines, Induction Machines.

LECTURES: 7

6. **Introduction of Electrical Measurement**: MI & MC types meter, Energy meter, Wattmeter.

LECTURES: 5

Text Book:

1. R.J. Smith and R.C. Dorf: Circuits, Devices, and Systems; John Wiley & Sons, 1992.
2. V. Del Toro: Electrical Engineering Fundamentals; PHI, 1994.
3. Van Valkenburg Network Analysis, Prentice Hall, India.

Reference Books*:*

1. Fundamentals of Electrical Engg. By Leonard S. Bobrow, Oxford.
2. Fundamentals of Electrical Engineering by R. Prasad, PHI Publication.
3. J. Nagrath and D. P. Kothari, 'Electric Machines', Tata McGraw Hill, 1985.

OBE 1101	**Outcome Base Education**	**1-0-0-1**
As per the syllabus prescribed by the Department of English		

CHP 1101	**Engineering Chemistry Laboratory**	**0-0-2-1.5**
As per the syllabus prescribed by the Department of Chemistry		

HUP 1101	**Language Laboratory**	**0-0-2-1**
As per the syllabus prescribed by the Department of English		

MEP 1101	**Engineering Mechanics Laboratory**	**0-0-2-1.5**
As per the syllabus prescribed by the Department of Mechanical Engineering		

EEP1101: BASIC ELECTRICAL ENGINEERING LABORATORY
L-T-P: 0-0-3 **Credit: 1.5**

Course Outcomes:

- Realization of KCL, KVL equations, and different network theorems.
- Determination of different parameters and phasor diagram of AC circuits.
- Energy Measurement using energy meter.
- Study of characteristics of fluorescent lamp connection and carbon tungsten lamp

List of Experiments

1. Study of Network Theorems (KCL & KVL, Thevenin's, Norton's, Maximum Power transfer Theorem).
2. Familiarization with Voltmeter, Ammeter & Wattmeter
3. Study of RL & RLC circuit.
4. Study of calibration of Energy Meter.
5. Study of characteristic fluorescent lamp connection.
6. Study of the characteristic of a carbon tungsten lamp.
7. Study of RL, RC, and RLC series and parallel circuits.

Text Book:

1. R.J. Smith and R.C. Dorf: Circuits, Devices, and Systems; John Wiley & Sons, 1992.
2. V. Del Toro: Electrical Engineering Fundamentals; PHI, 1994.

2nd SEMESTER

MAL 1202	**Engineering Mathematics – II**	**3-1-0-4**
As per the syllabus prescribed by the Department of Mathematics		

PHL 1201	**Engineering Physics**	**3-0-0-3**
As per the syllabus prescribed by the Department of Physics		

HUL 1202	**Social Science**	**2-0-0-2**
As per the syllabus prescribed by the Department of English		

CSP 1201	**Introduction to Computer Programming**	**3-0-0-3**
As per the syllabus prescribed by the Department of Computer Science and Engineering		

ECL 1201	**Basic Electronics Engineering**	**3-0-0-3**
As per the syllabus prescribed by the Department of Electronics and Communication Engineering		

PHP 1201	**Engineering Physics Laboratory**	**0-0-2-1.5**
As per the syllabus prescribed by the Department of Physics		

CSL 1201	**Introduction to Computer Programming Laboratory**	**0-0-3-1.5**
As per the syllabus prescribed by the Department of Computer Science and Engineering		

MEP 1202	**Engineering Drawing**	**0-0-4-2**
As per the syllabus prescribed by the Department of Mechanical Engineering		

MEP 1203	**Workshop**	**0-0-4-2**
As per the syllabus prescribed by the Department of Mechanical Engineering		

ECA 1201	**Extracurricular Activity**	**0-0-0-0**
As per the syllabus prescribed by the Department of Electronics and Communication Engineering		

3rd SEMESTER

EEL 1301: CIRCUIT THEORY **Prerequisite: EEL 1101**
L-T-P: 3-1-0 **Credit: 4**

Course Outcomes:

- Describe different types of circuits and networks and explain different network theorems for solving different problems by applying the knowledge of mathematics, science, and engineering.
- Transient analysis and resonance for various circuits.
- Analyze electrical circuits by utilizing Laplace Transform and Fourier Transform.
- Analyze the two port networks for calculating different circuit parameters.
- Design the various types of filter circuits.

1. **Network Theorems:** Nodal and Mesh analysis, Superposition theorem, maximum power transfer theorem, Reciprocity theorem, Millman's theorem, substitution theorem, compensation theorem, Tellegen's theorem, all theorems using examples of AC networks.
LECTURES: 8
2. **Transient Analysis and Resonance:** Introduction of transient phenomena, initial conditions, and analysis of RL, RC, and RLC circuits; series resonance, parallel resonance, and comparison of series and parallel resonant circuits
LECTURES: 4
3. **Two-Port Network:** One port and two port network, Sign convention, Admittance Parameter, Parallel connection of two port network, Impedance parameter, the Series connection of the two-port network. Hybrid parameters, Inverse Hybrid parameters, Transmission parameters, Inverse Transmission parameters, Concept of driving point impedance and admittance, Symmetrical two ports and bisection, Image impedance.
LECTURES: 8
4. **Graph Theory:** Graph of a network, Trees, Co-trees, Loops, Incidence matrix, cut-set matrix, Ties matrix and loop currents, Number of possible trees of a Graph, Analysis of Networks, Network Equilibrium Equation, Duality, General network transformation.
LECTURES: 4
5. **Laplace Transform:** Basics of signals and systems**,** a brief review of Laplace transform technique, Initial and final value Theorem, Solution of circuit transient using Laplace transform. Use of Laplace's transform in electrical circuit analysis.
LECTURES: 10
6. **Fourier Analysis:** Trigonometric Fourier Series, Evaluation of Fourier Coefficients, Waveform Symmetry, Exponential form, Fourier transform techniques applied in networks.
LECTURES: 4
7. **Filter Circuits:** Classification of filters, equation of an ideal filter, Theory of pie section, Constant K-type filters, low pass filters, design of low pass filter, high pass filters, band pass filters, band rejection filters, and all-pass filters. M-derived filters, theory of M-derived filters, M-derives low pass and high pass filters. Approximation theory of filters (Butter worth and Chebyshev).
LECTURES: 4

Text Books

1. Hayt & amp; Kemmerly, Engineering Circuit Analysis, Mc Graw Hill, 9th Edition, 2019.
2. Roy Choudhury, Network and Systems, New Age, Second edition, 2013.
3. Abhijit Chakrabarti., Circuit Theory Analysis and Synthesis, Dhanpat Rai & Co., 2008.

Reference Books

1. Rajeswaran, Electric circuit Theory, Pearson publications 2004
2. Wadhwa, Network analysis and synthesis, New Age Publication,2007
3. Soni and Gupta, A Course in Electrical Circuit Analysis, Dhanpat Rai & Sons,2016
4. Van Valkenburg, Network Analysis & Synthesis, PHI publications, 2019

EEL1302: ELECTROMAGNETIC FIELD THEORY **Prerequisite: EEL 1101**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Finding DEL operator, Gradient of a scalar, Divergence of a vector using the Divergence theorem, Curl of a vector using Strokes theorem, Laplacian of a scalar, and classifying vector fields.
- Solve problems in Cartesian coordinates, Circular cylindrical coordinates, and Spherical coordinates transform vectors from one coordinate system to other.
- Use Coulomb's law, Gauss's law, and Poisson's and Laplace's equation to find field intensity, Electric potential, and Potential gradient, and deduce the Relation between E and V.
- Use Biot- Savart law, and Ampere's circuit law to find Magnetic flux density, Magnetic static, and Vector potential, Forces due to the magnetic field, Magnetic torque and moments, Magnetisation in material, Magnetic boundary condition, Inductor and Inductances, Magnetic energy and Force on magnetic material.
- Use Faraday's law and Maxwell's equations to solve problems related to Transformer and motional emf, Displacement current, Time-varying Potential, Time harmonic fields and deduce Wave equation and Transmission line equation, Wave propagation in the lossy dielectric, Plane waves in loss less dielectric, free space, good conductor, Skin effect, Power & Poynting vector, Reflection of a plane wave at normal incidence, the reflection of a plane wave at oblique incidence, polarisation.

1. Introduction to Vector Calculus: DEL operator, Gradient of a scalar, Divergence of a vector & Divergence theorem, Curl of a vector & Strokes theorem, Laplacian of a scalar, Classification of vector fields.

LECTURES: 4

2. Co-ordinate Systems: Cartesian coordinates, Circular cylindrical coordinates, Spherical coordinates & their transformation. Differential length, area and volume in different coordinate systems. Solution of problems.

LECTURES: 3

3. Electrostatic Field: Coulomb's law, field intensity, Gauss's law, Electric potential, Potential gradient, Relation between E and V, an Electric dipole, and flux lines. Energy density in the electrostatic field. Boundary conditions: Dielectric-dielectric, Conductor –dielectric, Conductor-free space. Poisson's and Laplace's equation, General procedure for solving Poisson's and Laplace's equation.

LECTURES: 8

4. Magneto Static Field: Biot- Savart law, Ampere's circuit law, Magnetic flux density, Magnetic static and Vector potential, Forces due to the magnetic field, Magnetic torque and moments, Magnetisation in material, Magnetic boundary condition, Inductor and Inductances, Magnetic energy, Force on magnetic material.

LECTURES: 8

5. Electromagnetic Fields: Faraday's law, Transformer and motional emf, Displacement current, Maxwell's equations, Time-varying Potential, Time harmonic fields.

LECTURES: 4

6. Electromagnetic Wave Propagation: Wave equation, Wave propagation in lossy dielectric, Plane waves in loss less dielectric, Plane wave in free space, Plane wave in good conductor, Skin effect, Skin depth, Power & Poynting vector, Reflection of a plane wave at normal incidence, the reflection of a plane wave at oblique incidence, Polarisation. Transmission line equation & solutions, Physical significance of solutions, Propagation constants, Characteristic impedance, Wavelength, Velocity of propagation.

LECTURES: 9

Books

1. M. N. O. Sadiku, Elements of Electromagnetics, Oxford University Press, 2012.
2. D. K. Cheng, Field and Wave Electromagnetics, Pearson, 2013.

Reference Books

1. R. K. Shevgaonkar, Electromagnetic Waves; McGraw Hill, 2017.
2. R. F. Harrington, Time-Harmonic Electromagnetic Fields, Wiley-IEEE, 2001.
3. N. Ida, Engineering Electromagnetics, Springer, 2015.

EEL1303 ELECTRICAL AND ELECTRONIC MEASUREMENTS **Prerequisite: EEL 1101**
L-T-P: 3-1-0 **Credit: 4**

Course Outcomes:

- Develop an understanding of the construction and working of different measuring instruments.
- Develop an understanding of the different types of interferences, their causes, and methods for their reduction.
- Develop an understanding of the construction and working of different AC and DC bridges and their applications.
- Develop an ability to use measuring instruments and AC and DC bridges for measurement.
- Develop an understanding of the construction and working of Cathode ray oscilloscope and signal analyzer.
- Develop an understanding of construction and working of non-electrical quantities.

1. Introduction: Introduction of signals, measurement and instruments, static and dynamic characteristics of instruments; different types of instruments; operating forces required for working of indicating instruments; different types of damping and control systems; construction and working principles of PMMC, MI, induction type and electrodynamometer type instruments, Galvanometer: dynamics, sensitivity, D'Arsonval galvanometer, Vibration Galvanometer, Potentiometers, and their applications advantages and disadvantages.

LECTURES: 9

2. Bridges for Measurements: Measurement of medium resistance using Wheatstone bridge, Measurement of low resistance using Kelvin Double bridge, measurement of insulation resistance by loss of charge method; Maxwell's inductance bridge, Maxwell's inductance-capacitance bridge, Owen's bridge, Schering bridge, Anderson's bridge, Hay's Bridge, Campbell's Mutual Inductance Bridge.

LECTURES: 8

3. Measurement of Power, Power Factor, and Energy: Measurement of power and energy, use of current transformer and potential transformer, electrodynamometer type of wattmeter, induction type energy meter, indicating type frequency meter, electrodynamometer type p.f. meter.

LECTURES: 5

4. Electronic Instruments: Introduction, electronic voltmeters-advantages, types. differential amplifier; DC voltmeter. Electronic voltmeters using rectifiers. Electronic multimeters, electronic ohmmeter. Consideration in selecting an analog voltmeter; differential voltmeter.AC voltage measurement, AC and DC current measurement using the electronic instrument.

LECTURES: 7

5. Cathode Ray Oscilloscope and Signal Analyzer: Advantages & disadvantages of digital instruments over analog instruments; digital multimeter and description and field of application, C.R.O.—block diagram representation and operation, applications; use of dual trace oscilloscope; function generator—a working principle with block diagram; frequency counter-working principle with block diagram**.**

LECTURES: 7

6. Measurement of Non-electrical Quantities: Concept of measurement using transducers as an input element, active, passive transducers—differences. study of transducers: RTD, Thermistor, thermocouple. Strain gauge.

LECTURES: 6

Text Books:

1. A.K.Sawhney, A course in Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai Publications,2015.
2. E.W. Golding. And F.C.Widdis A Text Book of Electrical Measurement and Measuring Instruments, Wheeler Publications, 1968.
3. D. Cooper and A.D. Heifrick, Modern electronic instrumentation and measuring techniques, PHI, 2015.

Reference Books

1. R. A. Witte, Electronic Test Instruments, Pearson Education, 2002.
2. B. E. Jones, Instrumentation, Measurement and Feedback, Tata McGraw-Hill, 2000.
3. R. P. Areny and T. G. Webster, Sensors and Signal Conditioning, Wiley-Interscience, 2000.
4. C. F. Coombs, Electronic Instruments Handbook, McGraw-Hill, 2000.

MAL 1304	**Numerical Methods and Probability Theory**	**3-0-0-3**
As per the syllabus prescribed by the Department of Mathematics		

ECL 1302	**Digital Logic Design**	**3-0-0-3**
As per the syllabus prescribed by the Department of Electronics and Communication Engineering		

EEP 1301: CIRCUIT THEORY LABORATORY
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Verify various Laws and Theorems and determine two-port network parameters.
- Determine the resonant frequency, quality factor & bandwidth of the RLC circuits.
- Analyze DC and AC circuits using MATLAB and compare these results to those experimentally measured.

1. Transient response in R-L and R-C Network: Simulation/hardware
2. Transient response in R-L-C Series & Parallel circuits Network: Simulation/hardware.
3. Determination of Impedance (Z) and Admittance(Y) parameters of two port networks.
4. Frequency response of LP and HP filters.
5. Frequency response of BP and BR filters.
6. Generation of Periodic, Exponential, Sinusoidal, damped sinusoidal, Step, Impulse, and Ramp signals using MATLAB in both discrete and analog form.
7. Evaluation of convolution integral, Discrete Fourier transform for periodic & non-periodic signals, and simulation of difference equations using MATLAB.
8. Representation of poles and zeros in z-plane, determination of partial fraction expansion in z-domain, and cascade connection of second order system using MATLAB.
9. Determination of Laplace transform and inverse Laplace transformation using MATLAB.
10. Spectrum analysis of different signals.

Text/References:

1. Hayt & Kemmerly, Engineering Circuit Analysis, Mc Graw Hill.
2. Roy Choudhury, Network and Systems, New Age

EEP1303: ELECTRICAL AND ELECTRONIC MEASUREMENTS LAB
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Determine the resistance, and inductance using AC and DC bridges.
- Energy measurement using single phase energy meter.
- Understand the Power measurement for single and three phases using the ammeter voltmeter method and wattmeter method.
- Understand the measurement of different AC quantities using AC bridges.
- Understand the use of CRO and different digital meters.

List of Experiments:

1. Measurement of medium resistance using portable Wheatstone bridge.
2. Measurement of inductance using hay’s bridge.
3. Measurement of inductance using Maxwell Inductance Bridge.
4. Measurement of low resistance using Kelvin double bridge.
5. Study and calibration of single-phase energy

6. Using Lissajous figures to measure phase and frequency.
7. Measurement of power using an ammeter voltmeter.
8. Study of the range extension of an ammeter.
9. Measurement of capacitance using Schering Bridge.
10. Measurements of three-phase power using two wattmeter method.
11. Calibration of voltmeter using the potentiometer
12. Measurement of power factor, and frequency by using the electronic method.
13. Study of Digital Multimeter, LC R meter, DSO.

Text/References:

1. A.K.Sawhney, A course in Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai Publications, 2012.
2. E.W. Golding. And F.C.Widdis A Text Book of Electrical Measurement and Measuring Instruments, Wheeler Publications, 1968.

ECP 1302	**Digital Logic Design Laboratory**	**0-0-2-1**
As per the syllabus prescribed by the Department of Electronics and Communication Engineering		

4^{TH} SEMESTER

EEL1401 ELECTRICAL MACHINES-I **Prerequisite: EEL 1101, EEL 1302**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Acquire knowledge about the fundamental principles and classification of electromagnetic machines.
- Acquire knowledge about the constructional details and principles of operation of DC machines.
- Acquire knowledge about the working of DC machines as generators and motors.
- Acquire knowledge about testing and applications of dc machines.
- Acquire knowledge about the constructional details, principle of operation, testing and applications of transformers.
- Acquire knowledge about the constructional details and principle of operation of three phase induction motors.
- Acquire knowledge about the starting and speed control of induction motors.
- Acquire knowledge about testing and applications of induction motors.

1. Electromagnetism: Electromagnetism, effect of magnetic field on current carrying conductor, magnetic circuit, magnetising curve, characteristics of magnetic material, electromagnetic induction, excitation to magnetic circuit, hysteresis and eddy current losses, energy stored in magnetic circuit, mmf, mutual inductance and transformer.

LECTURES: 6

2. Transformer: Emf equation, relation between voltage per turn and KVA output, phasor diagram based on approx. and exact equivalent circuit, per unit equivalent resistance reactance, open circuit and short circuit tests, back-to-back test, regulation, losses and efficiency, max. efficiency, all day efficiency, wall cooling; two winding and three winding transformers, auto transformer, phase transformation and connections, parallel operation.

LECTURES: 9

3. DC Generators: Classification on methods of excitation, armature reaction, interpoles and compensating winding, commutation, load characteristics of DC generators, regulation, parallel operation.

LECTURES: 6

4. DC Motors: Torque equation, characteristic curves of shunt, series and compound motors, starting starter and grading of starting resistance, speed control – armature voltage control and field control methods; Ward Leonard method, choice of motors for different duties, losses and efficiency, testing- Swinburn's test, back-to-back test, retardation test and brake test.

LECTURES: 6

5. Polyphase Induction Motor: Operation of polyphase induction motors, effect of slots on performance of the motor, equivalent circuit and phasor diagram, locus diagrams, torque and power, speed – torque curve – effect of rotor resistance, deep barand double cage rotors, performance calculation from circle diagram, methods of speed control, testing, losses and efficiency, slip power recovery schemes application, induction generators and induction regulator.

LECTURES: 9

Text Books:

1. Electric Machinery Fundamental, Stephen J. Chapman, 5th edition, 2012.
2. Electric Machinery, P.S. Bhimbra, Khanna Publishers, 5th, 2011.
3. Electric Machines, D. P. kothari, I. J. Nagrath, McGrawHill, 2011.

Reference books:

1. Electrical Machines, S.K. Bhattacharya, McGrawHill, 4th,2014.
2. Electrical Machinery, S.K. Sen, Khanna Publishers, 5th, 2015.

EEL1402: POWER SYSTEMS-I **Prerequisite: EEL 1101**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the basics, economic aspects and tariff of electrical energy and power.
- Calculations and analysis of line parameters of transmission lines.
- Understand and realize per unit representation of power system.
- Explain different terminologies and mechanical designing of power system network components.
- Explain insulation and types of underground cables.

1. Introduction of Power System: Structure of power systems, single line diagram.

LECTURES: 1

2. Economics of Power Systems: Definitions of load, connected load, demand, peak load, demand intervals, demand factor, average load, load factor, diversity factors, utilization factor, capacity factor, load curves, base load, and peak load; calculations based on the above factors; economics of power factor improvement; tariffs: structures, calculation on tariff and economics of power factor improvement.

LECTURES: 4

3. Line Constants: Introduction to overhead line (OHL) constants; Inductance: inductance of solid cylindrical conductor, composite conductors, two conductor single phase line, three phase single circuit and double circuit lines with symmetrical and unsymmetrical spacing, transposed and untransposed line, skin and proximity effects Capacitance: potential difference between two points due to charge, capacitance of two wire line, three phase symmetrical and unsymmetrical line, charging current, effect of earth on capacitance of transmission line.

LECTURES: 8

4. Steady State Performance of Transmission lines: Classification of transmission lines; performance of short and medium transmission lines, nominal T and nominal π methods; performance of long transmission lines, economic choice of conductor size, Kelvin's law, Basic concepts of EHV AC and DC transmission systems.

LECTURES: 6

5. Per-Unit Representation of Power Systems: The one-line diagram, impedance and reactance diagrams, per unit quantities, changing the base of per unit quantities, advantages of per unit system.

LECTURES: 4

6. Mechanical Design of Overhead Line: Transmission towers and their classifications, components in transmission towers and lines, calculation of sag, ice and wind loading; stringing chart, sag template.

LECTURES: 4

7. Over Head Line Insulators: Types of insulators, voltage distribution of suspension insulators, string efficiency, methods of improving string efficiency, corona: disruptive critical and visual critical voltages, factors effecting corona, corona power loss; advantages and disadvantages of corona, radio interference.

LECTURES: 4

8. Underground Cables: Insulator materials; construction of single core and three core cables; classification of cables and their construction; laying of cables; jointing of cables; stress and capacitance of single core and three core cables; most economical size of conductor; grading of cables; types of grading; breakdown voltages and mechanism of breakdown, thermal characteristics of cables; comparison of overhead and underground supply system.

LECTURES: 5

Readings:

Prescribed Text Books

1. D. P. Kothari and I. J. Nagrath, Power System Engineering, McGraw-Hill, 2011
2. A. Chakrabarti, S. Halder, Power System Analysis Operation and Control, PHI, 2016
3. C. L. Wadhwa, Electrical Power systems, New Age International, 2007
4. Ashfaq Husain, Electrical Power Systems, CBS Publishers, 2007
5. B. R. Gupta, Generation of Electrical Energy, S. Chand & Co. 2009

Reference Books

1. M.LSoni, P.V Gupta, U.S Bhatnagar, Electric Power, DhanpatRai& Sons, 1984
2. J. B. Gupta, A course in Power Systems, S. K. Kataria& Sons, 2002
3. O.I.Elgerd Electric Energy System Theory - An Introduction Tata McGraw-Hill, 2002

EEL1403: POWER PLANT ENGINEERING **Prerequisite: EEL 1101**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To introduce students to different aspects of power plant engineering.
- To familiarize the students with the working of power plants based on different fuels.
- To expose the students to the principles of safety and environmental issues

1. 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.

LECTURES-8

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

LECTURES-8

3. Hydro Stations; selection of site, mass curve, flow duration curve, hydrograph, classification of hydro plants, types of hydro turbines, and pumped storage plants.

LECTURES-4

4. Nuclear Stations; main parts, location, the principle of nuclear energy, types of nuclear reactors, reactor control, nuclear waste disposal.

LECTURES-4

5. Power Station Control and Interconnection – excitation systems, excitation control, automatic voltage regulator action; the advantage of interconnection.

LECTURES-8

6. Alternate Energy Sources – solar, wind, geo-thermal, ocean-thermal, tidal wave MHD and mass**.**

LECTURES-8

Text Books

1. B. R. Gupta, Generation of Electrical Energy S. Chand limited, 2009
2. P. Kundur, Power system stability, and control McGraw-Hill, 1994

Reference Books

1. M.V. Deshpande, Elements of Electrical Power Station Design, Wheeler Publishing Co., 1979
3. Soni, Gupta, Bhatnagar Electric Power Dhanpat Rai & Sons, 1984
4. J.B.Gupta A course in Power Systems S.Kataria & SONS, 2002

EEL 1404: Control System-I **Prerequisite: EEL 1301**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Developing the mathematical model of the physical systems.
- Understanding the concepts of time domain analysis.
- Analyze the response of the closed and open loop systems.
- Analyze the stability of the closed and open loop systems.
- Design the various kinds of compensator.

1. Introduction: The control problem and its solution, feedback, regulation, and tracking problems.

LECTURES: 3

2. Physical Systems and Models: Transfer function, examples with mechanical, electrical, hydraulic, pneumatic systems and systems with dead zone; control system components: error detectors, gears, gyroscope, dc motors, servomotors, tacho generators, servo amplifiers; block diagrams and reduction techniques, signal flow graphs, Mason's gain formula.

LECTURES: 8

3. Time Domain Analysis: Time domain analysis of 1st and 2nd order systems; transient and steady-state responses; transient and steady-state responses with unity feedback system; sensitivity and error analysis.

LECTURES: 5

4. Root Locus Analysis: Root locus; effects of pole/zero on root locus; stability and relative stability using root locus.

LECTURES: 5

5. Frequency Domain Analysis: Routh array analysis; Bode, polar and Nyquist plots; stability and relative stability using these plots; M and N circles; Nichols's plot.

LECTURES: 10

6. Controller/ Compensator Design: Design of lag, lead, and lag–lead compensators; P, PD, PI, and PID error control strategies.

LECTURES: 5

Text Books

1. K. Ogata, Modern Control Engineering, Pearson Education, 2009
2. M. Gopal, Control Systems Principles and Design, Tata McGraw Hill, 2012

Reference Books

1. D' Azzo and Houpis, Linear Control Systems Analysis and Design McGraw Hill, 1995
2. N S Nise, Control Systems Engineering John Wiley & sons, 201
3. R. C. Dorf and R. H. Bishop, Modern Control Systems, Addison Wesley, 1999

ECL 1401	**Analog Circuits**	**3-1-0-4**
As per the syllabus prescribed by the Department of Electronics and Communication Engineering		

EEP1401: Electrical Machines-I Laboratory
L-T-P: 0-0-2 **Credit: 1**
Course Outcomes:

- Acquire hands-on experience of conducting various tests on dc machines and obtaining their performance indices using standard analytical as well as graphical methods.
- Acquire hands-on experience of conducting various tests on transformers and obtaining their performance indices using standard analytical as well as graphical methods.
- Acquire hands-on experience of conducting various tests on alternators and obtaining their performance indices using standard analytical as well as graphical methods.
- Acquire hands-on experience of conducting various tests on induction machines and obtaining their performance indices using standard analytical as well as graphical methods.

Experiments:

1. To pre-determine the efficiency and regulation of a Transformer by conducting open circuit and short circuit tests and to draw the equivalent circuit
2. To study and verify the operating characteristics of a DC Series motor
1. 3 To study and verify the speed control of a DC Series motor by Armature resistance control
5. To study and verify the speed control of a DC Series motor by the Field diverter method
6. Study of load characteristics of DC Shunt Generator
7. Study of no-load and load characteristics of a Separately excited DC Shunt motor and draw N-T & N-Ia characteristics
8. Speed control of separately excited DC shunt motor by
9. To study and verify the Load characteristics of Short Shunt DC compound motor
    a. Armature voltage control
    b. Field Current control
10. To study and verify the load characteristics of Long Shunt DC compound Motor.
11. Study of No-Load test on a Three phase Induction Motor
12. Study of Block Rotor test on a Three phase Induction Motor

Text/References:

1. S. Chapman, Electric Machinery Fundamentals, 4/e, McGraw-Hill, 2003.
2. R. K. Rajput, Electrical Machines, 3/e, Laxmi Publications (P) Ltd., 2003.

EEP1402: POWER SYSTEMS-I LABORATORY
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Understand the line parameters.
- Knowledge of different types of electrical faults.
- Understand relays operation and characteristics.
- Understand the load flow analysis.
- Know Economic load dispatch problems.

List of Experiments

1. Computation of Line parameters (Inductance).
2. Computation of Line parameters (Capacitance).
3. Automatic as well as manual Synchronization of generator with grid supply.
4. Study of V curve & inverted V curve.
5. Study of Generator performance chart.
6. Study of voltage variation & control.
7. Study of voltage regulation for constant cosϕ.
8. Study of No load test and Ferranti effects on transmission line.
9. Load test and calculation of efficiency, regulation and power flow in pi model of TL.
10. Load test and calculation of efficiency, regulation and power flow in short model of TL

Text/References:

1. C.L. Wadhwa, Electrical Power systems, New Age International, 2007
2. A. Hussain, Electrical Power System, CBS Publishers,2007

ECP 1401	**Analog Circuits Laboratory**	**0-0-3-1.5**
As per the syllabus prescribed by Department of Electronics and Communication Engineering		

5TH Semester

EEL1501: ELECTRICAL MACHINES-II **Prerequisite: EEL 1101, EEL 1302**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Acquire knowledge about the constructional details and principle of operation of alternators.
- Acquire knowledge about the working of synchronous machines as generators and motors.
- Acquire knowledge about testing and applications of synchronous machines.
- Acquire knowledge about the constructional details and principle of operation single phase induction motors.
- Acquire knowledge about the starting and speed control of induction motors.
- Acquire knowledge about testing and applications of induction motors.
- Acquire knowledge about the constructional details and principle of operation single phase linear induction motors.
- Acquire knowledge about the constructional details and principle of operation single phase stepper motors.

1. Synchronous Generator (SG): Principle of operation, construction, excitation systems, cooling, emf equation, flux and mmf diagram, synchronous impedance, voltage regulation, short circuit ratio, external characteristics, power angle characteristics of cylindrical rotor alternator, parallel operation, synchronous generator connected with infinite bus, salient pole generators, two reaction theory and phasor diagrams, determination of $X_d$and X_q, power angle characteristics of salient pole machine, synchronizing power and synchronizing torque, hunting and damper winding, Losses and efficiency.

LECTURES: 15

2. Synchronous Motors: Principle of operation, equivalent circuit and phasor diagram, starting, power and torque developed in a cylindrical rotor and salient pole rotor synchronous motor, effect in change of load and excitation, V-curves, hunting and its mitigation, application.

LECTURES: 5

3. Single Phase Commutator Motors: Series, repulsion and universal motors – construction, principle of operation, commutation, starting methods; speed control; power factor and methods of compensation.

LECTURES: 6

4. Single Phase Induction Motors: Construction, analysis of starting and running characteristics; starting methods.

LECTURES: 4

5. Linear Induction Motors: Introduction, operating principles and application areas.

LECTURES: 3

6. Stepper Motor: Construction, torque-stepping rate characteristics, application areas.

LECTURES: 2

Text Books

1. S. Chapman, Electric Machinery Fundamentals, 4/e, McGraw-Hill, 2003.
2. R. K. Rajput, Electrical Machines, 3/e, Laxmi Publications (P) Ltd., 2003.
3. A. Chakrabarti and S. Debnath, Electrical Machines, McGraw-Hill Education, 2015

Reference Books

1. S.K. Sen, Electrical Machinery, Khanna Publishers, 2002
2. P.S. Bimbhra, Generalized Theory of Electrical Machines, Khanna Publishers, 2002
3. D. P. Kothari, I. J. Nagrath, Electrical Machines, TMH, 2004
4. A.S. Leinsdorf, Theory of A.C. Machines, MH, 2001

EEL1502: POWER SYSTEMS-II **Prerequisite: EEL 1101, EEL 1402**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Study and analysis of types of faults, symmetrical and unsymmetrical components.
- Analysis of swing equation and stability studies of power system.
- Perform load flow analysis of power system networks using Gauss-Seidel, Newton-Raphson and Fast-Decoupled iterative methods.
- Analysis of economic operation of energy generation systems and operation of automatic generation control.
- Understand protective relays, circuit breakers and neutral grounding.

1. Fault Analysis: Causes of faults, types of faults, importance of fault analysis in electrical power systems, identification of system fault, fault analysis for generators, transmission lines, concepts of generator reactance's; transient, sub-transients etc, current limiting reactors, types, functions.

LECTURES: 6

2. Symmetrical Components and Unsymmetrical Fault Analysis: Concepts of symmetrical components, Fortescue's theorem, power in terms of symmetrical components, sequence impedances and sequence networks for generators, transformers, transmission lines etc, unsymmetrical fault (L-G, L-L, LL-G) analysis.

LECTURES: 7

3. Power System Stability: Operation of synchronous machine on infinite bus; stability-classification, power limit of transmission lines, steady state stability, Clarke's diagram, transient stability- the swing equations, equal area criterion, critical clearing angles; power angle curves for fault and post fault conditions for various types of faults; solution of swing equation, dynamic stability; factors affecting stability.

LECTURES: 5

4. Load Flow Analysis: Static load flow equation, system, bus classification, Formation of admittance matrix. Gauss Seidel, Newton-Raphson and fast-decoupled load flow methods and comparison of methods. **LECTURES:6**

5. Economic Operation of Energy Generation Systems: Generation Cost Curves; Economic Operation of Thermal System; Plant Scheduling; Transmission Loss and Penalty Factor; Hydro-Thermal Scheduling.

LECTURES: 5

6. Automatic Generation and Voltage Control: Automatic voltage control, Load frequency control of single and two area system, AGC in restructured power system.

LECTURES: 4

7. Lightning Arrester& Neutral Grounding: Principals of operation, ungrounded system- arcing ground, types of grounding- solid, resistance, reactance and resonant grounding, generator neutral breaker, grounding practices.

LECTURES: 3

Text Books

1. J.H. Grainger and W.D. Stevenson Jr., Power System analysis, McGraw-Hill, 1994
2. D. P Kothari and I J Nagrath, Modern *Power System*, Tata McGraw-Hill, 2008
3. A. Chakrabarti and S. Halder, Power system operation analysis and control, PHI, 2016
4. C.L. Wadhwa, Electrical Power systems, New Age International, 2007
5. Ashfaq Husain, Electrical Power System, CBS Publishers, 2007

Reference Books:

1. M.L. Soni, P.V. Gupta, U.S. Bhatnagar Electric Power, Dhanpat Rai& Sons, 1984
2. P. Kundur, Power system stability and control, McGraw-Hill, 1994
3. P. Venkatesh, Electrical Power Systems, PHI Learning , 2012.

EEL1503: POWER ELECTRONICS **Prerequisite: EEL 1101, EEL 1301**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To introduce students to the basic theory of power semiconductor devices and passive components, their practical applications in power electronics.
- To familiarize students to the principle of operation, design and synthesis of different power conversion circuits and their applications.
- To provide strong foundation for further study of power electronic circuits and systems.

1. Introduction: Scope and applications.

LECTURES-2

2. Power semiconductor Devices: Power diodes, power transistors, SCRs, TRIACs, GTOs, power MOSFETs and IGBTs- principles of operation and V-I characteristics, device specifications, ratings, protection and cooling; methods for turning on SCRs, gate triggering circuit, methods for turning-off SCRs.

LECTURES-8

3. AC to DC Converter: single and three phase diode rectifiers for various loads, single and three phase thyristor rectifiers for various loads, effect of source impedance; symmetrical and unsymmetrical semi converter and dual converter- effect on power factor and total harmonic distortion (THD).

LECTURES-10

4. DC to DC Power Converters: limitations of linear power supplies, switched mode power supplies (buck, boost, buck-boost, cuk, fly-back and forward converters.

LECTURES-4

5. DC to AC Converters: principle of operation of inverters, half bridge, full bridge, three phase-six step operations, voltage control- pulse width modulation (PWM) techniques.

LECTURES-4

6. AC Controllers: Principle of on-off and phase control, single phase and three phase controllers with R and R-L loads. Principle of operation of cycloconverters, circulating and non-circulating mode of operation, single phase to single phase steps up and step down cycloconverters, three phase to single phase Cycloconverters, three phase to three phase Cycloconverter.

LECTURES: 8

7. Applications: HVDC transmission. Static circuit breaker, UPS, static VAR controller

LECTURES: 3

Text Books

1. N. Mohan, T. Undeland, W. Robbins, Power Electronics Converter, Applications And Design, John Wiley & Sons, 2003
2. G.K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House,2003

Reference Books

1. S. B. Dewan &A. Straughen, Power Semiconductor Circuits, John Wiley & Sons,2012.
2. B.K Bose, Modern Power Electronics and AC Drives, Pearson Education, 2003
3. M. Rashid, Power Electronics, Prentice Hall India Ltd, 2004

ECL 1501	**Digital Signal Processing**	**3-0-0-3**
As per the syllabus prescribed by Department of Electronics and Communication Engineering		

ECL 1502	**Microprocessors & Microcontrollers**	**3-0-0-3**
As per the syllabus prescribed by Department of Electronics and Communication Engineering		

HUL 1501	**Humanities/Managerial Economics**	**2-0-0-2**
As per the syllabus prescribed by Department of Humanities and Management.		

EEP1501: ELECTRICAL MACHINES –II LABORATORY **Prerequisite: NA**
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Identify relevant information to supplement to the Electric Machine II
- Students to get hands on experience in relation to transformers and AC machines in a laboratory setting.

List of Experiments

1. Study of No-Load test on a single-phase Induction Motor
2. Study of Block Rotor test on a single-phase Induction Motor
3. Study of Load test on a single-phase Induction Motor
4. To study the Open circuit characteristics of Three Phase Synchronous Generator
5. To study the short circuit characteristics of Three Phase Synchronous Generator.
6. Study of V- curve and Inverted V-curve of a Three Phase Synchronous motor.

Text/References:

1. S. Chapman, Electric Machinery Fundamentals, 4/e, McGraw-Hill, 2003.
2. R. K. Rajput, Electrical Machines, 3/e, Laxmi Publications (P) Ltd., 2003.

EEP1503 Power Electronics Laboratory **Prerequisite: NA**
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Able to elucidate the basic operation of various power semiconductor devices and passive components.
- Able to analyze power electronics circuits l Able to apply power electronic circuits for different load.

List of Experiments

1. Study of the characteristics of an SCR.
2. Study of the characteristics of a TRIAC
3. Study of different triggering circuits of an SCR
4. Study of firing circuits suitable for triggering SCR in a single phase full controlled bridge.
5. Study of the operation of a single phase full controlled bridge converter with R and R-L load.
6. Study of performance of single-phase half controlled symmetrical and asymmetrical bridge converters.
7. Study of performance of step-down chopper with R and R-L load.
8. Study of performance of single phase-controlled converter with and without source inductance (simulation)
9. Study of performance of step up and step-down chopper with MOSFET, IGBT and GTO as switch(simulation).
10. Study of performance of single-phase half controlled symmetrical and asymmetrical bridge converter. (simulation)
11. Study of performance of three phase-controlled converter with R & R-L load. (simulation)
12. Study of performance of PWM bridge inverter using MOSFET as switch with R and R-L load.
13. Study of performance of three phase AC controller with R and R-L load (simulation)
14. Study of performance of a Dual converter. (simulation)
15. Study of performance of a Cycloconverter (simulation)

Text/References:

1. N. Mohan,T. Undeland, W. Robbins, Power Electronics Converter ,Applications And Design, John Wiley & Sons, 2003

2. G.K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House,2003

ECP 1502	**Microprocessors & Microcontrollers Laboratory**	**0-0-3-1.5**
As per the syllabus prescribed by Department of Electronics and Communication Engineering		

6^{TH} SEMESTER

EEL 1601: SWITCHGEAR AND PROTECTION **Prerequisite: EEL 1402, EEL 1502**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand different types of circuit breaker, protective relays and fuses.
- Knowledge of substation layout and different equipments.
- Understand the function of neutral grounding and lightning arrester

1. Circuit Breakers (CBs): Function, arc phenomenon and arc interruption theories, CB types (min. oil, vacuum and SF_6), circuit breaking transients, restriking and recovery voltages, CB ratings, testing of CBs; introduction to solid state CBs.

LECTURES: 5

2. Protective Relays: Operating principles, classification, electromagnetic type relays theories for torque generation, protective zones, over current relay-characteristics, directional relay-torque generation, feeder protection- time grading and current grading, distance relays and their characteristics, differential protections, protection of transmission lines, generator and transformers, transley relay, negative sequence relay. Principal, operation, types and application.

LECTURES: 18

3. Substation Layouts for Protection: Single line diagram with different busbar arrangement, reactors, isolators, bus-tie breakers, substation grounding, surge protection.

LECTURES: 5

4. Neutral Grounding: Principals of neutral grounding, ungrounded system-arcing ground, types of grounding- solid, resistance, reactance and resonant grounding, generator neutral breaker, grounding practices.

LECTURES: 5

5. Lightning Arrester: Function, types, working principles and surge absorbers.

LECTURES: 2

Text Books

1. S. S Rao, Switchgear and Protection, Khanna Publisher, 1999
2. D.N Vishwakarma, Badri Ram, Power System Protection and Switchgear, Tata McGraw - Hill Education 2011

Reference Books

1. J B Gupta, Switchgear and Protection, S.K. Kataria & Sons, 2002
2. A. Wright and C. Christopoulos, Electrical Power system protection, Chapman & Hall, 1993.

EEL1602: ELECTRIC DRIVES **Prerequisite: EEL1401, 1501, 1503**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To understand the fundamental of Electric Drives.
- To learn the motor power rating (heating and cooling characteristics and operation).
- To learn details about DC drives (Motoring, Braking and speed control of DC drives)
- To study details about AC drives (Induction motor and synchronous motor drives)

1. Fundamentals of Electric Drive: Concept, classification, parts and advantages of electrical dives. Types of Loads, Components of load toques, Fundamental torque equations, Equivalent value of drive parameters for loads with rotational and translational motion. Determination of moment of inertia, Steady state stability, Transient stability. Multi-quadrant operation of drives. Load equalization.

LECTURES: 8

2. Motor Power Rating: Thermal model of motor for heating and cooling, classes of motor duty, determination of motor rating for continuous, short time and intermittent duty, equivalent current, torque and power methods of determination of rating for fluctuating and intermittent loads. Effect of load inertia & environmental factors.

LECTURES: 6

3. DC Motor Drives: Modeling of DC motors, State space modeling, block diagram & Transfer function, Starting and braking of DC motor, Acceleration time Energy relation during stating, methods to reduce the Energy loss during starting and braking. Single phase, three phases fully controlled and half controlled DC drives. Dual converter control of DC drives. Power factor, supply harmonics and ripple in motor current chopper-controlled DC motor drives, closed loop control of DC motor.

LECTURES: 10

4. Induction Motor Drives: Performance of induction Motor, Starting and braking of induction motor, Stator voltage variation by three phase controllers, Speed control using chopper resistance in the rotor circuit, slip power recovery scheme. Pulse width modulated inverter fed and current source inverter fed induction motor drive. Volts/Hertz Control, Vector or Field oriented control.

LECTURES: 10

5. Synchronous Motor Drives: Performance of synchronous motor drive, Starting and braking of synchronous motor drive, Variable frequency control, Self-Control, Voltage source inverter fed synchronous motor drive, Vector control, Permanent magnet motor, Stepper motor, Switched Reluctance motor drive

LECTURES: 8

Text Books

1. Fundamental of Electrical Drives, G.K. Dubey, New Age International Publication.
2. Electric Drives, Vedam Subrahmanyam, TMH
3. A first course on Electrical Drives, S.K. Pillai, New Age International Publication.

Reference Books

1. Electric motor drives, R. Krishnan, PHI
2. Modern Power Electronics & Ac drives, B.K. Bose, Pearson Education.
3. Electric Motor & Drives. Austin Hughes, Newnes.

EEL1603: CONTROL SYSTEM-II **Prerequisite: EEL 1404**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Developing and analyzing state space models.
- Linearize the non-linear physical systems.
- Study the non-linear system behavior by phase plane and describing function methods.
- Study the stability of linear and nonlinear systems by Lyapunov method.
- Understand mathematical models of linear discrete-time control systems using transfer functions and state-space models.

1. Introduction to Discrete Time Systems: mathematical preliminaries- difference equations, Z Transform and properties; sampling quantization and reconstruction process, discrete time systems, system response, transfer function stability and the jury stability criterion, implementation of digital controllers and digital controllers for deadbeat performance.

LECTURES: 12

2. State Space Representation of Continuous Time and Discrete Time Systems: state space models, state space representation of simple electrical and mechanical systems, canonical forms, solution of state equation, state transition matrix, relation between transfer function and state variable representations; controllability and observability, pole- placement using state variable feedback; design of full order and reduced order observer, observer-based state feedback controller.

LECTURES: 12

3. Introduction to Nonlinear Feedback Control Systems: characteristics of nonlinear systems; linearization techniques; phase plane analysis, singular points, limit cycle vs closed trajectory; stability analysis using phase plane analysis- describing function (DF) of common nonlinearities, stability analysis using DF; stability in the sense of Lyapunov, Lyapunov's stability theorems for linear and nonlinear systems; effect of non-linearity in root locus and Nyquist plot.

LECTURES: 12

Readings:

Prescribed Text Books

1. K. Ogata, Modern Control Engineering, Pearson Education, 2009
2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 2003

Reference Books

1. R. C. Dorf and R. H. Bishop, Modern Control Systems, Prentice Hall, 2010
2. B C. Kuo, Digital Control Systems, Oxford University Press, 1995
3. M. Gopal, Modern Control System Theory, New Age International, 1993

EEL 16XX	**Departmental Elective-I**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

CHL 1601	**Environmental Science**	**2-0-0-0**
As per the syllabus prescribed by Department of Chemistry.		

EEP1601: POWER SYSTEMS-II LABORATORY
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Understanding of different types of buses in power system network
- Understanding of fault analysis
- Understanding of load flow analysis
- Understanding of load frequency control
- Understanding of different types of protection in power system

List of Experiments

1. Formation of Bus Admittance and Impedance Matrices.
2. Unsymmetrical fault analysis through MATLAB.
3. Symmetrical fault analysis through MATLAB.
4. Study of symmetrical and asymmetrical faults on transmission line through Hardware Simulator.
5. Newton-Raphson Load flow analysis of multi-bus power system network.
6. Three & Four bus load flow study through Hardware Simulator.
7. Economic load dispatch in power systems.
8. Load flow analysis of power system network using ETAP.
9. Load Frequency Dynamics of Single and Two Area Power System
10. Study of distance protection using distance relay.
11. Study of Auto recloses function of distance relay.
12. Study of Distribution transformer protection for differential & over current faults.
13. Study of generator protection for differential, over current, over/under voltage, over/under frequency, reverse power and earth faults using generator protection relay.

Text/References:

1. C. L. Wadhwa, Electrical Power systems, New Age International, 2007
2. J. H. Grainger and W.D. Stevenson Jr., Power System analysis, McGraw-Hill, 1994

EEP1602: ELECTRIC DRIVES LABOTORY
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- To impart knowledge on Performance of the fundamental control practices associated with AC and DC machines (starting, reversing, braking, plugging, etc.) using power electronics.
- To impart industry oriented learning.
- To evaluate the use of computer-based analysis tools to review the major classes of machines and their physical basis for operation.

List of Experiments

1. Simulation of 1-phase and 3-Phase uncontrolled Rectifier fed DC motor drives using MATLAB-SIMULINK/PSIM software.
2. Simulation of 1-phase fully controlled Converter fed DC motor drives using MATLAB-SIMULINK/PSIM software.

3. Simulation of 3-phase fully controlled Converter fed DC motor drives using MATLAB-SIMULINK/PSIM software.
4. Simulation of Different Braking methods of DC motor drives using MATLAB-SIMULINK/ PSIM software.
5. Simulation of Different Braking methods of induction motor drives using MATLAB-SIMULINK/ PSIM software.
6. Simulation of DC to DC Converter fed DC motor drives using MATLAB SIMULINK/PSIM software.
7. Simulation of 3-phase VSI fed AC motor drives using MATLAB-SIMULINK/PSIM software.
8. Simulation of 3-phase PWM VSI fed AC motor drives using MATLAB-SIMULINK/PSIMsoftware.
9. Simulation of 3-phase CSI fed AC motor drives using MATLAB-SIMULINK/PSIM softwarestudy of V/f control of Induction motor drives.
10. Performance & Operation of a 1-phase A.C. Voltage controller and TRIAC on 1-phase induction motor load using MATLAB-SIMULINK/PSIM software.
11. Study of V/f control operation of 3Φ induction motor drive.
12. DSP & FPGA based AC and DC motor drives.

Text/References:

1. Fundamental of Electrical Drives, G.K. Dubey, New Age International Publication.
2. Electric Drives, Vedam Subrahmanyam, TMH

EEP1603: CONTROL SYSTEMS LABORATORY
L-T-P: 0-0-2 **Credit: 1**

Course Outcomes:

- Determination the response of common nonlinearity and response in Z- domain.
- Determination of pole-zero configuration, step response, stability analysis using Bode and Nyquist plots
- Understand the modeling of linear-time-invariant systems using transfer function and state-space representations.
- Understand the concept of stability and its assessment for linear-time invariant systems.
- Design simple feedback controllers.

List of Experiments

1. Design of load compensation and by compensation using MATLAB
2. Familiarization and use of MATLAB command associated with state variable analysis and Digital Control System.
3. Determination of phase plane trajectory and possibility of limit cycle common non-linearities.
4. Familiarisation with digital controller and determination of response due to variation of controller parameters.
5. Determination of response with common nonlinearity as introduced into the forward path of a 2nd order unity feedback control system using MATLAB.
6. Determination of response in Z- domain using MATLAB SIMULINK Toolbox or
7. Study of pole-zero configuration, step response, stability analysis using Bode and Nyquist plots, study of gain and phase margins.

8. Design of compensators, controllers.
9. Study of open loop and closed loop frequency response and effect of addition of poles and zeros.
10. Study of relay control system.
11. Study of P, PI and PID controller of type 0 and type 1 system with time delay
12. Study of closed loop behaviour of first, second and third order systems.
13. Study of Lead lags controller design.

Text Books

1. K. Ogata, Modern Control Engineering, Pearson Education, 2009
2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 2003

EEP 1604: ELECTRICAL MACHINE DESIGN **Prerequisite: NA**
L-T-P: 1-0-3 **Credit: 2**

Course Outcomes:

- Determine different parameters and design of DC Machine.
- Understand the principles of electrical machine design and carry out a basic design of an ac machine.
- Use software tools to do design calculations.

List of Experiments

1. Analytical design of DC series motor.

2. Design of DC shunt motor (self and separately excited).

3. Design of 3-phase Transformer.

4. Design of 3-phase of squirrel cage Induction motor.

Text / References:

1. K. Sawhney, "A Course in Electrical Machine Design", Dhanpat Rai and Sons, 1970.
2. M.G. Say, "Theory & Performance & Design of A.C. Machines", ELBS London.
3. S. K. Sen, "Principles of Electrical Machine Design with computer programmes", Oxford and IBH Publishing, 2006.

7TH SEMESTER

EEL 17XX	**Departmental Elective-II**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EEL 17XX	**Departmental Elective-III**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EEL 17XX	**Departmental Elective-IV**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EEL 17XX	**Open Elective-I**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EED 1701	**Project Phase-1**	**0-0-8-4**
EEG 1702	**Seminar**	**0-0-2-1**
EEV 1702	**Industrial Training Viva**	**0-0-2-1**

8TH SEMESTER

EEL 18XX	**Departmental Elective-V**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EEL 18XX	**Departmental Elective-VI**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EEL 18XX	**Open Elective-II**	**3-0-0-3**
As per the syllabus from list of Program Elective course.		

EED 1804	**Final Project**	**0-0-20-10**
EEV 1804	**Grand Viva**	**0-0-2-1**

EEL 1X11: HIGH VOLTAGES AND INSULATION ENGINEERING **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Elucidate the concepts used for the generation and measurement of high voltages and currents and design corresponding circuits.
- Understand breakdown phenomena in gases and to elucidate the concepts used for the generation of high voltages and currents.
- Understand high voltage testing techniques of Power apparatus and causes of over voltage in Power systems.
- Understand the generation of transients and the concept of insulation coordination.

1. Overview of High Voltage Engineering and Electrostatic Field distribution:
Overview of High Voltage Engineering and numerical methods applied in calculating electrostatic field in complex insulating configurations.

LECTURES: 2

2. Generation of high voltages and currents, AC voltages:
Cascade transformers-series resonance circuits DC voltages: voltage doubler-cascade circuits-electrostatic machines Impulse voltages: single stage and multistage circuits wave shaping-tripping and control of impulse generators Generation of switching surge voltage and impulse currents.

LECTURES: 8

3. Measurement of high voltages and currents:
DC, AC and impulse voltages and currents-DSO-electrostatic and peak voltmeters-sphere gaps-factors affecting measurements-potential dividers (capacitive and resistive)-series impedance ammeters-rogowskicoils-hall effect generators.

LECTURES: 6

4. Breakdown mechanisms in Solid, Liquid and Gaseous Dielectrics:
Solid Dielectrics Breakdown through Intrinsic, Thermal, Electrochemical, Treeing, Tracking, partial discharges, Liquid Dielectrics Breakdown through Electronic, in Pure and Commercial Dielectric, Breakdown in uniform and non-uniform fields-Paschens law-Townsends criterion-streamer mechanism-corona discharge-breakdown in electro negativegases.

LECTURES: 8

5. Lightning and Switching Transients, Insulation Coordination:
Transients and its causes and Effects, Use of Bewley Lattice Diagram in calculation of Transients, Nominal and Maximum System Voltage, Factor of Earthing, Insulation Level, Earth Wire, Conventional and Statistical methods of Insulation Coordination.

LECTURES: 6

6. High voltage testing of materials and apparatus:
Preventive and diagnostic tests-dielectric loss measurements-schering bridge-inductively coupled ratio arm bridge-partial discharge and radio interference measurement-testing of circuit breakers and surge diverter.

LECTURES: 6

Text Books:

1. Kuffel, Zaengl, Kuffel, High Voltage Engineering Fundamentals, Newnes Publications, 2000.
2. C.L. Wadhwa , High Voltage Engineering, New Age publication, 2007

Reference Books:

1. D. Kind and K. Feser, High Voltage Test Technique, SBA Publication, 1999
2. M.S. Naidu & V. Kamaraju, High Voltage Engineering, McGraw Hill, 1995

EEL 1X12: EXTRA HIGH VOLTAGE AC AND DC TRANSMISSION **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the advantages of dc and ac transmission and Principal application of AC and DC Transmission.
- Understand the operation of Line Commutated Converters and Voltage Source Converters.
- Understand the control strategies used in HVAC and DC transmission system.
- Understand the improvement of power system stability using an HVDC system.

1. Constitution of EHV AC and DC Links, Kind of DC Links, Limitations and advantages of AC and DC Transmission, Principal application of AC and DC Transmission, trends EHV AC and DC Transmission, Power-handling capacity, Converter analysis Garentz circuit, Firing control, overlapping.

LECTURES: 7

2. Extra-long distance lines, Voltage profile of loaded and unloaded line along the line, Compensation of lines, series and shunt compensation, Shunt reactors, Tuned power lines, Problems of extra-long compensated lines, FACT concept and application.

LECTURES: 7

3. Travelling waves on transmission systems, Their shape, attenuation and distortion, effect of junction and termination on propagation of traveling waves, Over voltages in transmission system, Lightning, switching and temporary over voltage: Control of lighting and switching over voltages.

LECTURES: 7

4. Components of EHV dc system, converter circuits, rectifier and inverter valves, Reactive power requirements, harmonics generation, adverse effects, Classification, Remedial measures to suppress, filters, Ground return, Converter faults & protection harmonics mis operation, Commutation failure, Multi-terminal D.C.

LECTURES: 8

5. Control of EHV dc system desired features of control, control characteristics, constants current control, Constant extinction angle control, Ignition angle control, parallel operation of HVAC & DC system, Problems and advantages.

LECTURES: 7

Text Books

1. K. R. Padiyar, HVDC Power Transmission Systems, Wiley Eastern Ltd, 1990.
2. Begmudre, EHV AC Transmission.

Reference Books:

1. J. Arrillag, High Voltage Direct Transmission, Peter Peregrinus, 1983.
2. E. W. Kimbark, Direct Current Transmission, Vol.I, Wiley Interscience, 1971.
3. S.Rao, EHV AC & DC Transmission.

EEL 1X13: UTILIZATION OF ELECTRICAL POWER **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To study the Electric Traction: D.C. and A.C traction, speed control and braking etc.
- To learn the methods of electric heating, resistance, dielectric, induction and arc heating, high frequency heating, comparison of electric heating methods, Applications.
- To learn the methods of welding, resistance, electric arc, ultrasonic and laser welding's; welding-transformer, power sources and control circuits, control of current flow.
- To study the Illumination, nature of radiation, definitions, polar curves, laws of illumination, luminous efficiency, sources of light, incandescent, vapour, compact florescent lamp, LED and florescent lighting; factory lighting, flood lighting, street lighting and residential lighting.
- To know the necessity of energy audit, types of energy audit.

1. Electric Traction: D.C. and A.C traction, electric traction motors- starting, speed control and braking; system of power supply in traction.

LECTURES: 5

2. Electric Heating: Classification, methods of electric heating, resistance, dielectric, induction and arc heating, high frequency heating, comparison of electric heating methods, Applications.

LECTURES: 4

3. Electric Welding: Classification, methods of welding, resistance, electric arc, ultrasonic and laser welding's; welding-transformer, power sources and control circuits, control of current flow.

LECTURES: 6

4. Illumination: introduction, nature of radiation, definitions, polar curves, laws of illumination, luminous efficiency, sources of light, incandescent, vapour, compact florescent lamp, LED and florescent lighting; factory lighting, flood lighting, street lighting and residential lighting.

LECTURES: 10

5. Energy Audit: necessity of energy audit, types of energy audit- preliminary and detailed energy audit, energy management (audit) approach-understanding energy costs, bench marking, energy performance, matching energy use to requirement, maximizing system efficiencies, energy audit methods of saving electricity in drives, lighting, and distributions systems metering, case study of energy auditing and potential energy saving.

LECTURES: 11

Text Books

1. Albert, Plant Engineers & Managers Guide to Energy Conservation, the Fairmont Press, 2011
2. C. Wayne, Turner Energy management handbook, John Wiley and Sons, 1982
3. H. Partab, Art and Science of Electrical Energy, Dhanpat Rai and Co. Pvt. Ltd, 1994
4. H. Partab, Modern Electric Traction, Dhanpat Rai and Co. Pvt. Ltd, 1998

Reference Books:

1. NPC energy audit manual and reports
2. Barney L. Capehart, Wayne C. Turner, William J. Kennedy Guide to Energy Management, 2008.

EEL 1X14: Advanced Control System **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Developing and analyzing state space models.
- Study the nonlinear system behavior by phase plane and describing function methods.
- Study the stability of linear and nonlinear systems by Lyapunov method.
- Understand mathematical models of linear discrete-time control systems using transfer functions and state-space models.

1. State Variable Analysis and Design:
State space models, state space representation of simple electrical and mechanical systems, canonical forms, solution of state equation, state transition matrix, relation between transfer function and state variable representations; controllability and observability, pole- placement using state variable feedback; design of full order and reduced order observer, observer based and state feedback controller, optimal control concept, solution of linear quadratic regulator.

LECTURES: 12

2. Sample Data Control System:
Mathematical preliminaries- difference equations, Z Transform and properties; sampling quantization and reconstruction process, discrete time systems, system response, transfer function stability, bilinear transformation and the jury stability criterion, implementation of digital controllers and digital controllers for deadbeat performance. Root loci - Frequency domain analysis - Bode plots - Gain margin and phase margin - Design of Digital Control Systems based on Root Locus Technique, state space analysis of discrete system.

LECTURES: 12

3. Nonlinear Control Systems:
Characteristics of nonlinear systems; linearization techniques; phase plane analysis, singular points, limit cycle vs closed trajectory; stability analysis using phase plane analysis- describing function (DF) of common nonlinearities, stability analysis using DF; stability in the sense of Lyapunov, Lyapunov's stability theorems for linear and nonlinear systems; effect of non-linearity in root locus and Nyquist plot. Introduction to Modern Nonlinear control system. Introduction to modern nonlinear control system.

LECTURES: 12

Text Books:
1. K. Ogata, Modern Control Engineering, Pearson Education, 2009
2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 2003
3. H.K.khalil, Non linear Systems, prentice, 3rd Edition.

Reference Books:
1. R. C. *Dorf* and R. H. *Bishop*, *Modern Control Systems*, Prentice Hall, 2010
2. B C. *Kuo*, *Digital Control Systems*, Oxford University Press, 1995.
3. M. Gopal, Modern Control System Theory, New Age International, 1993

EEL 1X15: Smart Grid **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand conventional power grid system.
- Knowledge of smart grid and it definition.
- Know the power system market.
- Understand the smart grid communication system.
- Operation and understanding of demand side management.
- Know the wide area measurement and security issues.

1. Overview of Conventional Grid Power system: Basic components of power system, power generation scenarios, Conventional and restructured power system function of energy control centers, short comings of exciting power grids-emissions, blackouts, emergence of the concepts of smart grid.

LECTURES-6

2. Renewable Generation: Renewable Resources: Wind and Solar, Micro-grid Architecture, Distributed Storage and Reserves, Dealing with short term variations, stochastic models based on price forecasting.

LECTURES-6

3. Smart Grid: Definition, Various components, Application and standards, Impacts of Smart Grid on reliability, Impacts of Smart Grid on air pollutant emissions reduction.

LECTURES-6

4. Smart Grid Communications: Two-way Digital Communications Paradigm, Network Architectures, IP-based Systems Power Line Communications, Advanced Metering Infrastructure.

LECTURES-5

5. Demand Side Management: Definition, Applications, Load characteristics, load curve and load duration curve, Energy Consumption Scheduling, Controllable Load Models, Dynamics, and Challenges, Plug-in-hybrid Vehicles and smart appliances.

LECTURES-5

6. Wide Area Measurement: Sensor Networks, Phasor Measurement Units, Communications Infrastructure, Fault Detection and Self-Healing Systems, Applications and Challenges.

LECTURES-4

7. Security and Privacy: Cyber Security Challenges in Smart Grid, Load Altering Attacks, False Data Injection Attacks, Defense Mechanisms, Privacy Challenges.

LECTURES-4

Reference Books:

1. D.S. Kirshen, Fundamentals of Power System Economics, John Wiley & Sons.
2. A. J. Wood, B. F. Wollenberg, Power Generation Operation and Control, John Wiley & Sons.
3. G. M. Masters, Renewable and Efficient Electric Power Systems, John Wiley & Sons.
4. S. Stoft, Power System Economics: Designing Markets for Electricity, Wiley-Interscience.

EEL 1X16: Power System Operation and Control **Prerequisite: NA**

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Aware of the power system stability problems.
- Understand the small and large disturbance stabilities.
- Know the modelling if synchronous machines and power system components.
- Understand the different power system stability analysis.
- Measures taken to improve power system stability.

1. Introduction to Power System Operations: Introduction to power system stability. Power System Operations and Control. Stability problems in Power System. Impact on Power System Operations and control.

LECTURES-3

2. Analysis of Linear Dynamical System and Numerical Methods: Analysis of dynamical System, Concept of Equilibrium, Small and Large Disturbance Stability. Modal Analysis of Linear System. Analysis using Numerical Integration Techniques. Issues in Modeling: Slow and Fast Transients, Stiff System.

LECTURES-5

3. Modelling of Synchronous Machines and Associated Controllers: Modelling of synchronous machine: Physical Characteristics. Rotor position dependent model. D-Q Transformation. Model with Standard Parameters. Steady State Analysis of Synchronous Machine. Short Circuit Transient Analysis of a Synchronous Machine. Synchronization of Synchronous Machine to an Infinite Bus. Modeling of Excitation and Prime Mover Systems. Physical Characteristics and Models. Excitation System Control. Automatic Voltage Regulator. Prime Mover Control Systems. Speed Governors.

LECTURES-8

4. Modelling of other Power System Components: Modelling of Transmission Lines and Loads. Transmission Line Physical Characteristics. Transmission Line Modelling.

Load Models - induction machine model. Frequency and Voltage Dependence of Loads. Other Subsystems – HVDC and FACTS controllers, Wind Energy Systems.

LECTURES-8

5. Stability Analysis: Angular stability analysis in Single Machine Infinite Bus System. Angular Stability in multimachine systems – Intra-plant, Local and Inter-area modes. Frequency

Stability: Centre of Inertia Motion. Load Sharing: Governor droop. Single Machine Load Bus System: Voltage Stability. Introduction to Torsional Oscillations and the SSR phenomenon. Stability Analysis Tools: Transient Stability Programs, Small Signal Analysis Programs.

LECTURES-8

6. Enhancing System Stability: Planning Measures. Stabilizing Controllers (Power System Stabilizers). Operational Measures-Preventive Control. Emergency Control.

LECTURES-4

Text Books:

1. K.R. Padiyar, "Power System Dynamics, Stability and Control", B. S. Publications, 2002.
2. P. Kundur, "Power System Stability and Control", McGraw Hill, 1995.
3. P. Sauer and M. A. Pai, "Power System Dynamics and Stability", Prentice Hall, 1997.

EEL 1X17: Advanced Electric Drives **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Study different types Power Converters for DC and AC drives.
- Study different methods for Speed controlled of DC and AC drives.
- Study and analysis of special machine drives (PMSM, BLDC, SRM, Stepper motor)

1. Characteristics of Electric Motors:

Characteristics of DC motors, 3-Phase induction motors and synchronous motors, Starting and braking of electric motors. Dynamics of Electric Drives, Mechanical system, Fundamental torque equations, components of load torques, Dynamic conditions of a drive system, Multi quadrant operation, Criteria for selection of motor for drives Energy loss in transient operations, Steady State Stability, Load equalization.

LECTURES-8

2. Converter Control of DC Drives

Analysis of series and separately excited DC motor with single phase and three phase controlled rectifiers operating in different modes and configurations. Analysis of series and separately excited DC motors fed from different choppers for both time ratio control and current limit control, four quadrant control. Single quadrant variable speed chopper fed DC drives. Four quadrant variable speed chopper fed DC Drives. Single phase/ three phases - dual converter fed DC Drive, design of speed and current loop control. Different application.

LECTURES-10

3. AC Motor Drives:

Induction Motor Drive**:** Variable voltage variable frequency drive, Slip power recovery, Static Scherbius and Cramer drives. CSI fed Induction motor drives. Synchronous Motor Drive: variable frequency drives, self-control synchronous motor drives.

LECTURES-12

4. Special Motor Drives: Brushless DC motor, Permanent magnet Synchronous motor, switched reluctance motor, stepper motor, linear induction and synchronous motor and other advanced drives.

LECTURES-6

Advanced Control and Estimation of AC drives:
Small signal models, FOC control, sensor less control, DTC, model reference adaptive control, DSP, FPGA based implementation control and estimation technique.

LECTURES-6

Text Books:

1. M. H. Rashid, Power Electronics - Circuits, Devices and Applications, P.H.I Private Ltd. New Delhi.
2. B. K Bose, Modern Power Electronics and AC Drives, PHI
3. G.K. Dubey, Power Semiconductor controlled drives, Prentice Hall inc, A division of Simon and Schester England cliffs, New Jersey.
4. Sheperal, L.N. Wand Hully, Power Electronic and Motor control, Cambridge University Press Cambridge
5. R Krishnan, Electric Drives-Modelling Analysis and control,PHI publication.

Reference Books:

1. S. Dewan, B. Slemon, A.G.R Straughen, Power Semiconductor drives, John Wiley and Sons, New York.
2. P.C. Sen, Thyristor DC Drives, John Wiley and sons, NewYork.
3. V. Subramanyam, Electric Drives–Concepts and applications, TataMcGraw Hill Publishing Co., Ltd., New Delhi.
4. B.K. Bose, Power Electronics and Variable frequency drives, Standard Publishers Distributors

EEL 1X18: Instrumentation Engineering **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the functional description of instrumentation system.
- Learn the working of different types Transducers and sensors.
- Study the various pressure, flow, temperature and liquid level.
- Study the advance topics in instrumentation like: Digital data acquisition systems, Smart sensors, Intelligent Instrumentation, Instrumentation for remote control system, Internet based tele-metering.

1. **Introduction:** Functional description of instrumentation. Overview of transducers, signal conditioners, filters, amplifiers, OP-AMP, display devices; instrumentation amplifiers and circuits.

LECTURES-2

2. Transducers and sensors for analytical instrumentation:
Measurement of displacement using linear variable differential transducers (LVDTs). Null reduction techniques. Phase compensation circuits. Phase sensitive demodulation.
Rotary variable differential transformers (RVDTs). Capacitive transducers: variable air gap, variable plate overlap, variable dielectric. Level gauge. Thickness gauge. Humidity sensor. Capacitive microphone. Piezoelectric transducers. Fundamental concepts, materials, charge sensitivity, voltage sensitivity. Force/displacement transducers. Charge amplifiers. Accelerometers. Optical pyrometers. Measurement of pressure using elastic transducers:

bourdon tubes, diaphragms, bellows. Hall Effect transducers and their applications. Measurement of flow: electromagnetic flowmeters, ultrasonic flowmeters, hot wire anemometers.

LECTURES-16

3. Signal Conditioning: Instrumentation amplifiers, A.C. amplifiers. Chopper type D.C. amplifiers. Operation amplifier circuits in instrumentation systems. Amplitude modulation and demodulation. Transformer ratio bridges. Electrical filters: low-pass, high-pass, band-pass and band-stop filters. ADCs and DACs. General considerations of analog to digital and digital to analog conversions. DACs: Binary-weighted resistance, R-2R ladder. DAC characteristics and specifications. DAC errors. ADCs: Successive-approximation type, Dual-slope type.

LECTURES-12

4. Electronic instruments: AC voltmeters using rectifiers, True-RMS voltmeters, electronic multimeters, digital voltmeters, Q meters.

LECTURE-4

5. Fibre optic sensors and instrumentation: basic principles; optical fibre cable- dispersion and losses; connectors and splices, sources and detectors. Examples of typical fibre optic sensing systems.

LECTURES-2

Text Books:

1. E.O. Doebelin, Measurement Systems, McGraw Hill,2004
2. A. D. Helfrick and W. D. Cooper, Modern Electronic Instrumentation and Measurement Techniques, Pearson Education, 2007.
3. A. K. Sawhney, A Course in Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai and Sons.
4. D. Patranabis, Principles of Electronic Instrumentation, Prentice Hall of India, 2008.
5. S.K.Singh, Industrial Instrumentation and Control

Reference Books:

1. C.S Rangan, G.R. Sarma & VSV Mani, Instrumentation, Devices & system, Tata McGraw Hill, 2002.
2. D.V.S Murthy, Transducers & Instrumentation, PHI, 2004

EEL 1X19: Smart Appliances and Internet of Things — **Prerequisite: NA**
L-T-P: 3-0-0 — **Credit: 3**

Course Outcomes:

- Understand and evaluate the characteristics of smart home appliances.
- Understand the behavior of IoT and their applications.
- Manage smart communication systems with multiple sensors and protocols.
- Design and simulate smart homes and smart cities with IoTs and cloud computing

1. Modern Domestic Appliances

Solid State Lamps: Introduction - Review of Light sources - white light generation techniques-Characterization of LEDs for illumination application. Power LEDs- High brightness LEDs-Electrical and optical properties. LED driver considerations-Power management topologies - color issues of white LEDs- Dimming of LED sources, BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment.

LECTURES-8

2. IoT Communication Technologies

Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications. Interoperability in IoT.

LECTURES-9

3. IoT Control Technologies and Programming

Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

LECTURES-10

4. IoT Cloud Computation and Applications

Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring.

LECTURES-9

Text Books:

1. Vinod Kumar Khanna, "Fundamentals of Solid-State Lighting", CRC press, 1st Edition,2014.
2. Chang-liang Xia, "Permanent Magnet Brushless DC Motor Drives and Controls", John Wiley & Sons Singapore Pte. Ltd, 1st Edition,2012.
3. K. Siozios, D. Anagnostos, D. Soudris, E. Kosmatopoulos, "IoT for Smart Grids Design Challenges and Paradigms", Springer, 1st Edition,2019.

References Books:

1. Craig Di Louie, "Advanced Lighting Controls: Energy Saving Productivity, Technology & Applications", Fairmont Press, Inc., 1st Edition,2006.
2. Robert S Simpson, "Lighting Control: Technology and Applications", Focal Press, 1st Edition,2003.
3. Arturas Zukauskus, Michael S. Shur& Remis Gaska, "Introduction to solid state lighting", Wiley- Interscience, 1st Edition,2002.
4. Mohan, Undeland and Robbins, "Power Electronics: Converters, Applications and Design", John Wiley and Sons, 1st Edition,1989.

EEL 1X20: SCADA SYSTEMS & APPLICATIONS **Prerequisite-NA**

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand basics of SCADA systems and its various functions.
- Acquire knowledge regarding SCADA System Components and Programmable Logic Controller (PLC).

- Explore Various SCADA architectures, advantages and disadvantages.
- Investigate various industrial communication technologies.
- Learn and apply the SCADA Applications in Transmission and Distribution sector operations and industries.

1. SCADA

Data acquisition system, evaluation of SCADA, communication technologies, monitoring and supervisory functions. PLC: Block diagram, programming languages, Ladder diagram, Functional block diagram, Applications, Interfacing of PLC with SCADA.

LECTURES-12

2. SCADA System Components:

Schemes, Remote Terminal Unit, Intelligent Electronic Devices, Communication Network, SCADA server. **LECTURES-6**

3. SCADA Architecture:

Various SCADA Architectures, advantages and disadvantages of each system, single unified standard architecture IEC 61850 SCADA / HMI Systems.

LECTURES-4

4. SCADA Communication:

Various industrial communication technologies- wired and wireless methods and fiber optics, open standard communication protocols.

LECTURES-6

5. SCADA Applications

Utility applications, transmission and distribution sector operation, monitoring analysis and improvement. Industries, oil, gas and water, Automatic substation control, SCADA requirement and configuration in energy control systems, Energy management system, system operating states, system security.

LECTURES-6

Text Books

1. Stuart A Boyer, SCADA: Supervisory Control and Data Acquisition, ISA.
2. Gordan Clark, Deon Reynders, Practical Modem SCADA Protocols, Elsevier.

EEL 1X21: HVDC TRANSMISSION **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Apply scientific and engineering principles to analyze and design converter.
- Recognize harmonics in HVDC transmission.
- Appropriately analyze the control strategy of HVDC system
- Identify the converter faults and apply protection scheme for faults

1. Introduction:

Introduction of DC power transmission technology, comparison of AC and DC transmission, description of DC transmission system, modern trends in DC transmission.

LECTURES-4

2. Analysis of HDVC converters:
Choice of converter configuration, simplified analysis of Graetz circuit, converter bridge characteristics, Characteristics of a twelve pulse converter, detailed analysis of converters.

LECTURES-8

3. Control of HVDC converter and systems:
Rectifier control, compounding of rectifiers, power reversal of DC link, voltage dependent current order limit (VDCOL) characteristics of the converter, inverter extinction angle control, pulse phase control, starting and stopping of DC link, constant power control, control scheme of HVDC converters.

LECTURES-8

4. Harmonics and filters:
Generation of harmonics by converters, characteristics of harmonics on DC side, characteristics of current harmonics, characteristic variation of harmonic currents with variation of firing angle and overlap angle, effect of control mode on harmonics, non-characteristic harmonic. Harmonic model and equivalent circuit, use of filter, filter configuration, design of band-pass and high pass filter, protection of filters, DC filters, filters with voltage source converter HDVC schemes.

LECTURES-10

5. Fault and protection schemes in HVDC systems:
Nature and types of faults, faults on AC side of the converter stations, converter faults, fault on DC side of the systems, protection against over currents and over voltages, protection of filter units.

LECTURES-4

6. Multi-terminal HVDC systems:
Types of multi terminal (MTDC) systems, parallel operation aspect of MTDC. Control of power in MTDC. Multilevel DC systems. Power upgrading and conversion of AC lines into DC lines, Parallel AC/DC systems, FACTS and FACTS converters.

LECTURES-6

Text Books

1. S. Kamakshaiah& V. Kamaraju, HVDC Transmission, Tata McGraw hill education.
2. K.R.Padiyar, HVDC Power transmission system, Wiley Eastern Limited.
3. J. Arrillaga, Peter Pregrinu, High Voltage Direct Current Transmission

Reference Books

1. A. Chakraborty, D.P. Kothary, A.K. Mukhopadhyay,The Performance, Operation and Control of EHV Power Transmission Systems, Wheeler Pub.
2. Rakosh Das Begamudre, Extra High Voltage AC Transmission Engineering, New Age International (P) Ltd.
3. Colin Adamson and N.G.Hingorani, High Voltage Direct Current Power Transmission, Garraway Limited, London

EEL 1X22: SPECIAL ELECTRICAL MACHINES **Prerequisite-NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To study about stepper and Switched Reluctance Motors (Principle of operation, Types, Control techniques).
- To learn about Permanent Magnet Synchronous Motors and Brushless DC Motors (Principle of operation, Torque and voltage equations, Control techniques).
- To study about Servo and Linear Induction Motor (Principle of operation, Types, Control techniques)

1. Stepper Motors:
Constructional features, Principle of operation, Modes of excitation torque production in Variable Reluctance (VR) stepping motor, Dynamic characteristics, Drive systems and circuit for open loop control, closed loop control of stepping motor.

LECTURES-7

2. Switched Reluctance Motors
Constructional features, Principle of operation. Torque equation, Characteristics, Control Techniques, Drive Concept.

LECTURES-6

3. Permanent Magnet Synchronous Motors and Brushless DC Motors
Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power Controllers, Torque speed characteristics, Self-control, Vector control, Current control Schemes. Commutation in DC motors, Difference between mechanical and electronic commutators, Hall sensors, Optical sensors, Multiphase Brushless motor, square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Controllers-Microprocessors based controller.

LECTURES-12

4. Servomotors
Servomotor – Types – Constructional features – Principle of Operation – Characteristics - Control –Microprocessor based applications.

LECTURES-6

5. Linear Motors
Linear Induction Motor (LIM) Classification – Construction – Principle of operation – Concept of Current sheet –Goodness factor – DC Linear Motor (DCLM) types – Circuit equation –DCLM control-applications.

LECTURES-6

6. Some Other Electrical Motor:
Reluctance and hysteresis motor, Universal Motor.

LECTURES-3

Text Books:

1. Miller, T.J.E., Brushless Permanent Magnet and Reluctance Motor Drives, Clarendon Press, Oxford, 1989.
2. Kenjo, T, Stepping Motors and their Microprocessor control, Clarendon Press, Oxford, 1989.
3. K Venkataratam, Special Electrical Machines, University press.

Reference Books:

1. Naser A and Boldea I, Linear Electric Motors: Theory, Design and Practical Application, Prentice Hall Inc., New Jersey,1987
2. Floyd E Saner, Servo Motor Applications, Pittman USA, 1993.
3. Kenjo, T and Naganori, S, Permanent Magnet and brushless DC motors, Clarendon Press, Oxford, 1989.
4. P.S.Bimbra, Generalized Theory of Electrical Machines, Khanna publications-5th edition-1995

EEL1X23: Modeling and control of power electronics converters **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Design the power stage for various converter topologies based on specifications
- Derive the averaged switch model of the various converter for circuit simulation
- Derive the various transfer functions for different converter topologies operating in both CCM and DCM
- Design the controller for voltage and current mode control

1. Overview of Power electronics converters:
Overview of basic and advanced Power electronics converters, various applications, basics of utility power conversion, isolated and non-isolated converter circuit, types of power converter models.

LECTURES-4

2. Steady state analysis and Modeling of converters
Steady state converter analysis, Steady state modeling of power converters, DC transformer model, loss modeling. Dynamic modeling of power converters, AC modeling of converters, state space averaging, Transfer function and frequency domain analysis, Concept of controller design, stability analysis, nonlinear phenomenon.

LECTURES-16

3. Modeling of PWM Converters
Pulse Width Modulation (PWM) control of power converters, voltage source and current source inverter. Feedback control design, voltage mode and current mode control, control of inverters and rectifiers.

LECTURES-12

4. Application of DSP, FPGA for power electronics converter**,** practical converter design consideration.

LECTURES-8

Text Books:

1. Ned Mohan, T.M. Undeland and William P.Robbins, Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009.
2. M. H. Rashid, Power Electronics-Circuits, Devices and Applications, 3rd Edition, PHI, 2005
3. C.WLander, Power Electronics, McGraw-Hill book company,1981

Reference Books:

1. S. B. Dewan &A. Straughen, Power Semiconductor Circuits, John Wiley & Sons, 1975
2. B.K Bose, Modern Power Electronics and AC Drives, Pearson Education, 2003

EEL 1X24: Advanced Power System Protection **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand advanced topics of power system protection.
- Familiarize with the industrial practices.

1. Static Relays: Advantages of static relays – Basic construction of static relays – Level detectors – Replica impedance – Mixing circuits – General equation for two input phase and amplitude comparators -Duality between amplitude and phase comparators. Amplitude Comparators: Circulating current type and opposed voltage type – rectifier bridge comparators, Direct and Instantaneous comparators.

LECTURES-4

2. Phase Comparators: Coincidence circuit type – block spike phase comparator, techniques to measure the period of coincidence – Integrating type – Rectifier and Vector product type – Phase comparators. Static Over Current Relays: Instantaneous over-current relay – Time over-current relays-basic principles – definite time and Inverse definite time over-current relays.

LECTURES-8

3. Static Differential Relays: Analysis of Static Differential Relays – Static Relay schemes – Duo bias transformer differential protection – Harmonic restraint relay. Static Distance Relays: Static impedance-reactance – MHO and angle impedance relay-sampling comparator – realization of reactance and MHO relay using sampling comparator.

LECTURES-8

4. Multi-Input Comparators: Conic section characteristics -Three input amplitude comparator – comparator-switched distance schemes – Poly phase distance schemes – phase fault scheme – three phase scheme – combined and ground fault scheme. Power Swings: Effect of power swings on the performance of distance relays – Power swing analysis – Principle of out of step tripping and blocking relays – effect of line and length and source impedance on distance relays.

LECTURES-8

5. Microprocessor Based Protective Relays: (Block diagram and flowchart approach only) – Over current relays – impedance relays – directional relay – reactance relay – Generalized mathematical expressions for distance relays -measurement of resistance and reactance – MHO and offset MHO relays – Realization of MHO characteristics – Realization of offset MHO characteristics – Basic principle of Digital computer relaying.

LECTURES-8

Text Books:

1. Badri Ram and D. N. Vishwakarma, "Power system protection and Switch gear ", TMH publication New Delhi 1995.

Reference Books:

1. T.S. Madhav aRao , "Static relays", TMH publication, second edition, 1989.

2. Protection and Switchgear, Bhavesh Bhalja, R. P. Maheshwari, Nilesh G. Chothani, Oxford University Press.
3. Electrical Power System Protection, C. Christopoulos and A. Wright, Springer International.

EEL 1X25: FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand various types of power controllers in transmission lines.
- Understand the static VAR compensator and its applications.
- Understand the TCSC controller and its applications.
- Understand the transient stability and modelling of STATCOM.
- Learn the concept of coordination of FACTS controllers.

1. Introduction to Flexible Alternating Current Transmission System (FACTS):
Fundamentals of ac power transmission, transmission problems and needs, Emergence and advantages of FACTS technology in transmission system, Types of FACTS controller, Application of FACTS controllers in Distribution System.

LECTURES-3

2. Power Flow Control:
Theory and implementation of Power Flow Control Concepts, Analysis of uncompensated AC Transmission line, Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer.

LECTURES-6

3. Static VAR Compensation:
Analysis of SVC, Configuration of SVC, SVC Controller, Voltage Regulator Design, Harmonics and Filtering, Protection Aspects, Application of SVC

LECTURES-6

4. Series and Shunt Compensation:
Principles of shunt compensation, Variable Impedance type & switching converter type-Static Synchronous Compensator (STATCOM) configuration, characteristics and control, Basic concepts of controlled series compensation, Principles and operation of static series compensation using GCSC, TCSC and TSSC, applications, Static Synchronous Series Compensator (SSSC)

LECTURES-8

5. Static Voltage and Phase Angle Regulators:
Principles of operation-Steady state model and characteristics of a static voltage regulators and phase shifters power circuit configurations, Power-flow control and improvement of stability by phase angle regulator, Introduction to Thyristor Controlled Voltage and Phase Angle Regulators (TCVR and TCPAR)

LECTURES-7

6. UPFC & IPFC
Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the controlled series compensators and phase shifters, Applications of UPFC. Interline Power Flow Controller (IPFC), basic operating principles and characteristics, Applications of IPFC.

LECTURES-5

7. Modelling of FACTS devices **LECTURES-5**

Text Books:

1. Narain G. Hingorani, Laszlo Gyugyi, Concepts and Technology of Flexible AC Transmission Systems, Wiley, 2000.

3. K.R.Padiyar, FACTS controllers for transmission and Distribution systems, New Age international Publishers.

4. Y.H. Song and A. T. Johns, Flexible ac transmission systems (FACTS), Institution of Electrical Engineers Press, London.

Reference Books:

1. R. M. Mathur and R. K.Varma, Thyristor - based FACTS controllers for Electrical transmission systems, IEEE press, Wiley Inter science.

EEL 1X26: Energy Storage Systems
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the characteristics of energy storage devices
- Model and simulate the characteristics of energy storage systems
- Explore the possibilities of deployment of energy storage systems in smart cities and electric vehicles.
- Evaluate and suggest an efficient storage system in electric transportation.

1. Introduction
Impacts and requirements of Electrical Energy Storage system, Classification of Energy Storage Systems, Energy costs, and load analysis. Grid Applications of Energy Storage systems, Ancillary Services from Energy storage. Traditional generation costs and optimizations. Power flow and energy balance in a wide area network. Economics of energy and power tied to electrical rates and demand response.

LECTURES: 4

2. Electrochemical Energy Storage
Batteries: Introduction to battery storage including lead acid, lithium-ion, flow, and emerging battery technologies. Comprehensive analysis of design considerations and application-specific needs. Impacts on system cost in terms of the life cycle, environment, and reliability of the end solutions.
Ultra-Capacitors: Introduction to ultra-capacitors including operation, applications, and emerging technologies. Topics include the usage of mobile applications and close proximity to renewable energy sources. Discussion of primary target market usage in today's energy and power sectors.
Super Conducting Magnetic Energy Storage (SMES): Introduction to Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage, and emergent research, with a focus on large utility-scale energy storage facilities.
Mobile and Fixed Energy Storage: Advantages and disadvantages of mobile vs. stationary energy storage, with a focus on vehicle-to-grid applications and opportunities to leverage existing and

emergent technology to provide additional grid support functions. Concept of time-of-day metering for storage planning and management.

LECTURES: 16

3. Mechanical Energy Storage

Pumped Hydro: Models for pumped hydro capacity and availability, System cost, capacity, conversion efficiency, and siting.

Compressed Gas: Compressed gas storage technologies as bulk energy storage. Models for compressed gas capacity, efficiency, availability, System cost, capacity, conversion efficiency, siting, and associated barriers, and possible applications in carbon capture and appropriation.

Flywheel: Flywheel energy storage system, Models for flywheel capacity, availability, efficiency, and self-discharge, Applications in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage, Selection and design of flywheels for safety and availability in various applications.

Thermal: Introduction to thermal storage in residential and utility-scale applications including molten salts, cold reservoirs, and phase change materials, Analysis of design considerations, material selection, and application-specific constraints, Applications in renewable energy at utility-scale solar and geothermal power production.

LECTURES: 16

Text Books:

1. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks", IET Power Electronics Series, 2012.
2. Ali Keyhani Mohammad Marwali and Min Dai, Integration and Control of Renewable Energy in Electric Power System, John Wiley publishing company, 2nd Edition, 2010.

Reference Books:

1. Mini S Thomas and J. D MacDonald, " Power System SCADA and Smart Grid," CRC Press, 1st Edition, 2015.
2. N. Hatziargyriou, "Microgrids Architecture and control", Wiley-IEEE Press Series, 1st Edition 2013.
3. D. Mah, P. Hills, Victor O.K. Li, R. Balme, "Smart Grid Applications and Developments," Springer- Verlag London, 1st Edition, 2014.
4. J. Ekanayake, N. Jenkins, K. Liyanage, J. Wu, A. Yokoyama, "Smart Grid: Technology and Applications," John Wiley & Sons, 1st Edition, 2015.

EEL 1X27: Data Science Applications in Power Engineering **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Distinguish between Algorithmic based methods and Knowledge based Methods
- Able to distinguish between Artificial Neural Networks and Fuzzy Logic

- Adopt Soft Computing techniques for solving Power Systems and Power Electronics and Drives Problems
- Apply appropriate AI frame work for solving power systems and Power Electronics & Drives Problems

1. Artificial Neural Networks (ANN): Introduction to Artificial Neural Networks - Definition and Fundamental concepts -Biological Neural Network – Modeling of a Neuron -Activation functions – initialization of weights -Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – XOR Problem - ADALINE and MADALINE.

LECTURES-9

2. ANN Paradigms: Multi – layer perceptron using Back propagation Algorithm (BPA)-Self-Organizing Map (SOM)- Learning Vector Quantization (LVQ) - Radial Basis Function Network - Functional link network -Hopfield Network -Bidirectional Associate Memory (BAM).

LECTURES-9

3. Fuzzy Logic: Introduction – Classical and Fuzzy sets- Properties, Operations and relations- Fuzzy sets – Membership function – Basic Fuzzy set operations -Properties of Fuzzy sets – Fuzzy Cartesian Product - Operations on Fuzzy relations – Fuzzy logic – Fuzzy Cardinalities -Fuzzy Logic Controller (FLC): Fuzzy Logic System Components: Fuzzification- Inference Engine - Defuzzification methods.

LECTURES-10

4. Applications of ANN & Fuzzy Logic: Load flow studies -Economic load dispatch -Load frequency control – Single area system and two area systems -Reactive power control -Speed control of DC and AC Motors.- PWM Vector controlled drive -Speed estimation and flux estimation of induction motor.

LECTURES-8

Text Books:

1. S. Rajasekaran and G. A. V. Pai, "Neural Networks, Fuzzy Systems and Evolutionary Algorithms: Synthesis and Applications", PHI, New Delhi, 2nd Edition, 2017.
2. T. J. Ross, "Fuzzy Logic with Engineering Applications", Mc Graw Hill Inc, 3rd Edition, 2011.

Reference Books:

1. Simon Haykin: Neural Networks: A Comprehensive Foundations, Pearson Edition, 2003
2. G.J. Klir and T.A. Folger: Fuzzy sets, Uncertainty and Information, PHI, Pvt. Ltd, 1994.
3. Bart Kosko: Neural Network & Fuzzy System, Prentice Hall, 1992.
4. P.D. Wasserman: Neural Computing Theory & Practice, Van Nostrand Reinhold Co. New York, 1st Edition, 1989.

EEL 1X28: Machine Learning and Deep Learning **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the basic concepts of Machine Learning and Deep Learning Techniques
- Distinguish between supervised learning and reinforced learning
- Develop the skill in using machine learning and deep learning software for solving practical problems
- Apply Machine learning and deep learning Algorithm to solve electrical Engineering Problems

Learning Theory

Introduction to Machine Learning: What is Learning- Learning Objectives-Data needed- Bayesian inference and Learning- Bayes theorem- inference- naïve Bayes- Regularization- Bias-Variance Decomposition and Trade-off- Concentration Inequalities-Generalization and Uniform convergence- VC- dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning.

Supervised Learning

Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis Naïve Bayes- Kernal Method: Support Vector Machine (SVM)- Kernal function- Kernal SVM Gaussian Process- Tree Ensembles: Decision Trees- Random Forests- Boosting and Gradient Boosting.

Unsupervised Learning

K- mean Clustering Algorithm –Gaussian Mixture Model (GMM) –Expectation Maximization (EM)- Vibrational Auto Encoder (VAE)- Factor Analysis- Principal Components Analysis (PCA)- Independent component Analysis (ICA)

Reinforcement Learning

Markov Decision Processes (MDP)- Bellman's Equations-Value Iteration and Policy Iteration – Value Function Approximation-Q-Learning.

Deep Learning

Neutral Networks- Back progress Algorithm (BPM)- Deep Architectures- Convolution Neural Networks– Convolution Layer- Pooling Layer- Normalization Layer- Fully Connected Layer- Deep belief Networks- Recurrent Neural Networks. Use of machine learning and deep learning for forecasting of generation and demand, predicting equipment and systems malfunctions and failures.

Text Books:

1. C. Bishop, "Pattern Recognition and Machine Learning", Springer, 2011.
2. E. Alpaydin, "Machine Learning", MIT Press, 2010

Reference Books:

1. Ian Goodfelow, Yoshua Bengio, and Aaron Courville, Deep Learning," MIT Press Cambridge, Massachusetts, London, England, 2016.
2. Tom, M. Mitchell, "Machine Learning", McGraw Hill International Edition, 1997.

EEL 1X29: Deregulated Smart Grids **Prerequisite: NA**

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the need for restructured power system and economics.
- Discuss and analyze transmission congestion and loss allocation in Power System.
- Assess the role of demand response in smart grid systems.
- Evaluate economics and ancillary services within the Smart Grid.

1. Restructuring of power industry and Fundamentals of Economics
Introduction, Reasons for restructuring / deregulation of power industry, Fundamentals of Deregulation, Motivation of restructuring the power industries, restructuring process – unbundling & privatization, restructuring models and Trading Arrangements, Components of restructured systems.

LECTURES-4

2. Smart Grid in Power Market
Independent System Operator (ISO): Functions and responsibilities, Smart Grid trading arrangements (Pool, bilateral & multilateral), Open Access Transmission Systems, and Open Access Same time Information system (OASIS). Definitions transfer capability issues: ATC, TTC, TRM, CBM calculations, methodologies to calculate ATC, Electricity Pricing.

LECTURES-7

3. Smart Grid Bidding Strategies
Forward and Future market; Operation and control: Old vs New, Integrated bidding strategy in smart multi energy system, Smart grid Optimization with risk constraints-General risk measures, Portfolio selection problem, penalty formulation.

LECTURES-6

4. Transmission Congestion Management
Classification of congestion management methods, Calculation of ATC-TTC-CBM, Non-market methods, Market based methods, Nodal pricing, Inter-zonal Intra-zonal congestion management, Price area congestion management.

LECTURES-4

5. Demand Response in Smart Grid
Demand response, Potential benefits of demand response in smart grid, enabling smart technologies for demand response, control devices for demand response, Monitoring and communication system. Demand response for Electric Vehicles, Examples.

LECTURES-6

6. Ancillary Services within Smart Grid Framework
Reactive power as an ancillary service, Energy Storage System, Power Quality, Reliability analysis.

LECTURES-5

7. Smart Grid Economic and Market Operations
Energy and Reserve Markets, Market Power, Generation Firms, Locational Marginal Prices, Financial Transmission Rights. Concepts of block chain technologies in energy trading and power purchase agreements (PPA).

LECTURES-4

Text Books:

1. L. L. Lai, "Power System Restructuring and Deregulation", John Wiley & Sons Ltd., 1st Edition, 2012
2. D. Kirschen and G. Strbac, "Fundamentals of Power System economics", John Wiley & Sons Ltd, 2nd Edition 2019.

Reference Books:

1. S. Hunt, "Making competition work in electricity", John Wiley & Sons, Inc. 1st Edition, 2002.
2. K. Bhattacharya, J. E. Daadler, and Math H.J Bollen, "Operation of restructured power systems", Kluwer Academic Pub. 1st Edition 2001 (Reprint 2012).

EEL 1X30: Signal Processing in Smart Grids **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the applications of Digital signal filtering techniques in power systems
- Apply estimation techniques to evaluate power system parameters
- Understand different signal decomposition techniques
- Understand the WAMS signal processing

1. Power Systems signals in terms of Smart Grid
Basics of power quality issues, Inrush Current in Power Transformers; Over-Excitation of Transformers; Transients in Instrument Transformers; Frequency Variation; Voltage Magnitude Variations; Voltage Frequency Variations.

LECTURES-6

2. Power Systems and signal processing
Stochastic gradient based algorithms – LMS algorithm, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Mean-squared error behavior, Convergence analysis, Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms- GRLS, Gauss-Newton and RM. Basic Digital System, Parametric Notch FIR Filters; Sine and Cosine FIR Filters, Parametric Filters applications in smart grid.

LECTURES-9

3. Filters and Electrical Parameters Estimation
Forward and backward linear prediction, prediction error filters, AR lattice and ARMA Lattice – Ladder filters, Kalman filters, Wiener filter, Least Square methods for system modeling & Filter Design. Recursive least squares algorithms, Matrix inversion lemma, Spectrum estimation. Estimation of autocorrelation. Periodogram, Nonparametric and Parametric methods. Estimation Theory; Least-Squares Estimator; Frequency Estimation; Phasor Estimation; Phasor Estimation in Presence of DC Component; Spectrum Estimation; Windows; Frequency-Domain Windowing; Interpolation in Frequency Domain: Multitoned Signal .

LECTURES-9

4. Time-Frequency Signal Decomposition
Short-Time Fourier Transform; Sliding Window DFT; Filter Banks; Pattern Recognition, Feature Extraction on the Power Signal; Signal Detection for Electric Power Systems; Detection Theory.

LECTURES-6

5. Signal Processing Techniques Applications
Concepts of wavelet, s-transform, Heartly's-transforms; Hillbert transform; Gabor transform and applications in power fluctuations: load fluctuations, wind farm power fluctuations and smart microgrid.

LECTURES-6

Text Books:

1. J.G.Proakis, M. Salehi, “Advanced Digital Signal Processing”, McGraw –Hill, 1992.
2. P. F. Ribeiro, C. A. Duque, P. Marcio da Silveira and A. S. Cerqueira, “Power Systems Signal Processing for Smart Grids,” John Wiley and Sons Ltd., 2nd Edition, 2014.

Reference Books:

1. S. Haykin, “Adaptive Filter Theory”, Prentice Hall, 2nd Edition, 2001.
2. J. V. Candy, Signal Processing, The Model Based Approach, McGraw-Hill Book Company, 1987
3. M. H. Hayes, “Statistical Digital Signal Processing and modeling”, John Wiley & Sons, 1996
4. Handouts on DSP Processors.
5. S. K. Mitra, Digital Signal Processing – A computer Based Approach, MGH, 2nd Edition, 2001.

EEL 1X31: Microgrid Dynamics and Control **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand components of AC and DC microgrids
- Model and Analyze the behavior of Dynamic micro grids.
- Evaluate different hierarchical control schemes and communication between them.
- Analyze the influence of microgrids on electrical markets.

1. Concept of Microgrids
Introduction to the concept of microgrid, the overview of the structure and architecture of microgrid with brief control, operational aspects. Recent pilot microgrid projects and their outcomes.

LECTURES-3

2. Decentralized Local Controllers
AC-microgrids: Control Mechanism of the DGs connected in microgrid. Virtual synchronous generator (VSG) and Droop control. Transient frequency response, active power Response, reactive power sharing and voltage regulation.
DC-microgrids: DC microgrid control mechanism, droop control, issues in achieving active power sharing with impedance droop, remedies to achieve active power sharing.

LECTURES-6

3. Power System Stability
Power system stability classification, Basic definitions of transient, dynamic, and small signal stability Generator and load modeling, modeling and analysis of SMIB systems.

LECTURES-4

4. Dynamic and Stability Analysis of Microgrids
Dynamic modelling of individual components in AC and DC microgrids, state space modal analysis and influence of system parameters on the microgrid dynamics, brief concept on the design of microgrid stabilizers to improve stability.

LECTURES-6

5. Hierarchical Control Scheme for Microgrids

Control Objectives in AC Microgrids, bottleneck with only local control, need of secondary and tertiary control, implementation of hierarchical control with centralized and distributed control schemes for AC and DC microgrids. Advantages and disadvantages of centralized and distributed control schemes.

LECTURES-6

6. Multi-microgrid Coordination and Control

AC-AC, AC-DC and DC-DC microgird clustering, coordinated control schemes in multi-microgrids, frequency, voltage regulations and volt-VAR support.

LECTURES-6

7. Control of Smart Power Grid System

Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids.

LECTURES-4

8. Techno Economic Analysis of Microgrids

Technical, economic and environmental benefits of microgrid, Quantification of microgrids benefits under standard test conditions, market pricing and polices.

LECTURES-2

Text Books:

1. N. D. Hatziargyriou, "Microgrids Architecture and control", IEEE Press Series, John Wiley & Sons Inc, 1st Edition,2013.
2. H. Bevrani, B. François, T. Ise, "Microgrid Dynamics and Control", John Wiley & Sons, 1st Edition, 2017.

Reference Books:

1. A. Bidram, V. Nasirian, A. Davoudi, F. L. Lewis, "Cooperative Synchronization in Distributed Microgrid Control", Springer, 1st Edition,2017.
2. P. Kundur, "Power System Stability and Control", McGraw-Hill, Inc., 2nd Edition,1994.

EEL 1X32: Grid Integration of Electrical Vehicles **Prerequisite: NA**

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the Electric Vehicle concepts and its importance in power system.
- Assess the role of EV in modern distribution system and smart grids
- Understand the technology, design methodologies and control strategy of hybrid electric vehicles.
- Understand operation and importance of EVs in Grid Applications, grid balancing, ancillary services and demand response

1. Fundamentals of Electric Vehicles (EV)

Introduction to Electric Vehicle technology – Types –Fundamental issues related to electric vehicles (EVs) and hybrid electric vehicles (HEVs) – Interdisciplinary Nature of EVs – State of the Art of EVs – Advantages and Disadvantages – Challenges and Key Technologies of EVs – Challenges for EV Industry in India.

Lectures: 6

2. Electric Vehicle Batteries

Electric vehicle battery efficiency – type – capacity –charging/discharging –technical characteristics – performance – testing, EV battery for stationary applications (B2U).

Lectures: 4

3. Charging Techniques

Architecture/Components of EV charging station –EVSE (Electric Vehicle Supply Equipment) – Type of EV Chargers – Charging Methods – Automotive networking and communication, EV and EV charging standards.

Lectures: 7

4. Grid Applications

Concept of Vehicle to Grid (V2G/G2V)–Ancillary Services – peak saving – load-generation balance – Demand Response – Energy time shift – Energy Management strategies and its general architecture – integration of EVs in smart grid, social dimensions of EVs.

Lectures: 7

5. Advanced Topics

Different design and control aspects of electric drives and chargers for EVs and HEVs, Battery Charger Topologies, and Infrastructure for Plug-In-Electric and Hybrid Vehicles –Impact of Plug-in Hybrid Electric Vehicles on smart Grid/Distribution Networks – Sizing Ultra capacitors for Hybrid Electric Vehicles, concept of vehicle to Home (V2H), Effect of charging infrastructure on grid protection and control.

Lectures: 12

Text Books:

1. James Larminie, John Lowry, "Electric Vehicle Technology Explained", Wiley-Blackwell, 2nd Edition, 2012.
2. Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 1st Edition, 2016

References Books:

1. Sandeep Dhameja, "Electric Vehicle Battery Systems," Elsevier, 1st Edition, 2012.
2. Ali Emadi, "Advanced Electric Drive Vehicles," CRC Press, 1st Edition, 2017.
3. Iqbal Hussain, "Electric & Hybrid Vehicles Design Fundamentals", 2nd Edition, CRC Press, 2011.
4. Chris Mi, M. Abul Masrur, D. Wenzhong Gao, A Dearborn, "Hybrid electric Vehicles Principles and applications with practical perspectives," John Wiley & Sons Ltd., 2nd Edition, 2017.

EEL 1X33: Adaptive and Robust Control Systems **Prerequisite: NA**

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the fundamental concepts of adaptive and Robust control system
- Design the adaptive controllers for Micro Grid system
- Suggest robust control and design robust droop controller using loop shaping methods
- Design and apply nonlinear robust controller with suitable and efficient control approach for Micro Grids.

1. Introduction
Overview of Adaptive Control-Adaptive Schemes-Formulation of Adaptive Control problem-Preliminaries: Lyapunov Stability-Parameter Estimation: Least squares and Regression models-Recursive least squares (RLS)- Estimating parameters in Dynamic systems- Convergence of Parameter Estimation algorithms- Prediction error (PE) model structures-One step ahead PE method.

LECTURES-6

2. Self-Tuning Regulator (STR)/ Model Reference Adaptive Systems (MRAS)
Certainty Equivalent Principle-Pole placement design- direct self-tuning regulators -Indirect self-tuning regulators, continuous time self-tuners, Hybrid self-tuners- disturbances with known characteristics- The MIT rule- Determination of Adaptation gain- Design of MRAS using Lyapunov theory- Relationship between MRAS and STR.

LECTURES-8

3. Auto Tuning and Gain Scheduling
Auto tuning Principle and Techniques, Transient response methods- Methods based on Relay feedback- Relay Oscillation- Gain scheduling: the principle - Design of Gain scheduling controllers- Case Study: Adaptive droop control of Microgrid.

LECTURES-7

4. Robust Control
Types of Uncertainty -Kharitonov Theorem: Applications to Robust PI/PID controller design-Robust Stability /Performance Condition- H_2 and H_∞ norms-Concept of Loop Shaping-Controller design using the loop shaping methods: H_∞ Control, Quantitative feedback theory (QFT)- Case Study: Loop shaping methods to Robust droop control of Microgrid.

LECTURES-8

5. Sliding Mode Control (SMC)
Motivation-Matched and Unmatched Uncertainty-Sliding surface design- Stability of SMC-Equivalent control concept- Integral Sliding Mode Control (ISMC)- Composite nonlinear feedback (CNF) controller- Application of SMC to Load frequency control in Microgrid.

LECTURES-7

Text Books:

1. K.J. Astrom, B. Wittenmark, "Adaptive Control", Addison-Wesley, 2nd Edition,1995.
2. I. Postlethwaite, S.Skogestad, "Multivariable Feedback control: Design and Analysis", Wiley Publisher, 2nd Edition,2014.

Reference Books:

1. P.A. Ioannou, J. Sun, "Robust Adaptive Control", Dover Publications, 2nd Edition,2013.
2. C. Edwards, S.K. Spurgeon, "Sliding Mode Control: Theory and Applications", Taylor and Francis Publisher, 1st Edition,1998
3. I.D. Landau, R. Lozano, and M. M'Saad, A. Karimi, "Adaptive Control: Algorithms, Analysis and Applications", Springer, 2nd Edition,2011.

EEL 1X34: Evolutionary algorithms application in power engineering
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Discriminate the capabilities of bio-inspired system and conventional methods in solving Optimization problems.
- Examine the importance of exploration and exploitation swarm intelligent system to attain near global optimal solution.
- Distinguish the functioning of various swarm intelligent systems.
- Employ various bio-inspired algorithms for Power systems engineering applications.

1. Fundamentals of Soft Computing Techniques
Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

LECTURES-8

2. Genetic Algorithm and Particle Swarm Optimization
Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem.

LECTURES-8

3. Artificial Bee Colony Algorithms and Differential evolution
Artificial Bee Colony (ABC) Algorithm Binary ABC Algorithm- ACO and ABC algorithms for solving Economic dispatch of thermal Units, Motivation for differential Evolution (DE), Introduction to parameter optimization, single point, derivative based optimization, Local vs Global optimization, Differential mutation, Recombination, Selection, Benchmarking differential evolution, DE vs other Optimizers, DE and parallel processors.

LECTURES-8

4. Shuffled Frog-Leaping Algorithm and Bat Optimization Algorithm
Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation- Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frog's comparison of memes and genes -memeplex formation- memeplex updation- BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem.

LECTURES-6

5. Multi Objective Optimization
Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and applications to power systems.

LECTURES-4

6. Advanced Techniques
Soft sensor concepts in power systems.

LECTURES-2

Text Books:

1. Xin-She Yang, "Recent Advances in Swarm Intelligence and Evolutionary Computation," Springer International Publishing, Switzerland,2015.
2. Kalyanmoy Deb, "Multi-Objective Optimization using Evolutionary Algorithms," John Wiley & Sons,2001.
3. James Kennedy and Russel E Eberheart, "Swarm Intelligence," The Morgan Kaufmann Series in Evolutionary Computation,2001.

Reference Books:

1. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, "Swarm Intelligence-From natural to Artificial Systems," Oxford University Press,1999.
2. David Goldberg, "Genetic Algorithms in Search, Optimization and Machine Learning," Pearson Education,2007.
3. Konstantinos E. Parsopoulos and Michael N. Vrahatis, "Particle Swarm Optimization and Intelligence: Advances and Applications," Information science reference, IGI Global,2010.
4. N P Padhy, "Artificial Intelligence and Intelligent Systems," Oxford University Press,2005.
   Reference Papers:

EEL 1X35: Smart Grid Resiliency and Cyber Security **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the key technical threat types, communication protocols and resilient smart grid architectures.
- Deploy risk management, operational security and secure development of Smart Grid.
- Assess static and dynamic security analysis techniques to validate.
- Verify smart grid security and resiliency

1. Smart Grid Security Challenges

Security Goals and Challenges, Importance of security, Classification of the threats, Security Analytics for AMI and SCADA, Security Analytics for EMS Modules, Overview of SMT and Probabilistic Model Checking.

LECTURES-8

2. Security and Data Privacy in Smart Grid

Security Challenges in Smart Grid Implementation, Legal Protection of Personal Data in Smart Grid and Smart Metering Systems, Phases of smart grid system development cycle, Smart Grid Security and Privacy of Customer-Side Networks, Smart Grid Security Protection against False Data Injection (FDI) Attacks, Smart Grid Security, Secure V2G Connections, End-to-End security with devices/equipment, sensors, controllers, actuators, communication and systems.

LECTURES-10

3. Smart Grid Threat and Cross-Domain Risk

Smart Grid threat Landscape, Smart Grid Risk Assessment, Challenges and solutions, Emerging methods and techniques for the smart grid security.

LECTURES-10

4. Smart Grid Resiliency and Cyber attack

Types of physical attack on smart grid devices, Hardware security modules, Analytics for Smart Grid Security and Resiliency, Cyber security solutions for control and monitoring system, Control centric security tools and risk assessment methodology, Secure Communications in Smart Grid: Networking and Protocols.

LECTURES-8

Text Books:

1. Al-Shaer, Ehab, Rahman and Mohammad Ashiqur, "Security and Resiliency Analytics for Smart Grids', Springer Intr., 1st Edition,2016.
2. S. Goel, Goel, Y. Hong, V. Papakonstantinou, D. Kloza, "Smart Grid Security", Springer-Verlag, 1st Edition,2015

Reference Books:

1. A. Abdallah and X. Shen, "Security and Privacy in Smart Grid", Springer Intr., 1stEdition,2018.
2. Abdul Rahamanet al., 'Smart grids security challenges: Classification by sources of threat', Journal of Electrical Systems and Information Technology, 5 (3), pp. 468-483,2018.
3. A. Abur and A. G. Exposito, "Power System State Estimation: Theory and Implementation", CRC Press, 1st Edition,2004.
4. Roy D. Yates, David J. Goodman, "Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers", Wiley, 3rd Edition,2014.
5. J. A. Momoh, "Smart Grid: Fundamentals of Design and Analysis" Wiley India, 1st Edition,2015

EEL 1X36: Cloud Computing and Big Data Analytics in Smart Grid **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Enumerate research integrating cloud computing and big data applications for smart grid
- Analyze the benefits of cloud computing and big data analytics for smart grid technology.
- Explore applications of big data and cloud computing.
- Evaluate current status of smart grid simulation tools

1. Introduction: Introduction to Cloud Computing in Smart Grid - Introduction to Big Data Analytics - Fundamental Mathematical Prerequisites, Big Data Era, General Security Challenges.
LECTURES-6

2. Cloud Computing Applications for Smart Grid: Cloud computing in smart grid, Cloud computing architecture, Demand Response - Geographical Load- Balancing - Dynamic Pricing - Virtual Power Plant - Advanced Metering Infrastructure - Cloud-Based Security and Privacy.
LECTURES-7

3. Smart Grid Data Management and Applications: Pricing and energy forecasting in Demand Response, case study on Energy Forecast, Smart Meter Data Management -PHEVs: Internet of Vehicles - Smart Buildings.
LECTURES-7

4. Smart Grid Design and Deployment: Attack detection, current problem and techniques, Secure Data Learning Scheme, Logical Security Architecture, Smart Metering Data Set Analysis—A Case Study, Security Schemes for AMI Private Networks, Simulation Tools-Worldwide Initiatives.
LECTURES-8

5. Probability and Statistics: Random variable and sample space, empirical approach to probability - conditional probability - independent events - Bayes' Theorem, mathematical expectation - moment generating function - Chebyshev's inequality - Bernoulli trials - the Binomial, negative binomial, geometric, Poisson, normal, rectangular, exponential, Gaussian, beta and gamma distributions, sampling and large sample tests, chi- square test, theory of estimation, linear and polynomial fitting by the methods, correlation of bivariate frequency distribution.

LECTURES-8

Text Books:

1. S. Misraand S. Bera, "Smart Grid Technology A Cloud Computing and Data Management Approach" Cambridge University Press, 1st Edition,2018.
2. F. Ye, Y. Qian and R.Q. Hu, "Smart Grid Communication Infrastructure: Big Data, Cloud Computing and Security" Wiley IEEE Press, 1st Edition,2018.

Reference Book:

1. James A. Momoh, "Smart Grid: Fundamentals of Design and Analysis" Wiley India, 1st Edition, 2015

EEL 1X37: Challenges and Solutions in Renewable Integration **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the available grid Codes for the renewable integration in multiple countries.
- Understand market and forecasting challenges due to uncertainties in renewables.
- Assess power quality and inertia issues with increased penetration of RES in electric grids.
- Evaluate solutions and apply for RES operational and uncertainty issues.

1. **Energy System Challenges:** Handling Renewable Energy Variability and Uncertainty in Power System Operation, short-term frequency response challenges in power systems with high nonsynchronous penetration levels, technical impacts of high penetration levels of wind power on power system stability, constraints to the transformation rate of global energy infrastructure, demand supply flexibility, Voltage control, inertia response. Overview of the grid codes, components of the grid codes, development of the grid codes, classification and specifications of the grid codes, anomalies in grid codes, Fault-Ride Through criterion.

LECTURES-6

2. Integration of Renewable Energy: The Indian Experience Policy initiatives, Regulatory initiatives, Transmission planning initiatives, Experience with RECs in India, Challenges German Renewable Energy Sources Pathway: Increasing challenges of RES integration into the German electricity system. Danish Case Study: The Danish markets for balancing the electricity system, making wind as a part of the balancing solution, an hour with negative prices for downward regulation, Challenges to participation in the tertiary reserve market, Decentralized combined heat and power plants of the balancing solution. Texas Case Study: Study of the impacts of wind generation on ancillary service, Ancillary service requirement methodology improvements to integrate wind generation resources, Regulation-up and - down reserve service.

LECTURES-8

3. Photovoltaic Penetration in Distribution Network: Voltage imbalance sensitivity analysis, stochastic evaluation, Monte Carlo Evaluation, series and parallel custom power devices, dynamic and feasibility issues related to custom power, performance of grid connected solar photovoltaic system with MPPT controllers, mathematical model of grid connected three phase SPV system, performance evaluation of P&O and INC based MPPT algorithms, application of adaptive neuro fuzzy inference system (ANFIS) for control of DC-DC convertor for SPV system.

LECTURES-6

4. Market Operations and Forecasting Renewables: Analyzing the impact of variable energy resources on power system reserves, Advances in Market Management Solutions for Variable Energy Resources Integration, forecasting Renewable Energy for Grid Operations, Incorporating Forecast Uncertainty in Utility Control Center, Reserve Management for Integrating Renewable Generation in Electricity Markets, Scandinavian Experience of Integrating Wind Generation in Electricity Market, Economics of renewable generation integration and long term power purchase agreements (PPA) Solution for RES Uncertainties. Enabling and disruptive technologies for renewable integration, enhancing situation awareness in power systems: overcoming uncertainty and variability with renewable resources, managing operational uncertainty through improved visualization tools in control centers with reference to renewable energy providers, Synchro phasors for distribution networks with variable resources, Monitoring and control of RES using synchronized phasor measurements.

LECTURES-10

5. Solution for Operational Issues: Virtual inertial, reactive power control in response to voltage deviations, use of energy storage systems, advanced control strategies to improve dynamic and transient response time, Derated operation of the renewable resources.

LECTURES-6

Text Books:

1. J. Hossain and A. Mahmood, Renewable energy integration: Challenges and Solutions, Springer- Verlag, 2014 Edition,2014.
2. L. E. Jones, "Renewable Energy Integration Practical Management of Variability, Uncertainty, and Flexibility in Power Grids", Elsevier Inc., 2nd Edition,2017.

References Books:

1. L. Bird, M. Milligan, and D. Lew, "Integrating Variable Renewable Energy: Challenges and Solutions", Technical Report NREL/TP-6A20-60451 September2013.
2. AkshayUrja, "Challenges to Grid Integration of Renewable Energy in India", MNRE technical report,2019.
3. F. Katiraei and J. R. Aguero, "Solar PV Integration Challenges," IEEE Power and Energy Magazine, vol. 9, no. 3, pp. 62-71, May-June2011.
4. L. Xie et al., "Wind Integration in Power Systems: Operational Challenges and Possible Solutions," in Proceedings of the IEEE, vol. 99, no. 1, pp. 214-232, Jan.2011.

EEL 1X38: Smart Electrical Distribution System **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand structure and load patterns of a power distribution system.
- Model and analyze modern smart power distribution system.
- Analyze the performance of distribution power flow and short circuit studies.
- Suggest/follow Regulations and Market Models for Smart distribution system.

1. Introduction

Fundaments of the Electrical Power Distribution System and feeder configuration, Distribution system loading, Load Characteristics, SAIDI, SAIFI, Distribution Transformer, Single phase and three Phase Transformer connections.

LECTURES-5

2. Distribution system Modeling

Impedance of distribution system, Modeling of distribution line, cables, Distribution Transformer, Distributed generation, loads and reactive power sources. Modeling and study of voltage regulators in distribution network.

LECTURES-6

3. Distribution System Analysis

Load flow for distribution system: Backward/forward method, Direct method, load flow application for weakly meshed distribution system, Short Circuit analysis: Sequence based, Thevenin Equivalent and Phase variable based, LG, LL, LLG, LLLG fault analysis and its applications.

LECTURES-6

4. Smart Distribution Technologies

Distribution automation, outage management systems, automated meter reading (AMR), automated metering infrastructure (AMI), Net Metering, Automated Fault Location, Isolation and Service Restoration, Outage Management Systems (OMS), Energy Storage, Renewable Integration, Microgrids. Impacts of microgrids, EV charging and roof top solar in smart electric distribution system.

LECTURES-8

5. Regulations and Market Models for Smart Distribution System

Demand Response, Tariff Design, Time of the day pricing (TOD), Time of use pricing (TOU), Consumer privacy and data protection, consumer engagement etc. Cost benefit analysis of smart grid projects.

LECTURES-6

Text Books:

1. A.S. Pabla, "Electric Power Distribution", Tata McGraw Hill Publishing Co. Ltd., 4th Edition, 2017.
2. Abdelhay A. Sallam and Om P. Malik, "Electric Distribution Systems," IEEE Press Series, 2nd Edition,2019.

Reference Books:

1. W. H. Kersting, "Distribution System Modeling and Analysis", CRC Press, 4th Edition, 2017.
2. John D. McDonald (Editor), "Electric Power Substations Engineering", CRC Press, 3rd Edition, 2016.

EEL 1X39: Power Quality **Prerequisite: NA**

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To study various methods of power quality monitoring.
- To Study the production of voltages sags.
- To Study the interruptions types and its influence in various components.
- To Study the Effects of harmonics on various equipment's.

1. Introduction to Power Quality:
Terms and definitions: Overloading - under voltage - over voltage. Concepts of transients – short duration variations such as interruption - long duration variation such as sustained interruption. Sags and swells - voltage sag - voltage swell - voltage imbalance - voltage fluctuation - power frequency variations, different standers of power quality.

LECTURES-8

2. Voltage Sags and Interruptions:
Sources of sags and interruptions - estimating voltage sag performance. Thevenin's equivalent source - analysis and calculation of various faulted condition. Voltage sag due to induction motor starting. Estimation of the sag severity - mitigation of voltage sags, active series compensators. Static transfer switches and fast transfer switches.

LECTURES-8

3. Overvoltages:
Sources of over voltages - Capacitor switching – lightning - ferro resonance. Mitigation of voltage swells - surge arresters - low pass filters - power conditioners. Lightning protection – shielding – line arresters - protection of transformers and cables. An introduction to computer analysis tools for transients, PSCAD and EMTP.

LECTURES-8

4. Harmonics:
Harmonic sources from commercial and industrial loads, locating harmonic sources. Power system response characteristics - Harmonics Vs transients. Effect of harmonics - harmonic distortion - voltage and current distortion - harmonic indices - inter harmonics – resonance. Harmonic distortion evaluation - devices for controlling harmonic distortion - passive and active filters design. IEEE and IEC standards.

LECTURES-8

5. Power Quality Improvement Scheme:
STATCOM, UPQC **LECTURES-2**

6. Power Quality EMI & EMC issues **LECTURES-2**

7. Power Quality Monitoring
Monitoring considerations - monitoring and diagnostic techniques for various power quality problems- modeling of power quality (harmonics and voltage sag) problems by mathematical simulation tools. Different power quality monitoring tools.

LECTURES-8

Readings:

Prescribed Text Books

1. Roger. C. Dugan, Mark. F. McGranagham, Surya Santoso, H.WayneBeaty, 'Electrical Power Systems Quality' McGraw Hill, 2003.
2. C sankaran, Power Quality, CRC press

Additional Readings

1. G.T. Heydt, Electric Power Quality, 2nd Edition. (West Lafayette, IN, Stars in a Circle Publications, 1994).
2. M.H.J Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions, (New York: IEEE Press, 1999).
3. J. Arrillaga, N.R. Watson, S. Chen, Power System Quality Assessment', (New York: Wiley, 1999.

EEL1X51: RENEWABLE ENERGY **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the various forms of Non-conventional energy resources.
- Describe the use of solar energy and the various components used in energy production compared to applications like - heating, cooling, desalination, power generation, drying, cooking, etc.
- Appreciate the need for Wind Energy and the various components used in energy generation and know the classifications.
- Understand the concept of Biomass energy resources and their classification, types of biogas Plants- applications.
- Compare Solar, Wind, and bio-energy systems, their prospects, advantages, and limitations.
- Acquire the knowledge of fuel-cells, wave power, tidal power and geothermal principles and applications.

1. **Non-conventional Sources of Electrical Energy**- Solar, wind, geothermal, ocean, tidal, wave, magneto hydrodynamic (MHD), and biomass; their scope and potentialities for energy conversion.

LECTURES: 6

2. **Solar Energy**- Introduction, physical principles of conversion of solar radiation into heat, solar energy collectors, solar energy storage, solar-electrical power generation and other miscellaneous applications of solar energy.

LECTURES: 8

3. **Wind Energy** – Introduction, the basic principle of wind energy conversion, wind data and energy estimation, site selection, basic component of wind energy conversion system, wind turbines and their analysis, wind-electrical generation; stand-alone and grid-connected wind-electrical power system, various applications of wind energy.

LECTURES: 10

4. Modelling and control of wind and solar energy systems.

LECTURES: 6

5**. Optimisation Technique**-Wind / solar photovoltaic integrated systems design, grid synchronized inverter system.

LECTURES: 6

Prescribed Text Books

1. S. Rao and B.B. Parulekar, Energy Technology, Khanna Publishers, 2002.
6. G.D Rai, Non-conventional Energy Sources, Khanna Publishers, 2002.
7. S.P. Sukhatme, Solar Energy, Tata McGraw-Hill Publishing Co. Ltd., 2003

Reference Books

1. Thomas Ackermann, Wind Power in Power System, John Willey &Sons, 2005.
2. Rai G.D., Non - Conventional Energy Sources, Khanna Publishers, 1993.
3. Rai G.D., Solar Energy Utilisation, Khanna Publishers, 1993.

EEL 1X52 ELECTRICAL ENGINEERING MATERIALS **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Learn the basics of materials used in electrical engineering. Realize the dielectric properties of insulators in static and alternating fields.
- Explain the importance of magnetic properties and superconductivity.
- Explain the behavior of conductivity of metals and classifications of semiconductor materials.

1. **Conducting Materials**: Review of metallic conduction based on the free electron theory. Fermi-Dirac distribution – a variation of conductivity with temperature and composition, materials for electric resistors- general electric properties; material for brushes of electrical machines, lamp filaments, fuses, and solder.

LECTURES: 6

2. **Semiconductors**: Mechanism of conduction in semiconductors, the density of carriers in intrinsic semiconductors, the energy gap, and types of semiconductors. Hall effect, compound semiconductors, basic ideas of amorphous and organic semiconductors. Magnetic materials: Classification of magnetic materials- the origin of permanent magnetic dipoles, ferromagnetism, hard and soft magnetic materials, and magneto materials used in electrical machines, instruments, and relays.

LECTURES: 8

3. **Dielectrics:** Dielectric, polarization under static fields- electronic ionic and dipolar polarizations, the behavior of dielectrics in alternating fields, Factors influencing dielectric strength and capacitor materials. Insulating materials, complex dielectric constant, dipolar relaxation, and dielectric loss.

LECTURES: 6

4. **Insulating materials**: Inorganic materials (mica, glass, porcelain, asbestos), organic materials (paper, rubber, cotton silk fiber, wood, plastics, and Bakelite), resins and varnishes, liquid insulators (transformer oil) gaseous insulators (air, SF6, and nitrogen) and ageing of insulators.

LECTURES: 4

5. **Introduction Properties and Application of Piezoelectric materials:** Introduction Properties and Application of Piezoelectric materials, Electrostrictive materials, Ferromagnetic materials, Magnetostrictive materials, Shape memory alloys, Electro archeological fluids, Magneto archeological fluids, Smart hydrogels.

LECTURES: 6

6. **Ceramics:** properties, application to conductors, insulators & capacitors Plastics: Thermoplastics, rubber, thermostats, properties.

LECTURES: 6

Textbook

1. Electrical Engineering Materials Adrianus J Dekker, Phi Learning Publishers.
2. Electrical Properties of Materials, 8th Edition by Solymar, L, Oxford University Press New Delhi.
3. Introduction to Electrical Engineering Materials 4th Edn. 2004 Edition by Indulkar C, S.
4. Chand & Company Ltd-New Delhi. Electrical and Electronic Engineering Materials by SK Bhattacharya, Khanna Publishers, New Delhi.

EEL 1X53: CONTROL SYSTEM DESIGN **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes

- Understand various design specifications.
- Design controllers to satisfy the desired design specifications using simple controller structures (P, PI, PID, compensators).
- Design controllers using the state-space approach.

1. Design Specifications: Introduction to design problem and philosophy. Introduction to time domain and frequency domain design specification and its physical relevance. Effect of gain on transient and steady-state response. Effect of addition of pole on system performance. Effect of addition of zero on system response.

LECTURES: 4

2. Design of Classical Control System in the time domain: Introduction to the compensator. Design of Lag, lead lag-lead compensator in the time domain. Feedback and Feedforward compensator design. Feedback compensation. Realization of compensators.

LECTURES: 7

3. Design of Classical Control System in the frequency domain: Compensator design in the frequency domain to improve steady state and transient response. Feedback and Feedforward compensator design using bode diagram.

LECTURES: 8

4. Design of PID controllers: Design of P, PI, PD, and PID controllers in the time domain and frequency domain for first, second, and third-order systems. Control loop with auxiliary feedback – Feed-forward control.

LECTURES: 6

5. Control System Design in state space: Review of state space representation. Concept of controllability & observability, the effect of pole-zero cancellation on the controllability & observability of the system, pole placement design through state feedback. Ackerman's Formula for feedback gain design. Design of Observer. Reduced order observer. Separation Principle.

LECTURES: 8

6. Nonlinearities and its effect on system performance: Various types of non-linearities. Effect of various non-linearities on system performance. Singular points. Phase plot analysis.

LECTURES: 3

Text and Reference Books:

1. N. Nise, "Control system Engineering", John Wiley, 2000.
2. I. J. Nagrath and M. Gopal, "Control system engineering", Wiley, 2000.
3. M. Gopal, "Digital Control Engineering", Wiley Eastern, 1988.
4. K. Ogata, "Modern Control Engineering", Prentice Hall, 2010.
5. B. C. Kuo, "Automatic Control system", Prentice Hall, 1995.

EEL 1X54: SOFT COMPUTING TECHNIQUES AND APPLICATIONS **Prerequisite: NA**
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Learn about soft computing techniques and their applications.
- Analyze various neural network architectures.
- Understand perceptions and counter-propagation networks.
- Define fuzzy systems.
- Analyze the genetic algorithms and their applications.

1. Introduction to Soft Computing:
Introduction, importance, main components, Fuzzy Logic, ANN, Evolutionary Algorithms, Hybrid Intelligent Systems.

LECTURES-4

2. Artificial Neural Network and Supervised Learning:
Introduction, Comparison of Neural Techniques and AI, Artificial Neuron Structure, Adaline, ANN Learning, Back Propagation Learning, Properties & Limitations.

LECTURES-5

3. Development of Generalized Neuron and Its Validation:
Existing Neuron Model, Development, Advantages, Learning Algorithm of a Summation Type Generalized Neuron, Benchmark Testing of Generalized Neuron Model, Generalization of GN model, Discussion.

LECTURES-5

4. Introduction to Fuzzy Set Theoretic Approach:
Introduction, Uncertainty and Information., Types of Uncertainty, Fuzzy Logic- Introduction, development, Precision and Significance, set, Operations, Union Intersection, Complement, Combination, Concentration, Dilation, Intensification, α-Cuts. Quantifier/Modifier/Hedges, Characteristics, Normality, Convexity, Cross Over Point, Singleton, Height, Cardinality, Properties of Fuzzy Sets, Fuzzy Cartesian Product, shape & defining Membership Functions, Defuzzification, Rule-Based System.

LECTURES-8

5. Applications of Fuzzy Rule-Based System:
Introduction, Modelling and Simulation, approach, selection, Steady State D.C. Machine Model, Control Applications Adaptive Control, PID Control System, Transient Model of D.C. Machine, Fuzzy Control System, Power System Stabilizer Using Fuzzy Logic.

LECTURES-4

6. Evolutionary & Metaheuristic search and optimization Algorithms:
GA-Selection, cross over & mutation, simple GA algorithm, elitism. PSO- Particle swarm, velocity, mutation, selection, algorithm. DE- Selection, cross over & mutation, algorithm, elitism.

LECTURES-6

7. Integration of Neural Networks, Evolution Algorithms, and Fuzzy Systems:
Adaptive Neuro-Fuzzy Inference Systems, Neuro-Fuzzy Approach of Modelling. ANN – GA-Fuzzy Synergism and Its Applications Training of ANN, ANN Learning Using GA, Validation and Verification of ANN-GA Model.

LECTURES-4

Prescribed Text Books

1. S N Sivanandam, S.N. Deepa, Principles of Soft Computing, Wiley.
2. Goldenberg, soft computing, Allied publisher.

Reference Books

1. D K Chaturvedi, Soft Computing - Techniques and its Applications in Electrical Engineering, Springer

EEL 1X55: OPTIMIZATION TECHNIQUES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Acquire a systematic understanding of optimization techniques.
- Understanding in detail the problem formulation and the solution approaches.
- Understanding a class of nonlinear optimization problems where the optimal solution is also globally optimal.

1. Introduction:

Historical Development; Engineering applications of Optimization; Art of Modelling; Objective function; Constraints and Constraint surface; Formulation of design problems as mathematical programming problems; Classification of optimization problems based on the nature of constraints, the structure of the problem, deterministic nature of variables, separability of functions and the number of objective functions; Optimization techniques – classical and advanced techniques.

LECTURES-6

2. Linear Programming:

Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; Graphical method for two variable optimization problem; Examples; Simplex algorithm with equality and inequality constraints, integer programming.

LECTURES-6

3. Optimization using Calculus:

Stationary points - maxima, minima, and saddle points; Functions of single and two variables; Global Optimum; Convexity and concavity of functions of one and two variables; Optimization of the function of single and multiple variables; Gradient vectors; Optimization of the function of multiple variables subject to equality; Lagrangian function; Hessian matrix formulation; Kuhn-Tucker Conditions.

LECTURES-5

4. Non-Linear Programming Algorithms:

Unconstrained optimization techniques, Direct search methods, Descent methods, 2nd order methods, constrained optimization, Direct and indirect methods.

LECTURES-8

5. Dynamic Programming:

Sequential optimization; Representation of multistage decision process; Concept of sub-optimization and the principle of optimality; Computational procedure in dynamic programming (DP); the curse of dimensionality in DP.

LECTURES-7

6. Robust Optimization Techniques:

Limitation of conventional optimization techniques, robust techniques: Simulated annealing (SA), Genetic Algorithm (GA).

LECTURES-4

Prescribed Text Books

1. S S Rao, Engineering Optimization: Theory and Practice, New Age International (P) Ltd.
2. Suresh Chandra, Jaydeva, Numerical Optimization with Applications, Narosa publisher.
3. David Edward Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley Publishing Company.

Reference Books

1. Edvin K P Chong, Stanislaw H Zak, An Introduction to Optimization, John Wiley.
2. Mohan C Joshi, Kannan M Moudgalya, Optimization Theory and Practice, Narosa publisher.