

EE 322	Summer Industry Internship
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Minimum of six weeks in an Industry in the area of Electrical Engineering. The summer internship should give exposure to the practical aspects of the discipline. In addition, the student may also work on a specified task or project which may be assigned to him/her. The outcome of the internship should be presented in the form of a report.

EE 211	Electrical Circuit Analysis	3	1	0	4	4
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AIM

To learn about the basics of analysis and synthesis techniques used in electric circuits.

OBJECTIVES AND OUTCOMES :

- To study about various network theorems and analysis methods.
- To apply network theorems for analysis of electrical circuits.
- To understand the concept of transient and steady state response of electrical circuits • To analyse circuits in sinusoidal steady state (1 ph and 3 phase systems).
- To analyse two port network circuits and apply them for solving circuit problems

UNIT 1: Network Theorems(10 Hours):

Thevenin's theorem – Norton's theorems – Superposition theorem – Maximum power transfer theorem –Reciprocity theorem – Compensation theorem – Tellegen's theorem – Analysis of circuits with dependent and independent sources for voltage and current – Nodal Analysis- Mesh Analysis – Duality and Dual network (introduction).

UNIT 2: Analysis of 1st and 2nd order networks (8 hours):

Solution of 1st order and 2nd order differential equations for application in Electric Circuit Analysis Initial and Final conditions in Network elements- Forced and Free Response- Steady state and transient response of RL, RC and RLC Circuits to DC excitation – Natural and forced oscillations — Step response of R-L, R-C, R-L-C Circuit.

UNIT 3: Sinusoidal Steady state response (8 hours):

Sine function as a rotating phasor – phasor diagrams – impedance and admittances - Advantages – Relationship between Line and Phase Voltages and Currents in Star Connection – Relationship between Line and Phase Voltages and Currents in Delta Connection – Measurement of Power and Power Factor of a Balanced Three Phase Load – Unbalanced Loads- Self and Mutual Inductance – Coefficient of Coupling – Series Connection of Coupled Circuits – Modelling – Dot Convention – Electrical Equivalents of Magnetically Coupled Circuits.

UNIT 4: Laplace Transform and its application in Electrical Circuit Analysis (8 hours):

Basics of Laplace transform – inverse Laplace transform – Convolution integral – transformed network with initial conditions – transfer function representation – poles and zeros – frequency response, series and parallel resonance.

UNIT 5: Two port networks (6 hours):

Network Elements – Classification of Network – Network Configuration – Parameters and Transfer Function – Z, Y, hybrid, ABCD parameters – Condition for Reciprocity and Symmetry – Interrelationships between Parameters of Two-Port Networks – Types of Interconnections: series, parallel and cascaded.

TEXT BOOKS:

1. William H. Hayt and Jack E. Kemmerly, "Engineering Circuit Analysis", McGraw-Hill International Edition.2013.

2. A. Chakrabarti, "Circuit Theory", Dhanpat Rai & Co. Pvt. Ltd. 2010.
3. Van Valkenburg, "Network Analysis", Prentice Hall of India Pvt. Ltd., 2006. 4. C.K. Alexander and M.N. O. Sadiku, "Electric Circuits", McGraw Hill Education, 2004.

REFERENCE BOOKS:

1. Joseph A Edminister "Electric Circuits", Third Edition,
Tata McGraw-Hill
2. M L Soni and J C Gupta "A Course in Electrical Circuits Analysis" Dhanpat Rai Publications

EE 214	Electrical Machines-I	3	0	0	3	3
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the concepts of magnetic circuits. Understand the operation of dc machines.
- Analyse the differences in operation of different dc machine configurations. Analyse single phase and three phase transformers circuits.

UNIT 1: Magnetic fields and magnetic circuits (6 Hours)

Review of magnetic circuits - MMF, flux, reluctance, inductance; review of Ampere Law and Biot Savart Law; Visualization of magnetic fields produced by a bar magnet and a current carrying coil - through air and through a combination of iron and air; influence of highly permeable materials on the magnetic flux lines.

UNIT 2: Electromagnetic force and torque (9 Hours)

B-H curve of magnetic materials; flux-linkage vs current characteristic of magnetic circuits; linear and nonlinear magnetic circuits; energy stored in the magnetic circuit; force as a partial derivative of stored energy with respect to position of a moving element; torque as a partial derivative of stored energy with respect to angular position of a rotating element. Examples - galvanometer coil, relay contact, lifting magnet, rotating element with eccentricity or saliency

UNIT 3: DC machines (8 Hours)

Basic construction of a DC machine, magnetic structure - stator yoke, stator poles, pole-faces or shoes, air gap and armature core, visualization of magnetic field produced by the field winding excitation with armature winding open, air gap flux density distribution, flux per pole, induced EMF in an armature coil. Armature winding and commutation - Elementary armature coil and commutator, lap and wave windings, construction of commutator, linear commutation Derivation of back EMF equation, armature MMF wave, derivation of torque equation, armature reaction, air gap flux density distribution with armature reaction.

UNIT 4: DC machine - motoring and generation (7 Hours)

Armature circuit equation for motoring and generation, Types of field excitations - separately excited, shunt and series. Open circuit characteristic of separately excited DC generator, back EMF with armature reaction, voltage build-up in a shunt generator, critical field resistance and critical speed. V-I characteristics and torque-speed characteristics of separately excited, shunt and series motors. Speed control through armature voltage. Losses, load testing and back-to-back testing of DC machines

UNIT 5: Transformers (12 Hours)

Principle, construction and operation of single-phase transformers, equivalent circuit, phasor diagram, voltage regulation, losses and efficiency Testing - open circuit and short circuit tests, polarity test, back-to-back test, separation of hysteresis and eddy current losses Three-phase transformer - construction, types of connection and their comparative features, Parallel operation of single-phase and three-phase transformers, Autotransformers - construction, principle, applications and comparison with two winding transformer, Magnetizing current, effect of nonlinear B-H curve of magnetic core material, harmonics in magnetization current, Phase conversion - Scott connection, three-phase to six-phase conversion, Tap-changing transformers - No-load and on-load tap-changing of transformers, Three-winding transformers. Cooling of transformers.

Text / References:

1. A. E. Fitzgerald and C. Kingsley, "Electric Machinery", New York, McGraw Hill Education, 2013.
2. A. E. Clayton and N. N. Hancock, "Performance and design of DC machines", CBS Publishers, 2004.
3. M. G. Say, "Performance and design of AC machines", CBS Publishers, 2002.
4. P. S. Bimbhra, "Electrical Machinery", Khanna Publishers, 2011.
5. I. J. Nagrath and D. P. Kothari, "Electric Machines", McGraw Hill Education, 2010.

EE 216	Electromagnetic Fields	3	1	0	4	4
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Course Outcomes:

At the end of the course, students will demonstrate the ability

- To understand the basic laws of electromagnetism.
- To obtain the electric and magnetic fields for simple configurations under static conditions.
- To analyse time varying electric and magnetic fields.
- To understand Maxwell's equation in different forms and different media. To understand the propagation of EM waves.

This course shall have Lectures and Tutorials. Most of the students find difficult to visualize electric and magnetic fields. Instructors may demonstrate various simulation tools to visualize electric and magnetic fields in practical devices like transformers, transmission lines and machines.

UNIT 1 : Review of Vector Calculus (6 hours)

Vector algebra- addition, subtraction, Components of vectors, scalar and vector multiplications, triple products, Three orthogonal coordinate systems (rectangular, cylindrical and spherical). Vector calculus differentiation, partial differentiation, integration, vector operator del, gradient, divergence and curl; integral theorems of vectors. Conversion of a vector from one coordinate system to another.

UNIT 2: Static Electric Field (6 Hours)

Coulomb's law, Electric field intensity, Electrical field due to point charges. Line, Surface and Volume charge distributions. Gauss law and its applications. Absolute Electric potential, Potential difference, Calculation of potential differences for different configurations. Electric dipole, Electrostatic Energy and Energy density.

UNIT 3: Conductors, Dielectrics and Capacitance (6 Hours)

Current and current density, Ohms Law in Point form, Continuity of current, Boundary conditions of perfect dielectric materials. Permittivity of dielectric materials, Capacitance, Capacitance of a two wire line, Poisson's equation, Laplace's equation, Solution of Laplace and Poisson's equation, Application of Laplace's and Poisson's equations.

UNIT 4: Static Magnetic Fields (6 Hours)

Biot-Savart Law, Ampere Law, Magnetic flux and magnetic flux density, Scalar and Vector Magnetic potentials. Steady magnetic fields produced by current carrying conductors.

UNIT 5: Magnetic Forces, Materials and Inductance (6 Hours)

Force on a moving charge, Force on a differential current element, Force between differential current elements, Nature of magnetic materials, Magnetization and permeability, Magnetic boundary conditions, Magnetic circuits, inductances and mutual inductances.

UNIT 6: Time Varying Fields and Maxwell's Equations (6 Hours)

Faraday's law for Electromagnetic induction, Displacement current, Point form of Maxwell's equation, Integral form of Maxwell's equations, Motional Electromotive forces. Boundary Conditions.

UNIT 7: Electromagnetic Waves (6 Hours)

Derivation of Wave Equation, Uniform Plane Waves, Maxwell's equation in Phasor form, Wave equation in Phasor form, Plane waves in free space and in a homogenous material. Wave equation for

a conducting medium, Plane waves in lossy dielectrics, Propagation in good conductors, Skin effect. Poynting theorem.

Text / References:

1. M. N. O. Sadiku, "Elements of Electromagnetics", Oxford University Publication, 2014.
2. A. Pramanik, "Electromagnetism - Theory and applications", PHI Learning Pvt. Ltd, New Delhi, 2009.
3. A. Pramanik, "Electromagnetism-Problems with solution", Prentice Hall India, 2012.
4. G. W. Carter, "The electromagnetic field in its engineering aspects", Longmans, 1954.
5. W. J. Duffin, "Electricity and Magnetism", McGraw Hill Publication, 1980.
6. W. J. Duffin, "Advanced Electricity and Magnetism", McGraw Hill, 1968.
7. E. G. Cullwick, "The Fundamentals of Electromagnetism", Cambridge University Press, 1966.
8. B. D. Popovic, "Introductory Engineering Electromagnetics", Addison-Wesley Educational Publishers, International Edition, 1971.
9. W. Hayt, "Engineering Electromagnetics", McGraw Hill Education, 2012.

EE 217	Digital Electronics	3	0	0	3	3
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand working of logic families and logic gates.
- Design and implement Combinational and Sequential logic circuits.
- Understand the process of Analog to Digital conversion and Digital to Analog conversion.
- Be able to use PLDs to implement the given logical problem.

UNIT 1: Fundamentals of Digital Systems and logic families (7Hours)

Digital signals, digital circuits, AND, OR, NOT, NAND, NOR and Exclusive-OR operations, Boolean algebra, examples of IC gates, number systems-binary, signed binary, octal hexadecimal number, binary arithmetic, one's and two's complements arithmetic, codes, error detecting and correcting codes, characteristics of digital ICs, digital logic families, TTL, Schottky TTL and CMOS logic, interfacing CMOS and TTL, Tri-state logic.

UNIT 2: Combinational Digital Circuits (7Hours)

Standard representation for logic functions, K-map representation, simplification of logic functions using K-map, minimization of logical functions. Don't care conditions, Multiplexer, DeMultiplexer/Decoders, Adders, Subtractors, BCD arithmetic, carry look ahead adder, serial adder, ALU, elementary ALU design, popular MSI chips, digital comparator, parity checker/generator, code converters, priority encoders, decoders/drivers for display devices, Q-M method of function realization.

UNIT 3: Sequential circuits and systems (7Hours)

A 1-bit memory, the circuit properties of Bistable latch, the clocked SR flip flop, J- K-T

And D-

types flip flops, applications of flip flops, shift registers, applications of shift registers, serial to parallel converter, parallel to serial converter, ring counter, sequence generator, ripple (Asynchronous) counters, synchronous counters, counters design using flip flops, special counter IC's, asynchronous sequential counters, applications of counters.

UNIT 4: A/D and D/A Converters (7Hours)

Digital to analog converters: weighted resistor/converter, R-2R Ladder D/A converter, specifications for D/A converters, examples of D/A converter ICs, sample and hold circuit, analog to digital converters: quantization and encoding, parallel comparator A/D converter, successive approximation A/D converter, counting A/D converter, dual slope A/D converter, A/D converter using voltage to frequency and voltage to time conversion, specifications of A/D converters, example of A/D converter ICs

UNIT 5: Semiconductor memories and Programmable logic devices. (7Hours) Memory organization and operation, expanding memory size, classification and characteristics of memories, sequential memory, read only memory (ROM), read and write memory (RAM), content addressable memory (CAM), charge de coupled device memory (CCD), commonly used memory chips, ROM as a PLD, Programmable logic array, Programmable array logic, complex Programmable logic devices (CPLDs), Field Programmable Gate Array (FPGA).

Text/References:

1. R. P. Jain, "Modern Digital Electronics", McGraw Hill Education, 2009.
2. M. M. Mano, "Digital logic and Computer design", Pearson Education India, 2016.
3. A. Kumar, "Fundamentals of Digital Circuits", Prentice Hall India, 2016.

EE 218	Digital ElectronicsLaboratory	0	0	1	1	2
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Hands-on experiments related to the course contents of EE07.

EE 219	Electrical Machines – II	3	0	0	3	3
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the concepts of rotating magnetic fields.
- Understand the operation of ac machines.
- Analyse performance characteristics of ac machines.

UNIT 1: Fundamentals of AC machine windings (8 Hours)

Physical arrangement of windings in stator and cylindrical rotor; slots for windings; single turn coil - active portion and overhang; full-pitch coils, concentrated winding, distributed winding, winding axis, 3D visualization of the above winding types, Air-gap MMF distribution with fixed current through winding - concentrated and distributed, sinusoidally distributed winding, winding distribution factor

UNIT 2: Pulsating and revolving magnetic fields (4 Hours)

Constant magnetic field, pulsating magnetic field - alternating current in windings with spatial displacement, Magnetic field produced by a single winding - fixed current and alternating current Pulsating fields produced by spatially displaced windings, Windings spatially shifted by 90 degrees, Addition of pulsating magnetic fields, Three windings spatially shifted by 120 degrees (carrying three-phase balanced currents), revolving magnetic field.

UNIT 3: Induction Machines (12 Hours)

Construction, Types (squirrel cage and slip-ring), Torque Slip Characteristics, Starting and Maximum Torque, Equivalent circuit, phasor Diagram, Losses and Efficiency, Effect of parameter variation on torque speed characteristics (variation of rotor and stator resistances, stator voltage, frequency), Methods of starting, braking and speed control for induction motors, Generator operation, Selfexcitation, Doubly-Fed Induction Machines.

UNIT 4: Single-phase induction motors (6 Hours)

Constructional features, double revolving field theory, equivalent circuit, determination of parameters. Split-phase starting methods and applications

UNIT 5: Synchronous machines (10 Hours)

Constructional features, cylindrical rotor synchronous machine - armature reaction, generated EMF, equivalent circuit and phasor diagram, synchronous impedance, open circuit characteristic, short circuit characteristics, Zero power factor characteristics; Potier Triangle; voltage regulation, Salient pole machine – two reaction theory, analysis of phasor diagram, Power flow equation, power angle characteristics, Parallel operation of alternators - synchronization and load division, Effect of change of excitation and mechanical input, Generator capability curve. Starting of synchronous motor, Damper winding, Operating characteristics of synchronous machines, Effect of variation of field excitation and load; Mechanical Power, V and Inverted V curves, Hunting.

Text/References:

1. P. S. Bimbhra, "Electrical Machinery", Khanna Publishers, 2011.

2. A. E. Fitzgerald and C. Kingsley, "Electric Machinery", McGraw Hill Education, 2013.
3. M. G. Say, "Performance and design of AC machines", CBS Publishers, 2002.
4. I. J. Nagrath and D. P. Kothari, "Electric Machines", McGraw Hill Education, 2010.
5. A. S. Langsdorf, "Alternating current machines", McGraw Hill Education, 1984.
6. P. C. Sen, "Principles of Electric Machines and Power Electronics", John Wiley & Sons, 2007.

EE 220	Electrical Machines Laboratory – II	0	0	1	1	3
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Hands-on experiments related to the course contents of EE219

EE 313	Control Systems	3	0	0	3	3
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

Understand the modelling 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.

UNIT 1: Introduction to control problem (4 hours)

Industrial Control examples. Mathematical models of physical systems. Control hardware and their models. Transfer function models of linear time-invariant systems.

Feedback Control: Open-Loop and Closed-loop systems. Benefits of Feedback. Block diagram algebra.

UNIT 2: Time Response Analysis (10 hours)

Standard test signals. Time response of first and second order systems for standard test inputs. Application of initial and final value theorem. Design specifications for second-order systems based on the time-response.

Concept of Stability. Routh-Hurwitz Criteria. Relative Stability analysis. Root-Locus technique. Construction of Root-loci.

UNIT 3: Frequency-response analysis (6 hours)

Relationship between time and frequency response, Polar plots, Bode plots. Nyquist stability criterion. Relative stability using Nyquist criterion – gain and phase margin. Closed-loop frequency response.

UNIT 4: Introduction to Controller Design (10 hours)

Stability, steady-state accuracy, transient accuracy, disturbance rejection, insensitivity and robustness of control systems.

Root-loci method of feedback controller design.

Design specifications in frequency-domain. Frequency-domain methods of design. Application of Proportional, Integral and Derivative Controllers, Lead and Lag compensation in designs. Analog and Digital implementation of controllers.

UNIT 5: State variable Analysis (6 hours)

Concepts of state variables. State space model. Diagonalization of State Matrix. Solution of state equations. Eigenvalues and Stability Analysis. Concept of controllability and observability.

Pole-placement by state feedback.

Discrete-time systems. Difference Equations. State-space models of linear discrete-time systems. Stability of linear discrete-time systems

UNIT 6: Introduction to Optimal Control and Nonlinear Control (5 hours)

Performance Indices. Regulator problem, Tracking Problem. Nonlinear system–Basic concepts and analysis.

Text/References:

1. M. Gopal, "Control Systems: Principles and Design", McGraw Hill Education, 1997.

2. B. C. Kuo, "Automatic Control System", Prentice Hall, 1995.
3. K. Ogata, "Modern Control Engineering", Prentice Hall, 1991.
4. I. J. Nagrath and M. Gopal, "Control Systems Engineering", New Age International, 2009

EE 314	Control Systems Laboratory	0	0	1
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Hands-on/Computer experiments related to the course contents of EE 313.

EE 315	Power Electronics	3	0	0	3	3
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Aim: The course discusses introductory topics in power electronics for the UG level students of electrical engineering

Course Outcomes:

At the end of this course students will demonstrate the ability to

- Understand the differences between signal level and power level devices. Analyse controlled rectifier circuits.
- Analyse the operation of DC-DC choppers.
- Analyse the operation of voltage source inverters.

UNIT I: Power Switching Devices : (8 Hours):

Power Diodes – General Purpose, Fast Recovery, Schottky Diode; BJT, MOSFET, SCR, IGBT and their V-I characteristics; SCR: Operating Principle, Gate Characteristics, Two-Transistor model, di/dt and dv/dt Protection, Firing circuits, series and parallel operation, rating, selection; Thyristor Triggering techniques; Thyristor Commutation techniques; Snubber circuits. Gate Drives for MOSFET and IGBT

UNIT II: Thyristor Rectifiers (8 hours):

1- ϕ and 3- ϕ semi, half-wave, dual and full-wave controlled rectifiers with R and RL loads; freewheeling diode; detailed derivation of rms, average value, harmonic factor, THD, crest factor; half wave and full wave controlled rectifiers; Input current wave shape and power factor Effect of Source impedance.

UNIT III: DC-DC Converters (10 Hours):

Principle; Elementary step-up and step-down choppers; concept of duty ratio and average voltage classification; power circuits of buck, boost and buck- boost converters, analysis and waveforms at steady state; control of duty ratio and the output; CCM and DCM modes of operation.

UNIT IV: DC-AC Converters/Inverter (single phase) (10 Hours):

Power Circuits of single-phase voltage source inverter; Concepts of switched mode inverters; Square wave operation; PWM switching; Series and parallel inverters; Concept of average voltage over a switching cycle; modulation; modulation index; modulation techniques.

UNIT V: DC-AC Converters/Inverter (Three phase) (8 Hours):

3- ϕ half bridge and full bridge inverter with R and RL loads; 120° & 180° degree conduction; harmonics reduction; Three phase sinusoidal modulation; Current source inverter; Zero current switching (ZCS); Zero voltage Switching (ZVS); Introduction of resonant inverters.

TEXT BOOKS:

1. Muhammad Rashid, Power Electronics- Circuits, Devices and Applications, 3/e, Pearson Education India 2009.
2. N. Mohan and T.M. Undeland, Power Electronics – Converters, Applications and Design, John Wiley & Sons, 2007.

REFERENCES:

1. B. K. Bose, Modern Power Electronics and AC Drives, Pearson Education, 2003.
2. R.W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, Springer Science and Business Media, 2007.

3. G. K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 2003.
4. L. Umanand, Power Electronics: Essential and Applications, Wiley, India, 2009.

EE 316	Power ElectronicsLaboratory	0	0	1	1	2
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Hands-on experiments related to the course contents of EE 315

EE 317	Electrical Machine Design	3L:0T:0P	3 credits
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the construction and performance characteristics of electrical machines.
- Understand the various factors which influence the design: electrical, magnetic and thermal loading of electrical machines
- Understand the principles of electrical machine design and carry out a basic design of an ac machine.
- Use software tools to do design calculations.

UNIT 1: Introduction

Major considerations in electrical machine design, electrical engineering materials, space factor, choice of specific electrical and magnetic loadings, thermal considerations, heat flow, temperature rise, rating of machines.

UNIT 2: Transformers

Sizing of a transformer, main dimensions, kVA output for single- and three-phase transformers, window space factor, overall dimensions, operating characteristics, regulation, no load current, temperature rise in transformers, design of cooling tank, methods for cooling of transformers.

UNIT 3: Induction Motors

Sizing of an induction motor, main dimensions, length of air gap, rules for selecting rotor slots of squirrel cage machines, design of rotor bars & slots, design of end rings, design of wound rotor, magnetic leakage calculations, leakage reactance of polyphase machines, magnetizing current, short circuit current, circle diagram, operating characteristics.

UNIT 4: Synchronous Machines

Sizing of a synchronous machine, main dimensions, design of salient pole machines, short circuit ratio, shape of pole face, armature design, armature parameters, estimation of air gap length, design of rotor, design of damper winding, determination of full load field mmf, design of field winding, design of turbo alternators, rotor design.

UNIT 5: Computer aided Design (CAD):

Limitations (assumptions) of traditional designs, need for CAD analysis, synthesis and hybrid methods, design optimization methods, variables, constraints and objective function, problem formulation. Introduction to FEM based machine design. Introduction to complex structures of modern machines PMSMs, BLDCs, SRM and claw-pole machines.

Text / References:

1. A. 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
4. K. L. Narang, "A Text Book of Electrical Engineering Drawings", SatyaPrakashan, 1969.
5. A. Shanmugasundaram, G. Gangadharan and R. Palani, "Electrical Machine Design Data Book", New Age International, 1979.
6. K. M. V. Murthy, "Computer Aided Design of Electrical Machines", B.S. Publications, 2008.
7. Electrical machines and equipment design exercise examples using Ansoft's Maxwell 2D machine design package

EE 318	Power Systems – II	3L:0T:0P	3 credits
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

Use numerical methods to analyse a power system in steady state.

Understand stability constraints in a synchronous grid.

Understand methods to control the voltage, frequency and power flow.

Understand the monitoring and control of a power system.

Understand the basics of power system economics

UNIT 1: Power Flow Analysis (7 hours)

Review of the structure of a Power System and its components. Analysis of Power Flows: Formation of Bus Admittance Matrix. Real and reactive power balance equations at a node. Load and Generator Specifications. Application of numerical methods for solution of nonlinear algebraic equations – Gauss Seidel and Newton-Raphson methods for the solution of the power flow equations. Computational Issues in Large-scale Power Systems.

UNIT 2: Stability Constraints in synchronous grids (8 hours)

Swing Equations of a synchronous machine connected to an infinite bus. Power angle curve. Description of the phenomena of loss of synchronism in a single-machine infinite bus system following a disturbance like a three--phase fault. Analysis using numerical integration of swing equations (using methods like Forward Euler, Runge-Kutta 4th order methods), as well as the Equal Area Criterion. Impact of stability constraints on Power System Operation. Effect of generation rescheduling and series compensation of transmission lines on stability.

UNIT 3: Control of Frequency and Voltage (7 hours)

Turbines and Speed-Governors, Frequency dependence of loads, Droop Control and Power Sharing. Automatic Generation Control. Generation and absorption of reactive power by various components of a Power System. Excitation System Control in synchronous generators, Automatic Voltage Regulators. Shunt Compensators, Static VAR compensators and STATCOMs. Tap Changing Transformers. Power flow control using embedded dc links, phase shifters.

UNIT 4: Monitoring and Control (6 hours)

Overview of Energy Control Centre Functions: SCADA systems. Phasor Measurement Units and WideArea Measurement Systems. State-estimation. System Security Assessment. Normal, Alert, Emergency, Extremis states of a Power System. Contingency Analysis. Preventive Control and Emergency Control.

UNIT 5: Power System Economics and Management (7 hours)

Basic Pricing Principles: Generator Cost Curves, Utility Functions, Power Exchanges, Spot Pricing. Electricity Market Models (Vertically Integrated, Purchasing Agency, Whole-sale competition, Retail Competition), Demand Side-management, Transmission and Distributions charges, Ancillary Services. Regulatory framework.

Text/References:

1. J. Grainger and W. D. Stevenson, "Power System Analysis", McGraw Hill Education, 1994.
2. O. I. Elgerd, "Electric Energy Systems Theory", McGraw Hill Education, 1995.
3. A. R. Bergen and V. Vittal, "Power System Analysis", Pearson Education Inc., 1999.
4. D. P. Kothari and I. J. Nagrath, "Modern Power System Analysis", McGraw Hill Education, 2003.

5. B. M. Weedy, B. J. Cory, N. Jenkins, J. Ekanayake and G. Strbac, "Electric Power Systems", Wiley, 2012.

Lectures/Demonstrations:

1. Principle, Working and Construction of PMMC, MI, Electrodynamometer type analog instruments.
2. Concepts relating to Measurements: True value, Accuracy, Precision, Resolution, Drift, Hysteresis, Dead-band, Sensitivity.
3. Errors in Measurements. Basic statistical analysis applied to measurements: Mean, Standard Deviation, Six-sigma estimation, Cp, Cpk.
4. Sensors and Transducers for physical parameters: temperature, pressure, torque, humidity, flow, speed and position Sensors.
5. Current and Voltage Measurements. Shunts, Potential Dividers. Instrument Transformers, Hall Sensors.
6. Measurements of R, L and C using D.C and A.C Bridges
7. Digital Multi-meter, True RMS meters, Clamp-on meters, Meggers.
8. Digital Storage Oscilloscope.

Experiments

1. Measurement of a batch of resistors and estimating statistical parameters.
2. Measurement of L using a bridge technique as well as LCR meter.
3. Measurement of C using a bridge technique as well as LCR meter. 4. Measurement of Low Resistance using Kelvin's double bridge.
5. Measurement of High resistance and Insulation resistance using Megger.
6. Usage of DSO for steady state periodic waveforms produced by a function generator. Selection of trigger source and trigger level, selection of time-scale and voltage scale. Bandwidth of measurement and sampling rate.
7. Download of one-cycle data of a periodic waveform from a DSO and use values to compute the RMS values using a C program.
8. Usage of DSO to capture transients like a step change in R-L-C circuit. Current Measurement using Shunt, CT, and Hall Sensor.

EE 321	Electronics Design Laboratory	1L:0T:2P	3 credits
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Course Outcomes:

At the end of the course, students will demonstrate the ability to

- Understand the practical issues related to practical implementation of applications using electronic circuits.
- Choose appropriate components, software and hardware platforms.
- Design a Printed Circuit Board, get it made and populate/solder it with components.
- Work as a team with other students to implement an application.

Basic concepts on measurements; Noise in electronic systems; Sensors and signal conditioning circuits; Introduction to electronic instrumentation and PC based data acquisition; Electronic system design, Analog system design, Interfacing of analog and digital systems, Embedded systems, Electronic system design employing microcontrollers, CPLDs, and FPGAs, PCB design and layout; System assembly considerations. Group projects involving electronic hardware (Analog, Digital, mixed signal) leading to implementation of an application.

Text/Reference Books

1. A. S. Sedra and K. C. Smith, "Microelectronic circuits", Oxford University Press, 2007.
2. P. Horowitz and W. Hill, "The Art of Electronics", Cambridge University Press, 1997.
3. H.W.Ott, "Noise Reduction Techniques in Electronic Systems", Wiley, 1989.
4. W.C. Bosshart, "Printed Circuit Boards: Design and Technology", Tata McGraw Hill, 1983.
5. G.L. Ginsberg, "Printed Circuit Design", McGraw Hill, 1991.

EE 323	Line-Commutated and Active PWM Rectifiers	3L:0T:0P	3 credits
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Analyse controlled rectifier circuits.
- Understand the operation of line-commutated rectifiers – 6 pulse and multi-pulse configurations.
- Understand the operation of PWM rectifiers – operation in rectification and regeneration modes and lagging, leading and unity power factor mode.

UNIT 1: Diode rectifiers with passive filtering (6 Hours)

Half-wave diode rectifier with RL and RC loads; 1-phase full-wave diode rectifier with L, C and LC filter; 3-phase diode rectifier with L, C and LC filter; continuous and discontinuous conduction, input current waveshape, effect of source inductance; commutation overlap.

UNIT 2: Thyristor rectifiers with passive filtering (6 Hours)

Half-wave thyristor rectifier with RL and RC loads; 1-phase thyristor rectifier with L and LC filter; 3-phase thyristor rectifier with L and LC filter; continuous and discontinuous conduction, input current waveshape.

UNIT 3: Multi-Pulse converter (6 Lectures)

Review of transformer phase shifting, generation of 6-phase ac voltage from 3-phase ac, 6-pulse converter and 12-pulse converters with inductive loads, steady state analysis, commutation overlap, notches during commutation.

UNIT 4: Single-phase ac-dc single-switch boost converter (6 Hours)

Review of dc-dc boost converter, power circuit of single-switch ac-dc converter, steady state analysis, unity power factor operation, closed-loop control structure.

UNIT 5: Ac-dc bidirectional boost converter (6 Hours)

Review of 1-phase inverter and 3-phase inverter, power circuits of 1-phase and 3-phase ac-dc boost converter, steady state analysis, operation at leading, lagging and unity power factors. Rectification and regenerating modes. Phasor diagrams, closed-loop control structure.

UNIT 6: Isolated single-phase ac-dc flyback converter (10 Hours)

Dc-dc flyback converter, output voltage as a function of duty ratio and transformer turns ratio. Power circuit of ac-dc flyback converter, steady state analysis, unity power factor operation, closed loop control structure.

Text / References:

1. G. De, "Principles of Thyristorised Converters", Oxford & IBH Publishing Co, 1988.
2. J.G. Kassakian, M. F. Schlecht and G. C. Verghese, "Principles of Power Electronics", Addison-Wesley, 1991.
3. L. Umanand, "Power Electronics: Essentials and Applications", Wiley India, 2009.
4. N. Mohan and T. M. Undeland, "Power Electronics: Converters, Applications and Design", John Wiley & Sons, 2007.

R. W. Erickson and D. Maksimovic, "Fundamentals of Power Electronics", Springer Science & Business Media, 2001.

EE 324 Electrical Drives: 3 0 0 3 3

Aim: The course discusses introductory topics in electrical drives for the UG level students of electrical engineering

Objectives:

- To learn the characteristics of dc motor and induction motor drives
- To study about the speed control of DC motor and Induction motor drives.
- To study the various power electronic converters used in DC motor and Induction motor drives and their control techniques.

UNIT I: DC motor Characteristics: (5 hours)

Review of emf and torque equations of DC machine, review of torque-speed characteristics of separately excited dc motor, change in torque-speed curve with armature voltage, example load torque-speed characteristics, operating point, armature voltage control for varying motor speed, flux weakening for high speed operation.

UNIT II: Chopper fed DC drive (5 hours)

Review of dc chopper and duty ratio control, chopper fed dc motor for speed control, steady state operation of a chopper fed drive, armature current waveform and ripple, calculation of losses in dc motor and chopper, efficiency of dc drive, smooth starting.

UNIT III: Multi-quadrant DC drive (6 hours)

Review of motoring and generating modes operation of a separately excited dc machine, four quadrant operation of dc machine; single-quadrant, two-quadrant and four-quadrant choppers; steady-state operation of multi-quadrant chopper fed dc drive, regenerative braking.

UNIT I V: Closed-loop control of DC Drive (6 hours)

Control structure of DC drive, inner current loop and outer speed loop, dynamic model of dc motor – dynamic equations and transfer functions, modeling of chopper as gain with switching delay, plant transfer function, for controller design, current controller specification and design, speed controller specification and design.

UNIT IV: Induction motor characteristics (6 hours)

Review of induction motor equivalent circuit and torque-speed characteristic, variation of torque-speed curve with (i) applied voltage, (ii) applied frequency and (iii) applied voltage and frequency, typical torque-speed curves of fan and pump loads, operating point, constant flux operation, flux weakening operation.

UNIT VI: Scalar control or constant V/f control of induction motor (6 hours)

Review of three-phase voltage source inverter, generation of three-phase PWM signals, sinusoidal modulation, space vector theory, conventional space vector modulation; constant V/f control of induction motor, steady-state performance analysis based on equivalent circuit, speed drop with loading, slip regulation.

UNIT VII: Control of slip ring induction motor (6 hours)

Impact of rotor resistance of the induction motor torque-speed curve, operation of slip-ring induction motor with external rotor resistance, starting torque, power electronic based rotor side control of slip ring motor, slip power recovery.

TEXT BOOKS:

1. N. Mohan, Power Electronics – Converters, Applications and Design, 3/e, John Wiley & Sons, 2003.
2. P. C. Sen, “Power Electronics” Tata McGraw Hill Book Co., New Delhi.
3. G. K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 2003.
4. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control”, Prentice Hall, 2001.
5. W. Leonhard, “Control of Electric Drives”, Springer Science & Business Media, 2001.

REFERENCES:

1. Muhammad Rashid, Power Electronics- Circuits, Devices and Applications, 3/e, Prentice Hall, 2004.
2. B. K. Bose, Modern Power Electronics and AC Drives, Pearson Education, 2003.

Aim: To acquaint the students with the knowledge of performing load flow studies, fault analysis and voltage stability analysis in power systems.

Objectives:

- To learn the Z-bus and Y-bus formulation.
- Learning to perform AC power flow analysis.
- To perform fault calculations and contingency analysis.
- To learn the concepts of steady state and Transient analysis.

The topics included in this course are:

UNIT I: Formulation of Network matrix: Primitive network, bus incidence matrix, formation of Y-bus by singular transformation, networks with mutually coupled elements, formation of Z-bus by matrix inversion, formation of Z-bus using the building algorithm – addition of a tree branch p to reference bus, addition of a link between buses p and q, addition of a link between bus p and reference bus .

UNIT II: AC Power Flow Analysis: Introduction, Modeling of Power System Components, Power Flow Equations, Power Flow Solution Algorithms, Gauss Seidel Load Flow Method, Newton Raphson Load Flow Method, Fast Decoupled Load Flow Method And DC Load Flow Method, ACDC System Power Flow Analysis - Sequential and Simultaneous Solution Algorithms, Overview of SCADA system.

UNIT III: Fault Calculation: Fault calculation using Z-bus and Y-bus, Symmetrical and Asymmetrical Faults, Short Circuit Analysis of Large Power Systems using Z-bus, Analysis of Open Circuit faults.

UNIT IV: Stability Analysis: Classification of Power System Stability, Classical Model of Synchronous Machines and Excitation System, Automatic regulation, Transient Stability Analysis of Multi-Machine Systems, Power-angle curve, Steady-state and transient Stabilities, Equal area criterion, Calculation of power-angle curves for fault and post – fault conditions for various types of fault, effect of reclosing, Small Signal Stability Analysis using Classical Model, Basic Concepts of Voltage Stability Analysis, Factors affecting stability.

UNIT V: Reactive Power Compensation and Control: Methods of voltage control, power flow in a transmission line, VAR compensation, reactive power injection and control, receiving-end and sending-end power circle diagrams, universal power circle diagram, load compensation – power factor correction, improving voltage regulation and balancing of load, passive compensators, Flexible AC Transmission (FACTS) devices, classification, series, shunt and series-shunt controllers.

COMPUTER AIDED POWER SYSTEMS ANALYSIS LABORATORY

1. Formulation of Z-bus & Y-bus matrix in MATLAB.
2. Implementation of Gauss Seidel Load Flow Method in MATLAB.
3. Implementation of Newton Raphson Load Flow Method in MATLAB.
4. Fault calculation using Z-bus and Y-bus in MATLAB.
5. Modelling of Synchronous Machines and Excitation System.

TEXT BOOKS

1. George Kusic, "Computer-Aided Power Systems Analysis" CRC Press, 2nd Edition, 2008
2. Ramasamy Natarajan, "Computer-Aided Power System Analysis", CRC Press, 2002
3. G.W.Stagg and A.H.El-Abiad, "Computer Methods in Power System Analysis", McGraw Hill 1968.

REFERENCE BOOKS

1. *A.R. Bergen and Vijay Vittal, "Power Systems Analysis", Pearson Education Asia, 2001.*
2. *J.J. Grainger and W.D. Stevenson, "Power System Analysis", McGraw-Hill, New York, 1994.*
3. *N. G. Hingorani and L. Gyugyi, "Understanding FACTS", Wiley 2000.*

Aim: The course discusses advanced topics in power electronics and drives for the UG level students of electrical engineering

Objectives:

- To study the power electronic converters for drive systems
- To study the modeling of DC machines
- To study the control of DC motor drives- phase and chopper control techniques
- To study the control of Induction motor drives
- To study the PMSM and BLDC motor drives and their control techniques
- To learn about expert systems, Fuzzy logic and Neural Networks for control of power electronic drives.

The topics included in this course are:

UNIT I: Power Electronic Converters for Drives: Development of Power Electronic converters and its application to drive technology, control of amplitude, converters for ac variable frequency drives, switch applications technology.

UNIT II: Modeling of DC Machines and Controlled DC Motor Drives:

Modeling of DC Machines: Theory of Operation, Induced emf, Equivalent circuit and Electromagnetic Torque, State space modeling, block diagram and transfer functions, field excitation- separately excited, shunt excited and series excited compound machine and PMDC machine, measurement of motor constants.

Controlled DC Motor Drives: Principle of dc motor speed control, phase controlled converters, steady state analysis of three phase converter controlled dc motor drive, two quadrant and four quadrant operation of dc motor drives, Harmonics and associated problems. Principle of operation of chopper, four quadrant chopper circuit, steady state analysis of chopper controlled dc motor drive, pulsating torques, closed loop operation.

UNIT III: Controlled Induction Motor Drives: Introduction, Stator voltage control, slip-energy recovery scheme. Static frequency changers, Voltage source inverters, VSI driven Induction motor, Constant V/f control, Constant slip-speed control, air-gap-flux control, Torque pulsations and harmonics, CS Induction motor drives.

UNIT IV: Permanent Magnet, Synchronous and Brushless dc motor drives:

Synchronous machines with PM, vector control of PMSM, control strategies, speedcontroller design, sensorless control, PMBDCM-modeling, half-wave PMBDCM drives, sensorless control of PMBDCM drives, torque smoothing, design of speed controllers.

UNIT V: Expert system, Fuzzy logic and Neural Networks in Power Electronics and Drives: Expert systems- principles, knowledge, methodology and application in power electronics and drives, Fuzzy logic- Principle, control, modeling and estimation, design methodology and control implementation, application, Neural Network Principles, design methodology and implementation, application in power electronics and drives.

TEXT BOOKS

1. B.K. Bose, "Power Electronics and Variable Frequency Drives – Technology and Applications", IEEE Press, Standard Publisher Distributors, 2001.

2. R. Krishnan, "Electric Motor Drives- Modeling, Analysis and Control", 2001 Pearson Education

REFERENCE BOOKS

1. G.K. Dubey, S.R. Doradla, A. Joshi and R.M.K. Sinha, "Thyristorised Power Controllers", New Age International Private Limited., 2008.
2. M. Rashid, "Power Electronics- Circuits, Devices and Applications", 3rd Ed., Pearson Education, 2008.
3. N. Mohan, T.M. Underland and W.P. Robbins, "Power Electronics - Converters, Applications and Design", 3rd Ed., Wiley India. 2008.

EE 413	Wind and Solar Energy Systems	3L:0T:0P	3 credits
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the energy scenario and the consequent growth of the power generation from renewable energy sources.
- Understand the basic physics of wind and solar power generation.
- Understand the power electronic interfaces for wind and solar generation.
- Understand the issues related to the grid-integration of solar and wind energy systems.

UNIT 1: Physics of Wind Power: (5 Hours)

History of wind power, Indian and Global statistics, Wind physics, Betz limit, Tip speed ratio, stall and pitch control, Wind speed statistics-probability distributions, Wind speed and power-cumulative distribution functions.

UNIT 2: Wind generator topologies: (12 Hours)

Review of modern wind turbine technologies, Fixed and Variable speed wind turbines, Induction Generators, Doubly-Fed Induction Generators and their characteristics, Permanent-Magnet Synchronous Generators, Power electronics converters. Generator-Converter configurations, Converter Control.

UNIT 3: The Solar Resource: (3 Hours)

Introduction, solar radiation spectra, solar geometry, Earth Sun angles, observer Sun angles, solar day length, Estimation of solar energy availability.

UNIT 4: Solar photovoltaic: (8 Hours)

Technologies-Amorphous, monocrystalline, polycrystalline; V-I characteristics of a PV cell, PV module, array, Power Electronic Converters for Solar Systems, Maximum Power Point Tracking (MPPT) algorithms. Converter Control.

UNIT 5: Network Integration Issues: (8 Hours)

Overview of grid code technical requirements. Fault ride-through for wind farms - real and reactive power regulation, voltage and frequency operating limits, solar PV and wind farm behavior during grid disturbances. Power quality issues. Power system interconnection experiences in the world. Hybrid and isolated operations of solar PV and wind systems.

UNIT 6: Solar thermal power generation: (3 Hours)

Technologies, Parabolic trough, central receivers, parabolic dish, Fresnel, solar pond, elementary analysis

Text / References:

1. T. Ackermann, "Wind Power in Power Systems", John Wiley and Sons Ltd., 2005.
2. G. M. Masters, "Renewable and Efficient Electric Power Systems", John Wiley and Sons, 2004.
3. S. P. Sukhatme, "Solar Energy: Principles of Thermal Collection and Storage", McGraw Hill, 1984.
4. H. Siegfried and R. Waddington, "Grid integration of wind energy conversion systems" John Wiley and Sons Ltd., 2006.
5. G. N. Tiwari and M. K. Ghosal, "Renewable Energy Applications", Narosa Publications, 2004.
6. J. A. Duffie and W. A. Beckman, "Solar Engineering of Thermal Processes", John Wiley & Sons, 1991

EE 417	Power Quality and FACTS	3L:0T:0P	3 credits
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

Understand the characteristics of ac transmission and the effect of shunt and series reactive compensation.

Understand the working principles of FACTS devices and their operating characteristics.

Understand the basic concepts of power quality.

Understand the working principles of devices to improve power quality.

UNIT 1: Transmission Lines and Series/Shunt Reactive Power Compensation (4 hours)

Basics of AC Transmission. Analysis of uncompensated AC transmission lines. Passive Reactive Power Compensation. Shunt and series compensation at the mid-point of an AC line. Comparison of Series and Shunt Compensation.

UNIT 2: Thyristor-based Flexible AC Transmission Controllers (FACTS) (6 hours)

Description and Characteristics of Thyristor-based FACTS devices: Static VAR Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Braking Resistor and Single Pole Single Throw (SPST) Switch. Configurations/Modes of Operation, Harmonics and control of SVC and TCSC. Fault Current Limiter.

UNIT 3: Voltage Source Converter based (FACTS) controllers (8 hours)

Voltage Source Converters (VSC): Six Pulse VSC, Multi-pulse and Multi-level Converters, PulseWidth Modulation for VSCs. Selective Harmonic Elimination, Sinusoidal PWM and Space Vector Modulation. STATCOM: Principle of Operation, Reactive Power Control: Type I and Type II controllers, Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC): Principle of Operation and Control. Working principle of Interphase Power Flow Controller. Other Devices: GTO Controlled Series Compensator. Fault Current Limiter.

UNIT 4: Application of FACTS (4 hours)

Application of FACTS devices for power-flow control and stability improvement. Simulation example of power swing damping in a single-machine infinite bus system using a TCSC. Simulation example of voltage regulation of transmission mid-point voltage using a STATCOM.

UNIT 5: Power Quality Problems in Distribution Systems (4 hours)

Power Quality problems in distribution systems: Transient and Steady state variations in voltage and frequency. Unbalance, Sags, Swells, Interruptions, Wave-form Distortions: harmonics, noise, notching, dc-offsets, fluctuations. Flicker and its measurement. Tolerance of Equipment: CBEMA curve.

UNIT 6: DSTATCOM (8 hours)

Reactive Power Compensation, Harmonics and Unbalance mitigation in Distribution Systems using DSTATCOM and Shunt Active Filters. Synchronous Reference Frame Extraction of Reference Currents. Current Control Techniques in for DSTATCOM.

UNIT 6: Dynamic Voltage Restorer and Unified Power Quality Conditioner (6 hours)

Voltage Sag/Swell mitigation: Dynamic Voltage Restorer – Working Principle and Control Strategies. Series Active Filtering. Unified Power Quality Conditioner (UPQC): Working Principle. Capabilities and Control Strategies.

Text/References

1. N. G. Hingorani and L. Gyugyi, "Understanding FACTS: Concepts and Technology of FACTS Systems", Wiley -IEEE Press, 1999.
2. K. R. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International (P) Ltd. 2007.
3. T. J. E. Miller, "Reactive Power Control in Electric Systems", John Wiley and Sons, New York, 1983.
4. R. C. Dugan, "Electrical Power Systems Quality", McGraw Hill Education, 2012.
5. G. T. Heydt, "Electric Power Quality", Stars in a Circle Publications, 1991

EE 418	Power System Dynamics and Control	3L:0T:0P	3 credits
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Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the problem of power system stability and its impact on the system.
- Analyse linear dynamical systems and use of numerical integration methods.
- Model different power system components for the study of stability.
- Understand the methods to improve stability.

UNIT 1: Introduction to Power System Operations (3 hours)

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

UNIT 2 : Analysis of Linear Dynamical System and Numerical Methods (5 hours) 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.

UNIT3 : Modeling of Synchronous Machines and Associated Controllers (12 hours)

Modeling 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.

UNIT4 : Modeling of other Power System Components (10 hours)

Modeling of Transmission Lines and Loads. Transmission Line Physical Characteristics. Transmission Line Modeling. Load Models - induction machine model. Frequency and Voltage Dependence of Loads. Other Subsystems – HVDC and FACTS controllers, Wind Energy Systems.

UNIT5 : Stability Analysis (11 hours)

Angular stability analysis in Single Machine Infinite Bus System. Angular Stability in multi-machine 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.

UNIT6 : Enhancing System Stability (4 hours)

Planning Measures. Stabilizing Controllers (Power System Stabilizers). Operational Measures Preventive Control. Emergency Control

Text/Reference 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

EE 420	Project Work II & Dissertation	0L:0T:10P	10 credits
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The object of Project Work II & Dissertation is to enable the student to extend further the investigative study taken up under EC P1, either fully theoretical/practical or involving both theoretical and practical work, under the guidance of a Supervisor from the Department alone or jointly with a Supervisor drawn from R&D laboratory/Industry. This is expected to provide a good training for the student(s) in R&D work and technical leadership. The assignment to normally include:

1. In depth study of the topic assigned in the light of the Report prepared under EEP1;
2. Review and finalization of the Approach to the Problem relating to the assigned topic;
3. Preparing an Action Plan for conducting the investigation, including team work;
4. Detailed Analysis/Modelling/Simulation/Design/Problem Solving/Experiment as needed;
5. Final development of product/process, testing, results, conclusions and future directions;
6. Preparing a paper for Conference presentation/Publication in Journals, if possible; 7. Preparing a Dissertation in the standard format for being evaluated by the Department. Final Seminar Presentation before a Departmental Committee