National Institute of Technology Raipur												
Course of Study and Scheme of Examination							B. Tech. 6th Semester				Branch:Electrical	
S. No.	Subject Code	Subject Name	Periods per Week			TA	Examination Scheme				Total Marks	Credits
			L	T	P		MSE/MTR		ESE/ESVE			
							Theory	Prac.	Theory	Prac.		
1	EL106101EL	Power System Protection & Switchgear	3	1	0	20	30		50		100	4
2	EL106102EL	High Voltage Engineering	3	1	0	20	30		50		100	4
3	EL106103EL	Electrical Machines-III	3	1	0	20	30		50		100	4
4	Program Elective (EXX2)		3	0	0	20	30		50		100	3
5	Program Elective (EXX3)		3	0	0	20	30		50		100	3
6	Open Elective (0XX2)		3	0	0	20	30		50		100	3
7	EL106401EL	Power System Protection & Switchgear Labortory	0	0	2	40		20		40	100	1
8	EL106402EL	High Voltage Engineering Labortory	0	0	2	40		20		40	100	1

Subject Code	Program Elective (EXX2)
EL106201EL	Advanced Digital Signal Processors for Power Application
EL106202EL	Simulation and Modeling of Electrical Systems
EL106203EL	Advanced Instrumentation
EL106204EL	Power Quality
EL106205EL	System Modelling and Identification
EL106206EL	Extra High Voltage AC Transmission
Subject Code	**Program Elective (EXX3)**
EL106207EL	Process Control
EL106208EL	Advanced Control System
EL106209EL	Electrical Machine Design
EL106210EL	Advanced Electric Drives
EL106211EL	Power Converter Design
EL106212EL	Industrial Electronics
EL106213EL	Power System Dynamics
Subject Code	**Open Elective (0XX2)**
EL106301EL	Design of Photovoltaic Systems
EL106302EL	Building Energy Management Systems
EL106303EL	Advanced Digital Signal Processing
EL106304EL	Basics of Electrical Machines
EL106305EL	Design and integration of optical sensors in mechatronic systems
EL106306EL	Introduction to Hybrid and Electric Vehicles

Power System Protection & Switchgear

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-1-0, (4)	Program Core	EL106101EL

[Pre-requisites: Electrical Power System (EL103105EL), Power System Analysis (EL105103EL)]

Course Objectives

1. Comprehensive exposure to philosophy and technology of protection.
2. To provide the students with a broad understanding of evolution process of different generation of protection system.
3. To provide the students with a broad understanding of development of numerical protection techniques.
4. To provide the students with a broad understanding of protection philosophy of different equipment.
5. To provide the students with a broad understanding of protection philosophy of different interconnected power system
6. Introduction to switchgear

Course Content

Unit 1 Protective Relays

Basic principle, Basic need of protective system, Features, Types of fault, Electromechanical relay, Static relay, Digital relay, Primary and backup protection, Zones of protection, Sequence component analysis, Broad classification of relaying system, Adaptive relaying, Current and Potential transformer.

Unit 2 Numerical Relay

Numerical relaying, Block diagram, Sampling, Anti-aliasing, Phasor estimation techniques, Frequency estimation.

Unit 3 Equipment Protection

Protection of alternator and transformer, Transmission line protection, Bus bar protection, Disturbance recorder, Relay coordination, Communication-based protection.

Unit 4 System Protection

Power swing, Out-of-step protection, Frequency relay, Load shedding, Wide Area Measurement System (WAMS), Phasor measurement unit, Concept of micro-grid and its protection system.

Unit 5 Circuit Breakers and Fuses

Arc formation, Arc interruption and Restriping voltage, Current chopping, Resistance switching, Air Blast Circuit Breakers, Minimum and bulk oil circuit breakers, SF_6 and Vacuum Circuit breakers, Circuit breakers rating, Testing of Circuit Breakers, Point on wave switching, Definitions of terms in fuses, HRC fuses.

Course Materials

Required Text: Textbooks

1. Mason C. R., "The Art and Science of Protective Relaying", Wiley Eastern Limited.
2. B. Ravindranath, M Chander, "Power System Protection and Switchgear", New Age International Publishers, Second edition, 2018.
3. Van A. R., Warrington C., " Protective Relays Their Theory & Practice ", Springer / BSP Books, 2019.
4. Y. G. Paithankar, S.R. Bhide, "Fundamentals of Power System Protection", Prentice Hall India Learning Private Limited, 2nd edition, 2010.

Optional Materials: Reference Books

1. Badri Ram, D. Vishwakarma, "Power System Protection", McGraw Hill Education, 2nd edition, 2017.
2. J. L. Blackburn, Thomas J. Domin, "Protective Relaying: Principles and Applications", CRC Press, 4th edition, 2014.
3. A.G. Phadke and J.S. Thorp, "Computer Relaying for Power Systems", Wiley India Pvt. Ltd., Second edition, 2012.

Course Outcomes:

Students are able to:

1. Appreciate the philosophy of protective relaying.
2. Apply over current protection to various power system elements.
3. Understand differential protection for transformer, bus bar and motor protection
4. Apply Distance Protection (Carrier and non-carrier) for EHV Lines
5. Comprehend switching phenomenon and the working of various types of circuit breakers and their duties.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	2		1				1	2
CO2	3	3	3	3	3		1				1	2
CO3	3	3	3	3	3		1				1	2
CO4	3	3	3	3	3		1				1	2
CO5	3	3	3	3	3		1				1	2

High Voltage Engineering

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-1-0, (4)	Program Core	EL106102EL

[Pre-requisites: Electrical Machines – II (EL105102EL), Electrical Power System (EL103105EL)]

Course Objectives

1. To provide strong knowledge on different types of electrical stresses on power system and equipment.
2. To gain in-depth knowledge on behavior of dielectrics under Static and alternating fields.
3. To impart knowledge on generation of high AC and DC voltages.
4. To expose the different techniques of measuring High voltages AC, DC, and impulse.
5. To acquire knowledge on the different types of testing as per IS/IEC/IEEE standards.

Course Content

Unit 1 Breakdown in Gases

Gases as insulating media, Ionization processes, Electron avalanche, Townsend's criterion for breakdown, Streamer theory of breakdown, Gaseous discharge in uniform field, Paschen's law, Breakdown in non-uniform field, Corona discharges, Effect of polarity of DC on breakdown voltage.

Unit 2 Dielectrics

Liquid Dielectrics-conduction & breakdown in pure liquids and commercial liquids, Methods for determination of breakdown strength, Factors affecting dielectric strength of liquids. Solid Dielectrics-Breakdown mechanism, Intrinsic breakdown, Electromechanical breakdown, Thermal breakdown, Breakdown of solid dielectric in practice, Breakdown due to treeing & tracking, Breakdown due to the internal discharges.

Unit 3 Generation of High Voltages

Generation of high D.C. voltages, Half wave & Full wave rectifier circuits, Voltage doublers and multiplier circuits Van De Graff generators, Electro-static Generators, Generation of high alternating voltages, Cascade transformers, Resonant transformer, Generation of impulse voltages, Standard impulse wave shapes, Analysis of model, Multistage Impulse generator, Marx circuit, Tripping & control of Impulse generators.

Unit 4 Measurement of high Voltages

Measurement of high AC and DC voltages by micro ammeter, Series Impedance voltmeter, Series capacitance voltmeter, Capacitance potential dividers & Capacitance voltage transformers, Resistance potential dividers, Generating voltmeters, Electrostatic voltmeter, Spark gap for measurement of high D.C., A.C. & Impulse voltages, Potential divider for impulse voltage measurements, CRO for impulse voltage measurements, Rogowski coils-Hall effect generators.

Unit 5 High Voltage Testing of Electrical Apparatus

Laboratory test procedures, Test on insulators, Dry & wet flash over tests & withstand tests with impulse and A.C, Testing of circuit breakers, Bushings and surge diverters, High voltage tests on cables, Impulse testing of transformers. Non-destructive Testing-Measurement of dielectric constant & loss factor, High voltage Schering Bridge, Partial Discharge Measurements.

Course Materials

Required Text: Textbooks

1. M.S. Naidu, V. Kamraju, "High Voltage Engineering", McGraw Hill Education, Fifth edition, 2017.
2. Kuffel E., Zaengl W.S., Kuffel J., "High Voltage Engineering Fundamentals", Elsevier, Second edition, 2008.

Optional Materials: Reference Books

1. Ravindra Arora, Bharat Singh Rajpurohit, "Fundamentals of High-Voltage Engineering", Wiley, 2019.
2. Wadhawa, C.L., "High Voltage Engineering" New Age, Third edition, 2012.
3. R. D. Begamudre, "Extra High Voltage A.C. Transmission Engineering", New Academic Science Ltd., 4th edition, 2011.

Course Outcomes:

After the completion of the course the student will be able to:

1. Understand high voltage breakdown phenomena in insulating materials.
2. Know the methods to generate different high voltages ac, dc and impulse.
3. Know the measurement of high voltages.
4. Analyze the test procedures as per the standards.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	1	1	2	1	2
CO2	3	3	3	3	3	3	3	1	1	2	1	2
CO3	3	3	3	3	3	3	3	1	1	2	1	2
CO4	3	3	3	3	3	3	3	1	1	2	1	2

Electrical Machines-III [6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-1-0, (4)	Program Core	EL106103EL

[Pre-requisites: Electrical Machines-II (EL105102EL)]

Course Objectives

1. To understand the thoery of ideal synchronous and induction machines.
2. To introduce to the fraction horsepower, commutator and special motors.

Course Content

Unit 1

Theory of Ideal Synchronous Machines

The ideal synchronous machine, Synchronous machine inductances, Transformation to direct and quadrature axis variables, Basic machine relation in dqo variables, Steady state analysis using dq0, Transient analysis, Three-phase short circuit, Transient power angle characteristics, Effect of additional rotor circuits.

UNIT 2

Theory of Ideal Poly-Phase Induction Machines

The ideal induction machine, Transformation to dq variables, Basic machine relation in dq variables, Steady state analysis using dq0, Electrical transients in induction machine, Single phasing of three-phase induction motor, Power invariance.

UNIT 3

Fractional Horsepower Motor

Qualitative examination, Starting and running performance ofsingle-phase induction motor, Revolving field theory of single-phase induction motor, AC tachometer, Unbalanced operation of symmetrical two-phase machine, The symmetrical component concept, Two-phase control motors.

UNIT4

AC Commutator Motors

Rotational EMFs in commutator windings, Action of commutator as frequency converter, Effect of EMF injection in secondary circuit of three-phase slip-ring induction motor, Secondary (slip) power, Constant HP and constant torque drives, Kramer and Scherbius system of speed control, Single-phase series motors, Universal motors, Phasor diagrams, Methods of improving commutation.

UNIT 5

Special Motors

Hysteresis motor, Reluctance motor, Stepper motor, Synchros and linear induction motor, Permanent magnet brushless DC motor.

Course Materials

Required Text: Textbooks

1. A. Fitzgerald, Charles Kingsley, Stephen Umans,"Electric machinery", McGrawHill Companies; 6th edition, 2003.
2. E. Openshaw Taylor, "The performance and design of A.C. commutator motors", Wheeler.

Optional Materials: Reference Books

1. P.S.Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers.
2. Edward Wilson Kimbark, "Power System StabilityVol I, II, III", Wiley, 2007.
3. Bernard Adkins,"General Theory of Electrical Machines", Chapman and Hall.
4. M.G. Say, "The Performance and Design of Alternating Current Machines",CBS, 2002.

Course Oucomes (COs)

1. Student can understand the theory of ideal synchronous machines and, basic machine relation.
2. Student would be able to understand the steady state analysis and electrical transients in polyphase machines.
3. Student would be able to understand the starting and running performance of single phase induction motor and revolving field theory.
4. Student can analyse the various speed control system for AC motors.
5. Student can study the basic operation and performance of special machine.

Mapping of COs and POs

COs \ POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	1	2	3							2
CO2	3	2	3	3	3							1
CO3	2	2	1	1	3							2
CO4	2	1	1	1	3							2
CO5	3	2	1	1	3							2

Advanced Digital Signal Processors for Power Application

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical	3-0-0, (3)	Program Elective	EL106201EL

[Pre-requisites: Signals & Systems (EL104104EL)]

Course Objectives

To expose student with respect to DSP architecture and its assembly programming for its application in power sector.

- Learn about the basics of various digital signal processors architecture and their programing.
- To demonstrate the configuration of various peripherals of digital signal processors
- Introduce the concepts of FPGA programing

Course Content

Unit 1 TMSLF2407 DSP Controller

Brief Introduction to Peripherals - Types of Physical Memory - Software Tools; C2XX DSP CPU and instruction set: Introduction to the C2xx DSP Core and Code Generation - The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory - Memory Addressing Modes -Assembly Programming Using the C2xx DSP Instruction Set.

Unit 2 Data transfer, Interrupts and ADC

Parallel and Serial Data Transfer: Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports. Interrupt system of TMS320LF2407: Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software, real time control with interrupts. The analog-to-digital converter (ADC): ADC Overview - Operation of the ADC and programming modes.

Unit 3 Event Managers

Event Managers (EVA, EVB): Overview of the Event Manager (EV) - Event Manager Interrupts - General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry - General Event Manager Information - PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSP TMSLF2407A. Introduction to TMS320F28335 DSP Controller, Architecture, Peripherals and Interrupts.

Unit 4 Sequences and Series

Field Programmable Gate Arrays: Introduction to Field Programmable Gate Arrays, CPLD Vs FPGA, Types of FPGA, Configurable logic Blocks (CLB), Input/output Block (IOB) –Programmable Interconnect Point (PIP)- HDL programming –overview of Spartan 6 & ISE Design Suite, Implementation of PWM technique with SPARTAN-6 FPGA.

Course Materials

Required Text: Textbooks

1. Hamid A. Tolyat, "DSP based Electromechanical Motion Control", CRC press, 1st edition, 2019.
2. Wayne Wolf, "FPGA based system design", Pearson Education, 1st edition, 2005.

Optional Materials: Reference Books

1. Philip Andrew Simpson, "FPGA Design", Springer Nature, 2nd edition, 2015.
2. A. Arockia Bazil Raj, "FPGA-Based Embedded System Developer's Guide", CRC Press, 1st edition, 2018.
3. Application Notes from Texas Instruments.
4. Spartan-6 FPGA Configurable Logic.
5. Xilinx Spartan 6 Data sheets.

Course Outcomes

On completion of this course, the students will be able to:

- CO1 Understand the basic concepts architecture and their programing of digital signal processors.
- CO2 Analyze the operation of interruptus and ADC in digital signal processors
- CO3 Implement the concepts of DSP programing to develop PWM Signal Generation with Event Managers.
- CO4 Implement the concepts of FPGA programing to develop PWM techniques in FPGA

Mapping of COs and POs

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	Po12
CO1	3		2		3	-	-	-	-	-	1	1
CO2	3		3		3	-	-	-	-	-	1	1
CO3	3		3	3	3	-	-	-	-	-	2	1
CO4	3		3	3	3	-	-	-	-	-	2	1

Simulation and Modeling of Electrical Systems

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Program Elective	EL106202EL

[Pre-requisites: Basic Electrical Engineering (EL101022EL), Power Electronics (EL104103EL)]

Course Objectives

1. To expose student to understand the basics of simulation of electrical energy systems.
2. To analyze various DC-DC, AC-DC and DC-AC power converters through modeling and simulation.
3. To develop models for Energy storage systems and power converters with their controls.

Course Content

Unit-1 Modeling and simulation of Solar Photovoltaic Systems

Mathematical modeling of PV array, analysis of I-V and P-V characteristics of PV, modeling and simulation of different MPPT algorithm, open loop control and close loop control.

Unit-2 Review of DC-DC Converters

Steady-state analysis of converter in continuous and discontinuous modes (CCM & DCM), and estimation of converter efficiency, Development of circuit model for simulating dynamic operating conditions in CCM & DCM, Feedback control for converters

Unit-3 Review of AC/DC and DC/AC converters

Design and simulation of AC/DC Converter and DC/AC Converter, open and close loop control.

Unit-4 Battery Interfaces

Mathematical modeling of battery, design of bidirectional dc-dc converter, open loop and close loop control.

Course Materials Required

Text: Text books

1. R.W. Erickson, Dragan Maksimovic, Fundamentals of Power Electronics (2 e), Springer
2. Advanced Simulation of Alternative Energy, Viktor M. Perelmuter, CRC Press
3. Modeling and Simulation using MATLAB – Simulink, Dr. Shailendra Jain, Wiley

Optional Materials: Reference Books

1. Simulation of Power Electronics Converters Using PLECS, FarzinAsadi, Kei Eguchi Academic Press
2. Modeling, Simulation, and Control of a Medium-Scale Power System, Bambaravanage, Tharangika, Rodrigo, Asanka, Kumarawadu and Sisil, Springer
3. Guide to Modeling and Simulation of Systems of Systems, P. Zeigler Bernard, Springer

Course Outcomes:

On successful completion of the course the students will be able to:

1. Analyze various aspects related to solar PV system and its operation.
2. Design and analyze the DC-DC converters along with feedback control.
3. Design and analyze the AC-DC converters and DC-AC converters along with feedback control.
4. Design and analyze the bidirectional DC-DC converters along with the mathematical modeling of the battery.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3		3				2	3
CO2	3	3	3	3	3		2					3
CO3	3	3	3	3	3		2					3
CO4	3	3	3	3	3		2				2	3

Advanced Instrumentation

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0 (3)	Program Elective	EL106203EL

[Pre-requisites:Electrical Measurement and Instrumentation (EL103101EL)]

Course Objectives

To provide in depth knowledge of intelligent sensors, transducers, and other instrumentation tools.

Course Content

Unit-1Introduction, Instrumentation-Functional elements of an instrumentation system-Data acquisition systems-DAS; Sensors & transducers, emerging fields, types of sensors, their parameters.

Unit-2 Microelectronic and micro electro-mechanical systems, Primary sensing principles and measurement variables, Sensor performance characteristics and terminology. Transducer measurement circuits, Signal conditioning circuits, Sensor data acquirement. Basic principles of the acquirement and transmission of the data; Fibre-optic sensors-types, working, applications. Bio-medical Instrumentation; Selection of Transducers and Electrodes, Transmission, and reception aspects of Bio-Medical signals.

Unit-3Non-Destructive Testing-NDT tools-Ultrasonics-Pulse Echo method of Flaw detection,Eddy-current testingSignature analysis. Gas Chromatography. Nucleonic sensors & their applications. Intelligent Sensor Systems-Intelligent pressure, Flow, Level, Temperature Sensors, Intelligent sensor application in process control, Complex sensors, biometric sensors, Application of intelligent sensor in biomedical engineering

Unit-4 Future scope of intelligent instruments- Structure, definitions and concepts, Smart sensors, The future of intelligent sensor systems- Multimodal sensors for target recognition, subject tracking, and event understanding. Real World Interfacing – LCD, ADC, Sensors, Stepper motor, keyboard and DAC, USB interfacing, etc.IOT based instrumentation.

Course Materials

Required Text: Textbooks

1. I. R. Sinclair, Sensors and Transducers, John Wiley & Sons.
2. ALAN S. Morris, Principles of Measurement & Instrumentation. New Delhi, PHI Pvt. Ltd.

Optional Materials: Reference Books

1. J. R. Brauer, Magnetic Actuators and Sensors, Wiley-IEEE Press.
2. D. Patranabis, Sensors and Transducers, PHI, New Delhi
3. Barney, G.C., Intelligent instruments, HemelHempsteao: Prentice Hall.

Course Outcomes

On successful completion of the course students will be able to:

1. Demonstrate an understanding of basic concept of industrial instrumentation.
2. Elucidate knowledge of different types of sensors with their working.
3. Illustrate about intelligent instrumentation using smart sensors.
4. Apply the concept of intelligent instrumentation for solving real world problems.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2		1		1		1	1	2
CO2	3	3	3	3	1	1		1		1	1	3
CO3	3	3	3	3	1	1		1		1	2	3
CO4	3	3	3	3	1	1		1		1	2	3

Power Quality

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical	3-0-0, (3)	PE	EL106204EL

[Pre-requisites: Power System and Power Electronics]

Course Objectives

1. To develop understandings of power quality issues
2. To enhance the ability to find out the solutions for those power quality issues.
3. To impart knowledge of different power quality improvement methods

Course Content

Unit 1 Introduction

Power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DIN-C-message weights-flicker factor transient phenomena- occurrence of power quality problems-power acceptability curves-IEEE guides, standards and recommended practices.

UNIT 2 Harmonics

Individual and total harmonic distortion-RMS value of a harmonic waveform-triplex harmonics-important harmonic introducing devices-SMPS-Three phase power converters-arcing devices saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipment and loads. Modelling of networks and components under non-sinusoidal conditions transmission and distribution systems- shunt capacitors-transformers-electric machines-ground systems loads that cause power quality problems-power quality problems created by drives and its impact on drives.

UNIT 3 Power factor improvement

Passive Compensation. Passive Filtering. Harmonic Resonance. Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End, Control Methods for Single Phase APFC, Three Phase APFC and Control Techniques, PFC Based on Bilateral Single Phase and Three Phase Converter. Static VAR compensators-SVC and STATCOM.

UNIT 4 Active Harmonic Filtering

Shunt Injection Filter for single phase, three-phase three-wire and three-phase four-wire systems. d-q domain control of three phase shunt active filters uninterruptible power supplies constant voltage transformers- series active power filtering techniques for harmonic cancellation and isolation. Dynamic Voltage Restorers for sag , swell and flicker problems. Grounding and wiring introduction-NEC grounding requirements-reasons for grounding-typical grounding and wiring problems- solutions to grounding and wiring problems.

Course Materials

Required Text: Text books

1. G.T. Heydt, "Electric power quality", McGraw-Hill Professional, 2007.
2. Math H. Bollen, "Understanding Power Quality Problems : Voltage Sags and Interruptions", Wiley India Pvt. Ltd., 2011.
3. J. Arrillaga N.R. Watson, S. Chen, "Power System Quality Assessment", Wiley India Pvt. Ltd., 2011.
4. J. Arrillaga, B.C. Smith, N.R. Watson & A. R.Wood , "Power system Harmonic Analysis",1st Edition, Wiley India Exclusive (CBS), 2018.

Optional Materials: Reference Books

1. R.C. Dugan, Mark F Mcgranaghan, H Wayne Beaty, Surya Santoso, "Electrical Power Systems Quality", 3rd edition, Mc-Graw-Hill Education, 2017.
2. Derek A. Paice, Power Electronic Converter Harmonics : Multipulse Methods for Clean Power, 1st edition, Wiley-IEEE Press, 1999.
3. T J E Miller, Reactive Power Control In Electric Systems, Wiley India Pvt. Ltd, 2010.

Course Outcomes: After the completion of the course the student will be able to

1. Recall knowledge of various issues related to power quality.
2. Experiment with the significance of harmonics.
3. Analyse the performance of power factor improvement methods.
4. Design of harmonic minimization techniques.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	2	2	2	2	1	1		3
CO2	3	3	3	3	3	2	2	2	1	2		3
CO3	3	3	3	3	3	3	3	3	2	2	2	3
CO4	3	3	3	3	3	3	3	3	2	1	2	3

System Modelling and Identification

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	PE	EL106205EL

[Pre-requisites: Control System Engineering(EL105101EL)]

Course Objectives

Exposing the students to techniques for system identification and parameter estimation of dynamical systems

Unit I: System Modeling

Mathematical modelling of physical systems, Representation of Lumped and Distributed Systems, Transfer Function, State Space Modeling, Black-box modeling

Unit II: Introduction to System Identification

Parameter estimation using input-output data, Least squares algorithm, Generalized, weighted and recursive least squares. Precision of parameter estimates, Instrumental variable method, Autoregressive modelling (linear and nonlinear). Applications of system identification in Electrical Engineering

Unit III: Identification in time and frequency domain

Kalman filter, extended Kalman filter, LMS based adaptive filter, Likelihood functions and maximum likelihood estimation (MLE); Singular value decomposition (SVD); Order and structure determination, Yule-Walker equation; Multi-variable system representation, controllability and observability indices

Unit IV: Nonlinear system identification

Use of optimization techniques in parameter estimation and system identification, Nonlinear system identification using soft computing techniques. Course Materials

Required Text: Text books

1.L Ljung, System Identification: Theory for the user, Prentice Hall, 1995.
2.O. Nellles, Nonliner System Identification, From classical approaches to neural networks and fuzzy models, Springer, 2001.
3.R. Pintelon and J. Schoukens, System Identification, A Frequency Domain Approach, Wiley-IEEE press, 2012

Course Outcomes(CO)

1. Apply fundamental laws and principles to mathematically model dynamic systems in both time and frequency domain
2. Estimate model parameters from the input-output experimental data.
3. Develop state space equations and transfer function for SISO and MIMO systems.
4. Identify nonlinear systems using optimization and soft-computing techniques

Mapping and Correlation of COs with POs

	PO1	PO2	PO3	PO4	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3									1
CO2	3	3	3	3	3								1
CO3	3	3	3										1
CO4	3	3	3										1

Extra High Voltage AC Transmission

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Program Elective	EL106206EL

[Pre-requisites: Electrical Power System (EL103105EL)]

Course Objectives

1. To understand the basic concepts of EHV AC transmission system.
2. To calculate Line inductance, capacitances, and voltage gradient of bundled conductors.
3. To identify corona effects on transmission line and understand the effect of Radio Interference.
4. To analyze the electrostatic field, travelling waves on EHV transmission system.
5. To understand and compute the induced over voltages due to lightning and switching signals.

Course Content

UNIT-I EHV Trends and Preliminaries

Overview of Electrical power transmission at high voltages, Standard Transmission Voltages, Average Values of Line Parameters, Power-Handling Capacity and Line Loss, Mechanical Considerations in Line Performance, Generation of high voltage AC, impulse voltage.

UNIT-II EHV Line parameters

EHV line conductor resistance, Temperature Rise of Conductors and Current-Carrying Capacity, Bundled Conductors, Inductance, and capacitance calculations of EHV line and multiconductor configurations, sequence inductance and capacitance.

UNIT-III Corona Effects

Power loss, Corona-Loss Formula, q–V Diagram and Corona Loss, Travelling Waves Attenuation due to corona, Audible Noise limits and measurements, Single-Phase and 3-Phase AN Levels, Corona Pulses Generation and Properties, Frequency Spectrum, modes of propagation – excitation function – measurement of RI, RIV and excitation functions.

UNIT-IV Electrostatic field and Theory of Travelling Waves

Electrostatic field of EHV/AC lines – effect on humans, animals and plants – electrostatic induction in unenergized circuit of double-circuit line – electromagnetic interference, Traveling wave expression and solution- source of excitation. Terminal conditions- open circuited and short-circuited end- reflection and refraction coefficients-Lumped parameters of distributed lines-generalized constants-No load voltage conditions and charging current.

UNIT-V Lightning and switching surges on EHV line

Lightning Strokes to Lines, Stroke Mechanism, Lightning Protection Problem, Tower-Footing Resistance, Insulation Coordination Based on Lightning, Switching Surges Calculation, Reduction of Switching Surge Overvoltage.

Course Materials

Required Text: Textbooks

1. Extra High Voltage AC Transmission Engineering by R.D. Begamudre, New age international, 2006.
2. High Voltage Engineering by M. S. Naidu, and V. Kamaraju, McGraw-Hill, 2013.
3. HVAC and DC Transmission by S. Rao, Khanna Publishers, 2012.

Course Outcomes: After successful completion of the course, the students will be able to

1. Understand the generation and transmission of EHV AC.
2. Understand various phenomenon associated with EHV lines.
3. Analyze the corona effect and methods, its causes and remedies on EHV lines.
4. Understand the generation and effect of travelling waves.
5. Understand the protection of EHV lines against various abnormal conditions.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	2							3
CO2	3	3	3	3	2		2					3
CO3	3	3	3	2		2	2					3
CO4	3	3	2	3		2						3
CO5	3	3	3	2	3							3

Process Control

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical	3-0-0, (3)	Program Elective	EL106207EL

[Pre-requisites: Control System Engineering (EL105101EL)]

Course Objectives

1. To understand the various process and their control in industries.
2. To develop the knowledge of advanced control strategies with their applications.

Course Content

Unit 1 Process control introduction

Process variables, Signs & Symbols used in Process industries, classification of variables, Process Characteristics, Constraints in implementation of process control, terms used in process control, process measurement, Comparison of P, I, D, PI, PD, & PID controllers.

Unit 2 Generation of control action in electronic and pneumatic controllers

Control valves, valve positioner, relief and safety valves, relays, volume boosters, pneumatic transmitters for process variable, Tuning of controllers–Zeigler Nichols and other techniques.

Unit 3 Different control techniques and interaction of process parameters

Feed forward, cascade, ratio, override controls, batch continuous process controls, Feed forward Control scheme.

Unit 4 Various process schemes / unit operations and their control schemes

Distillation columns, absorbers, heat exchangers, furnaces, reactors, mineral processing industries, etc. Use of control schemes for process optimization.

Unit 5 Advanced control strategies with case studies

Use of DDC and PLC, Introduction to supervisory control, Conversion of existing control schemes in operating plants, data loggers.

Course Materials

Required Text: Textbooks

1. Dale Patrick, Stephen Fardo ,"Industrial Process Control system", Delmar Cengage Learning, 2ND edition 1997.
2. R. P. Vyas, "Process Control and Instrumentation", Denett & Co., 7th edition, 2015.
3. Donald R Coughanower, Steven E LeBlanc, "Process System Analysis & Control", McGraw Hill Education, Third edition ,2017.
4. B. Wayne Bequette, "Process control, modeling, Design and simulation", Prentice Hall of India (P) Ltd., 2003.

Optional Materials: Reference Books

1. Curtis d Jonson, "Process Control Instrumentation Technology", Pearson, 8th edition, 2015.
2. Surekha Bhanot, "Process Control: Principles and Applications", Oxford University Press ,2008.
3. Bela G. Liptak, "Instrument Engineers' Handbook, Volume Two: Process Control and Optimization", CRC.
4. D. Patranabis, "Principles of Process Control", McGraw Hill Education, 3rd edition, 2017.
5. D. P. Eckman, "Automatic Process control", Wiley India Pvt. Ltd, September 2009.
6. S. K. Singh, "Process Control: Concepts, Dynamics and Applications", Prentice Hall India Learning Private Limited, 2009.
7. S. Sundaram, "Process Dynamics and Control", Cengage, 1st edition, 2012.

Course Outcomes: After successful completion of the course, the students will be able to

1. Apply the control techniques in industrial process.
2. Understand the advanced control techniques for present and future trends in the industries.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	3	2	2	1	1	2	2	2
CO2	3	3	2	3	3	3	3	1	1	1	2	3

Advanced Control System

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Program Elective	EL106208EL

[Pre-requisites: Control System Engineering (EL105101EL), Modern Control System (EL107101EL)]

Course Objectives

Making students

1. Understand the working of various engineering system using modern modeling tools.
2. Understand and apply the advanced concepts in controller design.

Course Content

Unit I Adaptive Control System

Introduction, Different approaches to adaptive control, Identification of adaptive systems, Model reference adaptive system, Classification of adaptive control, Gain scheduling, Applications of adaptive control.

Unit II Intelligent Control

Artificial Neural Networks Applications to System Identification & Control, fuzzy logic controller design, Fuzzy Modelling& identification

Unit III Robust Control

Signal and system norms, computing H2 and H∞ norms Singular value plots, input and output directions small gain theorem, representation of parameter uncertainty linear fractional transformation H∞ control with state and output feedback controller synthesis solving Linear matrix inequality constraints

Unit IV Stochastic Control

Basic issues in optimization stochastic vs. deterministic methods Random search, Recursive methods: LMS, RLS, Kalman filter, Stochastic linear quadratic control, Finite horizon control.

Course Material

Required Text: Textbooks

1. K. Ogata, "Modern Control Engineering", PHI, 2010.
2. Benjamin. C Kuo, "Digital Control Systems"Oxford University Press, 2nd edition, 1995.
3. K Ogata, "Discrete Time Control Systems", Pearson Education, Second Edition, 1995.
4. G.F. Franklin, J. D. Powell, M.L. Workman, *Digital Control of Dynamic Systems*, Pearson , 2008.
5. A. E. Bryson, Yu-Chi Ho, *Applied optimal Control: Optimization, Estimation and Control*, Taylor & Francis , 2016

Course Outcomes(CO)

1. Analyse the response and stability of LTI systems in time domain using state equations.
2. Design state feedback controllers and observers to improve the response of LTI systems.
3. Describe the behavior and evaluate the stability of nonlinear systems.
4. Appreciate the significance of digital control in industrial applications
5. Infer the requirement of optimal control for meeting the design specifications inindustrial control systems

Mapping and Correlation of COs with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3		2		1			2	2	1	3
CO2	3	3	3	2	3	1	1	2	1		1	3
CO3	3	3		2		1			2	2	1	3
CO4	3	3	3	2	3	1	3	2	1		2	3
CO5	3	3	3	2	3	1	3		1		3	3

Electrical Machine Design

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Program Elective	EL106209EL

[Pre-requisites: Electrical Machines-II (EL105102EL)]

Course Objectives

1. To impart the basic knowledge of design of the Electrical and Magnetic circuits.
2. To understand the design of DC machines.
3. To impart basic knowledge of design of transformers and AC machines.

Course Outcomes(Cos)

1. Students can understand the importance of choice of Electrical Engineering Materials and varios design criteria of electrical machines.
2. Student would be able to understand the performance prediction of electrical machines using design values.
3. Student would be able to learn about the design of electrical machines and their KVA outputs.
4. Student can analyse the various operating characteristics of electrical machines.
5. Student can study the temperature rise characteristics and methods of cooling of electrical machines.

Course Content

Unit 1Introduction

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, Standard specification.

DC Machines: Output Equations, Main dimensions, Magnetic circuit calculations, Carter’s co-efficient, Net length of iron, Real and apparent flux density, Selection of number of poles, Design of armature, Design of commutator and brushes, Performance prediction using design values.

Unit 2Transformer

Output equations, 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 tank, Methods of cooling of transformers.

Unit 3Induction Motors

Output equation of induction motor, Main dimensions, Length of induction motor, Main dimensions, Length of air gap, Rules for selecting rotor slots of squirrel cage machines, Design of rotor bars and slots, Design of end rings, Design of wound rotor, Magnetic leakage calculations, Leakage reactance of poly-phase machines, Magnetizing current, Short circuit current, Circle diagram, Operating characteristics.

Unit 4Synchronous Machines

Output equations, Choice of loadings, Design of salient pole machines, Short circuit ratio, Shape of pole face, Armature design, Armature parameters, Equation 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.

Course Materials

Required Text: Textbooks

1. Sawhney, A.K., "A course in Electrical Machine Design", Shree Hari Publications, 2019.
2. Say, M.G., "The Performance and Design Of Alternating Current Machines", CBS, 2002.

Optional Materials: Reference Books

1. Albert E. Clayton and Hancock,N.N, "The performance and Design of Direct Current Machines", CBS,2004.
2. Shanmugasundaram A., "Electrical Machine Design Data Book", New Age International Private Limited, Second edition, 2015.
3. M. Ramamoorty, "Computer aided Design of Electrical Equipment", East West Press Pvt. Ltd. Madras, 2008.

Mapping and Correlation of COs with POs

COs \ POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	3							2
CO2	3	2	3	3	3							2
CO3	2	2	2	2	3							2
CO4	3	3	2	2	3							2
CO5	3	2	1	1	3							2

Advanced Electric Drives

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Department of Electrical Engg	3-0-0, (3)	Program Elective	EL106210EL

[Pre-requisites: Power Electronics (EL104103EL), Electrical Machines-III (EL106103EL)]

Course Objectives

- Study about the separately excited DC motor drives in steady state and dynamic conditions
- Study about the scalar and vector control of IM drives
- Study about the PMSM drives, BLDC drives and SRM drives

Course Content

Unit-1 Separately Excited DC-motor Drives:

Study of Dynamics of DC motor through state-space Model, Simplified Model of a Power Converter, Review of controllers, need for anti-windup feature for integral controllers, Speed control of a separately excited DC drive with inner current loop and outer speed loop, Design of current loop with pole-zero cancellation, Design of speed loop with symmetrical optimization technique.

Unit-2 Induction Motor drives:

Implementation of V/f control with slip compensation scheme, PWM and transformation - abc, alpha-beta and d-q, Modelling of inverter using switching function, Inverters. Review of dq0 model of 3-Ph IM with simulation studies, Principle of vector control of IM, Indirect vector control, Direct Torque Control of Induction Motor Drives Inverter.

Unit-3 Permanent Magnet Drives:

PM Synchronous motors: Types, Construction, operating principle, Expression for torque, Model of PMSM, Implementation of vector control for PMSM, Introduction to BLDC drives.

Unit-4 Switched Reluctance Motor Drives:

Review of Switched Reluctance Motor, converters for SRM drives, Control of SRM drives with hard and soft chopping techniques.

Course Materials

Required Text: Textbooks

1. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Analysis of Electric Machinery & Drive Systems, IEEE Press, 3rd Edition.
2. B.K. Bose, Modern Power Electronics & AC Drives, Pearson, First edition.
3. R. Krishnan, Electric Motor Drives: Modeling, Analysis and Control, Prentice Hall.
4. Peter Vas, Vector Control of Electric Drives, Oxford Publishers.

Optional Materials: Reference Books

1. Bin-Wu, High-power Converters and AC Drives, IEEE Press, John Wiley &Sons
2. M. B. Patil, V. Ramanarayanan, V.T. Ranganathan, Simulation of Power Electronic Circuits, Narosa Publications, 2013.

Course Outcomes

On completion of this course, the students will be able to:

- CO1 Analyze and design separately excited DC motor drives in steady state and dynamic conditions
- CO2 Analyze the steady state behaviour of induction motor drives with scalar and vector control
- CO3 Analyze the permanent magnet drives and BLDC drives and to implement the vector control for PMSM drive
- CO4 Analyze SRM drives and to implement various chopping techniques used in control of SRM.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	Po12
CO1	3	3	3	3	2	1	2	-	-	-	-	3
CO2	3	3	3	3	3	1	2	-	-	-	-	3
CO3	3	3	3	3	3	1	2	-	-	-	-	3
CO4	3	3	3	3	3	1	2	-	-	-	-	3

Power Converter Design

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical	3-0-0, (3)	PE	EL106211EL

[Pre-requisites: Power Electronics]

Course Objectives

1. To understand the operations of different power converters
2. To enhance the knowledge of practical issues of power converters
3. To impart the ability of designing of converters for different applications

Course Content

Unit 1 Power Factor Correction Circuit

Basics of PFC, PFC using phase controlled rectifier and power factor circuits, Vienna rectifier circuit, Design examples

Unit 2 DC-DC Converter

Basic converters in CCM and DCM, Sepic and cuk converter, Converters with isolation Forward, Flyback, State space averaging for dc-dc converters, Transfer function for closed loop control and regulation; Design examples.

Unit 3 Multilevel Inverter

PWM techniques unipolar and bipolar, Space vector modulation technique, Concept, classification of multilevel inverters, Principle of operation, main features and analysis of Diode clamped, Flying capacitor and cascaded multilevel inverters. Matrix converter.

Unit 4 Soft-Switching Power Converters

Performance comparison hard switched and soft switched converters , Soft switching techniques. ZVS, ZCS, quasi resonance operation.

Course Materials Required

Text: Text books

1. M.H.Rashid, Butterworth-Heinemann, "Power Electronics Handbook", 4th edition, 2017.
2. Fang Lin Luo, Fang Lin Luo, "Advanced DC/DC Converters", CRC Press, 1st edition, 2003.
3. Marian P.Kazmierkowski, R.Krishnan, FredeBlaabjerg ,"Control in Power Electronics- Selected Problem", Academic Press, 1st edition, 2002.

Optional Materials: Reference Books

1. Issa Batarseh, "Power Electronic Circuits", John Wiley and Sons, Inc.2004.
2. Krein Philip T, "Elements of Power Electronics", Oxford University Press, Second edition, 2017.
3. Robbins Mohan, Undeland, "Power Electronics: Converters, Applications, and Design", Wiley, Third edition, 2007.
4. L. Umanand, "Power Electronics: Essentials and Applications", Wiley, 2009.
5. Cyril W Lander "Power Electronics" McGraw-Hill Inc. US; 2ND edition.
6. B. K Bose "Modern Power Electronics and AC Drives" Pearson Education India, 1st edition, 2015.
7. Abraham I Pressman "Switching Power Supply Design" McGraw Hill Exclusive, CBS, 2015.
8. Daniel M Mitchell ,"DC-DC Switching Regulator Analysis" McGraw Hill Publishing Company.

Course Outcomes:

After the completion of the course the student will beable to

1. Analyze and understand the operation of various PFC circuit .
2. Analyze and design DC-DC converter for various practical circuits.
3. Analyze and design multi-level inverter for their various application.
4. Analyze and design soft switching techniques for DC-DC converters

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	2	2	1	1		3
CO2	3	3	3	3	3	2	2	2	2	2	2	3
CO3	3	3	3	3	3	3	3	3	2	2	2	3
CO4	3	3	3	3	3	3	3	3	2	2	2	3

Industrial Electronics

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Program Elective	EL106212EL

[Pre-requisites: Utilization of Electrical Energy(EL104105EL), PowerElectronics (EL104103EL)]

Course Objectives

1. To acquire basic knowledge of various amplifiers and circuit operation.
2. To introduce different voltage control techniques in power converters and motor control.
3. To introduces various control scheme for traction system.

Course Content

Unit 1 Theory of Amplifiers

DC Amplifiers-Need for DC amplifiers, different terminologies of DC amplifiers, Darlington Emitter Follower, Cascade amplifier, Stabilization, DA with common current source, DA with common mode signal, Chopper stabilization, Operational Amplifiers, Ideal Specification of OP-Amp, Different terminologies,Instrumentation Amplifiers.

Unit 2 Power Supply

Review of Diodes, SCR, performance parameter of power supply, Filtering, Voltage multiplier, regulated power Supply-Switched Mode & IC Regulators: Switched Mode voltage regulator, Servo Voltage Stabilizer, Fixed and Adjustable IC Voltage regulators, 3-terminal Voltage regulators, Uninterrupted power supply(Online, Offline).

Unit 3 Motor Control

Voltage control at constant frequency, PWM control, Synchronous tap changer, Phase control of DC motor, Servomechanism,PLL control of a DC motor, recent advancement, and Applications.

Unit 4 Conventional DC and AC Traction

Electric traction services, Load sharing between traction motors, important features of traction drives, Conventional DC and AC traction drives, recent technologies in traction system.

Unit 5 Static converters for Traction

Semi-conductor converter-controlled drive for AC traction, Semiconductor chopper-controlled DC traction. Semi-conductor converter-controlled traction, advancement and applications.

Course Materials

Required Text: Textbooks

1. E. Openshaw Taylor, V. V. L. Rao, "Utilization of Electrical Energy", Universities Press.
2. Biswanath Paul, "Industrial Electronics and control:Including Programmable Logic Controller", Prentice Hall India Learning Private Limited, Third edition, 2014.

Optional Materials: Reference Books

1. H.Partap , "Art and Science of Utilization of Electrical Energy", Dhanpat Rai & Sons, 2017.
2. E. Openshaw Taylor, "Utilisation of Electric Energy “, Orient Longman.
3. S. Sivanagaruju," Generation and Utilization of Electrical Energy", Pearson Education, First edition 2010.

Course Outcome:

On successful completion of the course the students will be able to:

1. Impart the basic knowledge of various amplifiers and its terminologies.
2. Understand the design concept of various power supplies used in industries and Labs.
3. Apply the knowledge of various control methods used in motors for railways and industries.
4. Illustrate the concept and application of converters in traction system.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	3	2	2	1	1	3	2	1	2	3
CO2	3	3	3	3	2	2	1	3	3	1	2	3
CO3	3	3	3	3	2	2	1	3	3	1	2	3
CO4	3	3	3	3	2	2	1	3	3	1	3	3

Power System Dynamics

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Program Elective	EL106213EL

[Pre-Requisites-Electrical Power System (EL103105EL), Power System Analysis (EL105103EL)]

Course Objectives

1. To understand power stability problems
2. To understand basic concepts of modeling and analysis of dynamical systems.
3. To develop Models of power system components - generators, transmission lines, excitation and prime mover controllers etc.
4. To analyze Stability of single machine and multi-machine systems using digital simulation and small-signal analysis techniques.
5. To determine the impact of stability problems on power systems.

Course Content

Unit –I: Introduction to Power System Stability

Definition of stability, classification of stability, Rotor angle stability, frequency stability, voltage stability, mid-term and long-term stability, classical representation of synchronous machine in a single machine infinite bus (SMIB) system, Modal Analysis of Linear Systems, Analysis using Numerical Techniques.

Unit –II: Modeling of a 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, Analysis of Synchronous Machine Connected to Infinite Bus.

Unit –III: Modeling of Excitation, Prime Mover Systems, Transmission Lines and Loads

Physical Characteristics and Models for Excitation and Prime Mover Systems, Turbine governor, and exciter modeling, Control system components, Excitation System Controllers, Prime Mover Control Systems and their modeling, Transmission Line Modeling, Load Models.

Unit –IV: Stability Analysis in Interconnected Power Systems

Stability of Single Machine Infinite Bus System and Multi-machine Systems, Stability of Relative Motion, Frequency Stability: Centre of Inertia Motion, Concept of Load Sharing: Governors, Power System Stability Analysis Tools, Transient Stability Program, Small Signal Analysis Program, Real-Time Simulators.

Course Materials

Required Text: Text books

1. Power System Dynamics, Stability & Control by K.R. Padiyar, B.S. Publications, Hyderabad.
2. Power System Stability and Control by P. Kundur, McGraw Hill Inc, New York.

Optional Materials: Reference Books

1. Power System Dynamics & Stability by P. Sauer & M.A. Pai, Prentice Hall.
2. Power System Stability by Paul M. Anderson and A. A. Fouad, Wiley-interscience.
3. Power system stability by M. A. Pai and Peter W. Sauer, Pearson Education.

Course Outcomes:

On successful completion of the course the students will be able to:

1. Understand various types of stability of Power Systems and Develop dynamic mathematical modeling of a synchronous machine.
2. Describe and analyze the modeling of excitation and speed governing systems in a generator.
3. Analyze the small signal stability without controllers and with controllers.
4. Understand, Evaluate and apply various methods to enhance the stability of the power system.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	3	1	1	2	2	2	2	3
CO2	2	2	3	2	2	2	2	1	2	2	2	3
CO3	3	3	3	3	3	1	1	1	2	1	1	3
CO4	3	3	2	3	3	1	2	1	2	2	3	2

Design of Photovoltaic Systems

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Open Elective	EL106301EL

[Pre-requisites: Basic Electrical Engineering (EL101022EL), Power Electronics (EL104103EL)]

Course Objectives

1. To understand basic knowledge of solar cell, working principle and its interconnection methods
2. To impart modeling of PV system and knowledge of battery storage systems
3. To understand concept of maximum power point tracking algorithms in MATLAB.

Course Content

Unit-I PV Cell Fundamentals

PV cell characteristics and equivalent circuit, Model of PV cell Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature, Temperature effect calculation example, Fill factor, PV cell simulation.

Unit-II Series and Parallel Interconnection of PV modules

Identical cells in series, Load line, Non-identical cells in series, Protecting cells in series, Interconnecting modules in series, Simulation of cells in series, Identical cells in parallel, Non-identical cells in parallel, Protecting cells in parallel, Interconnecting modules, Simulation of cells in parallel, Measuring I-V characteristics.

Unit-III Sizing of PV and Battery Storage

Sizing PV for applications without batteries, PV sizing examples, Batteries - intro, Capacity, Efficiency, Energy and power densities, Batteries - Comparison, Battery selection, Other energy storage methods, PV system design- Load profile, selection of PV system design- Battery size and PV array size as per the applications.

Unit-IV Maximum Power Point Tracking

MPPT concept, MPPT algorithms, Input impedance of DC-DC converters - Boost converter ,Buck converter, Buck-Boost converter, PV module in MATLAB, Application in Engineering field.

Course Materials

Required Text: Textbooks

1. Chenming, H. and White, R. M., Solar Cells from B to Advanced Systems, McGraw Hill Book Co.
2. B. H. Khan, Non-conventional energy resources, McGraw hill.
3. Ruschenbach, H. S., Reinhold, N. Y., Solar Cell Array Design Handbook.

Optional Materials: Reference Books

1. Modeling of photovoltaic systems using Matlab: Simplified green codes. Khatib, Tamer, and Wilfried Elmenreich. John Wiley & Sons, 2016.
2. Solar electricity handbook: A simple, practical guide to solar energy-designing and installing photovoltaic solar electric systems. Boxwell, Michael. Greenstream publishing, 2010.
3. Photovoltaic design & installation for DUMMIES. Mayfield, Ryan. John Wiley & Sons.

Course Outcome:

On successful completion of the course the students will be able to:

1. Illustrate the various aspects of solar PV system and its operation.
2. Design and Analyze interconnected Solar PV systems and its usage in different fields.
3. Selection of battery storage systems for different PV system
4. Implement maximum power point tracking PV Systems for various converters used in Engineering applications

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	2	2	1	2	1	2	1	2	2
CO2	3	2	3	2	2	2	3	1	2	1	2	3
CO3	3	3	3	3	3	2	3	2	3	1	3	3
CO4	3	3	3	3	3	2	3	2	3	1	3	3

Building Energy Management Systems

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	EPR	EL106302EL
[Pre-requisites: NIL]			

Course Objectives

1. To understand the definition and objective of BEMS.
2. To analyze energy management in a building.
3. To understand and implement energy saving measures in buildings.
4. To plan and conduct effective energy audits.

Course Content

Unit-I: Introduction

BEMS (BMS) Control Systems Overview, Benefits of Building Energy Management Systems, BMS Architectures, Energy Systems Monitoring: Indirect Monitoring, Direct Monitoring, Hybrid Monitoring, Devices for Energy Sensing, Integrated Control of Active and Passive Heating, Cooling, Lighting, Shading, and Ventilation Systems, Electricity Network Architectures.

Unit-II: Energy Savings from Building Energy Management Systems

Energy Savings Opportunities, The Intelligent Building Approach, Energy Monitoring, Profiling, and Modeling, Smart Homes: Economic Feasibility and Likelihood of Widespread Adoption, Smart Home Energy Management; Energy Saving with Solar and Battery Integration, Energy Saving in Smart Home: Heating and Cooling, Lights, Automatic Timers, Motion Sensors, Light Dimmer, Energy-Efficient Light Bulbs, Evaluating the Number of Lamps Required for an Activity, Smart Energy Monitoring Systems to Help in Controlling Electricity Bill.

Unit-III: Advancing Building Energy Management System to Enable Smart Grid Interoperation

Data Management for Building, Communication for BEMS, Data Management for Building, Power Management: Levels of the Power Management System, Switching Status Acquisition and Measurements in the Power Distribution, Switchgear and Communications, Power Management Module.

Unit-IV: Energy Audit in Buildings

Types of Energy Audits, Building Details for Energy Audits, need and types of energy audit, energy audit instruments. Energy audit in residential and commercial buildings.

Course Materials

Required Text books

1. Energy conservation in residential, commercial, and industrial facilities, Hossam A. Gabbar, IEEE Press, John Wiley & Sons.
2. Energy Audit of Building Systems, MoncefKrarti, CRC Press.

Optional Materials: Reference Books

1. Utilization of Electrical Energy by JB Gupta, Kataria Publications.
2. Solar Passive: Building Science and Design, M S Sodha, N.K. Bansal, P.K. Bansal, A. Rumaar and M.A.S. Malik, Pergamon Preen.

Course Outcomes:

On successful completion of the course the students will be able to:

1. Understand and illustrate the fundamentals of green building concept and its practical utility in modern society.
2. Analyse and perform some building performance testing (e.g. energy audit, ratings etc.) and understand the process of Energy Audit in buildings.
3. Understand the policy recommendation on energy conservation and energy auditing for different types of buildings.
4. Design energy efficient buildings.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	3	2	3	2	3	2	2	2
CO2	2	2	3	2	2	2	3	1	2	3	2	3
CO3	3	3	3	3	3	2	3	1	3	3	3	3
CO4	3	3	2	3	2	2	2	2	2	1	3	2

Advanced Digital Signal Processing

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0 (3)	Open Elective	EL106303EL

[Pre-requisites: Signals & Systems (EL104104EL)]

Course Objectives

To provide rigorous foundations in multirate signal processing, power spectrum estimation and adaptive filters.

Course Content

Unit-1 Multirate Signal Processing

Decimation, Interpolation, Sampling Rate conversion by a rational factor I/D, Multistage implementation of sampling rate conversion, Polyphase filter structures, Applications of multirate signal processing.

Unit-2 Signal Modelling and Optimum Filters

Introduction, Least square method, Pade approximation, Prony's method, Levinson Recursion, Lattice filter, FIR Wiener filter, Linear Prediction filtering, Non-Causal and Causal IIR Weiner Filter, Mean square error, Discrete Kalman filter.

Unit-3 Adaptive Filters

Adaptive filters, Newton's steepest descent method, Widrow Hoff LMS Adaptive algorithm, Convergence, Normalized LMS, Applications, Noise cancellation, Channel equalization, Echo canceller, Adaptive Recursive Filters, RLS adaptive algorithm, Exponentially weighted RLS, sliding window RLS.

Unit-4 Power Spectrum Estimation

Bias and Consistency of estimators, Non-Parametric methods, Periodogram, Modified Periodogram, Barlett's method, Welch's method, Blackman-Turkey method, Parametric methods – AR, MA and ARMA spectrum estimation, Performance analysis of estimators.

Course Materials

Required Text: Text books

1. Proakis JG and Manolakis DG Digital Signal Processing Principles, Algorithms and Application, PHI.
2. Openheim AV & Schafer RW, Discrete Time Signal Processing, PHI.

Optional Materials: Reference Books

1. Vaidyanathan, Parishwad P - Multirate systems and filter banks, Pearson Education India.
2. Vaidyanathan, Palghat P- The theory of linear prediction, Morgan and Claypool Publishers.
3. Haykin, Simon S., Adaptive filter theory, Pearson Education India.

Course Outcomes

On successful completion of the course students will be able to:

1. Explain the design of decimator, interpolator and poly-phase filters.
2. Illustrate adaptive filter designing algorithms.
3. Explain the design and working of optimal filters.
4. Elucidate parametric and non parametric methods of power spectrum estimation.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	1	1		1		1	2	3
CO2	3	3	3	3	1	1		1		1	2	3
CO3	3	3	3	3	1	1		1		1	2	3
CO4	3	3	3	3	1	1		1		1	2	3

Basics of Electrical Machines

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Open Elective	EL106304EL

[Pre-requisite: Basic Electrical Engineering]

Course Objective

To make the students understand the significance of DC and AC motors for different industrial and commercial applications.

Course Content

Unit I Electromechanical Energy Conversion

Principle of Energy Conversion, Singly excited Magnetic System, Doubly excited Magnetic System, Faraday's Law of electromagnetic induction, Lorentz force on a conductor, Concept of Torque production, Concept of general terms pertaining to Rotating Machines, Generated emfs, Rotating magnetic field, Transformation of Energy, Introduction to Electrical machines

Unit II Transformer

Single phase transformer and basic equations, Working principle, Its equivalent circuit, Phasor diagram, losses, Leakage flux, Regulation & efficiency, Open circuit and short circuit tests, Different Types of Transformers, Role of transformer in Industries, Commercial and industrial application of transformer, Autotransformer, Measurement Transformer, Transformer ratings

Unit III DC Machines

Construction of DC machine, Types of DC machine, Internal generated voltage and induced torque equation in DC machine, DC Generator: Generator under load: the energy conversion process, Armature reaction, commutation, Generator applications, DC Motor: Operating principle, Mechanical Power and Torque, Starting, Speed control, DC motor types and their applications, Commercial and industrial use of DC motor

Unit IV AC Machines

Three Phase Induction Motors: Operating principle, Construction, Types of three phase induction motor, Speed torque characteristics, Speed Control methods, Synchronous Motors: Operating principle, Construction, Excitation methods, speed control methods, Industrial Applications of Electrical Motors, Electrical Motors in Robotics.

Course Materials

Required Text: Textbooks

1. Electric Machines by D P Nagrath & I J Kothari, Mc Graw Hill Education (India Private Ltd).
2. Electrical Machinery by A.E. Fitzgerald, Charles Kingsley Jr., Stephen D. Umans Tata McGraw-Hill Education Private Ltd.
3. Electrical Machinery Fundamentals by Stephen J. Chapman, McGraw-Hill Publisher.
4. Electrical Machinery by P.S. Bimbhra, Khanna Publisher

Optional Materials: Reference Books

1. Electrical Machines Drives and Power Systems by Theodore Wildi by Pearson Education
2. Principles of Electrical Machines and Power Electronics by P.C. Sen, Wiley Publisher.
3. Performance & Design of A.C. Machines by M.G. Say, C.B.S. Publishers

Course Outcomes

1. Appraise the concept and different components Electrical Machine and their role in our society.
2. Interpret the operating concept and analyze the performance of AC machines.
3. Interpret the operating concept and analyze the performance of DC machines.
4. To acquire the knowledge of different methods of starting and speed control of AC and DC motors.
5. Infer the practical application, and advantages of AC and DC machines used in different industry.

Mapping of COs and POs

POs / COs	1	2	3	4	5	6	7	8	9	10	11	12
1	3	3	3	1	1	3	2	2	1	1	1	3
2	3	3	3	3	3	2	2	1	1	1	1	3
3	3	3	3	3	3	2	2	1	1	1	1	3
4	3	3	3	3	3	3	2	1	1	1	1	3
5	2	2	3	3	1	3	3	2	2	2	2	3

Design and integration of optical sensors in mechatronic systems

[Sixth semester]

Course Description
Offered by Department Electrical Engineering | Credits: 3-0-0(3) | Status: Open Elective | Code:EL106305EL

Course Objectives:

1. To provide the students a broad understanding of the fundamentals of lasers: their unique properties, their operations, and their applications.
2. To equip the students with how a coherent light is generated and amplified.
3. To provide the students an understanding of different lasers' design and their applications.
4. To provide the students with a fundamental understanding of optical sensor systems' operation and principal components.
5. To provide the students with the basic knowledge of the Opto-mechatronics design process and real-time applications.

Course content

UNIT-I

(A) Science of light – evolution, ray/wave optics; Laser fundamentals Introduction; Importance: why laser? unique properties of lasers; Brief history of laser development; Laser basics

(B) Concept of stimulated emission; Population inversion; Amplification of stimulated emission; Laser instrumentation fundamentals: Cavity, resonator and pumping processes; Gain medium; Coherent radiation, standing waves, and modes; The kinetics of laser emission; Rate equations; Threshold conditions;

UNIT-II

(A) Pulsed and continuous-wave laser emission; Various pulsing techniques: cavity dumping, Q-switching and mode-locking, Transitions, lifetimes and linewidths: Three-level laser, Four-level laser, emission linewidth; Properties of laser light: monochromaticity, spatial and temporal coherence, intensity, beam-width.

(B) Laser sources; different types of lasers; Laser instrumentation details; Introduction to Semiconductor lasers; Semiconductor junction characteristics; Semiconductor light sources; Semiconductor light detectors.

UNIT-III

Historical Background of Opto-Mechatronic Technology; Understanding Opto-Mechatronic Systems: Definition and Basic Concept; Introduction to Optical Sensors: Building Blocks of an optical sensor system; Basic Roles of Optical Elements: Types of Opto-Mechatronic Systems; Fundamental Functions of Opto-Mechatronic Systems; Elements of Opto-Mechatronic Technology; Synergistic Effects of Opto-Mechatronic Systems.

UNIT-IV

Traditional vs. Opto-Mechatronic Designs; Opto-Mechatronic Design Process; Identification of Need and Design Specifications: Concept Generation, Detail Development and Evaluation. Opticaltransducers and controllers used in opto-mechatronic systems

UNIT-V

Case Studies: Environemental Gas Monitoring; Distributed Optical-Fiber Sensing, Biological-Based Optical Sensors and Transducers; Optical transducers in Material Processing; Welding process with optical information feedback

Course Materials

Text Books/Reference Books:

1. E. Hecht and A. R. Ganesan, "Optics", Pearson Education., 5th Edition, 2019.
2. N.Subrahmaniyam, Brij Lal and M.N. Avadhanulu, "A Text Book of Optics", S Chand andCompany Ltd., 25th Rev. Edition., 2012 .
3. B. E. A. Saleh and M. C. Teich, "Fundamentals of photonics", New York: Wiley., 3rd Edition2019.
4. H. Cho, "Opto-Mechatronics Systems Handbook- Techniques and Applications", CRC PressLLC, 2003.

Course Outcomes (COs)

On completion of this course, the students will be able to:

1. Identify the essential components of a laser system for generating lasing action.
2. Categorize various laser sources based on the properties of the system.
3. Analyze the operation of various components associated with an opto-mechatronic system.
4. Analyze the optical transducers and controllers used in opto-mechatronic systems
5. Design optical transducers related to real-time applications.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2	1	-	-	-	1	1	-	1
CO2	3	2	2	2	1	-	-	-	1	1	-	1
CO3	3	3	3	3	3	-	-	-	2	1	-	2
CO4	3	3	3	3	3	-	-	-	2	1	-	2
CO5	3	3	3	3	3	-	-	-	2	3	-	2

Introduction to Hybrid and Electric Vehicles

[6th Semester, Third Year]

Course Description :This course provides a comprehensive understanding of electric vehicular technology (EVT), covering the principles, components, and systems involved in EVT. The course explores various aspects of electric vehicular technology, including vehicle dynamics, electric propulsion systems, energy storage systems, electric motors, power converters, charging infrastructure. Students will gain knowledge of the key technologies and trends driving the advancement of electric vehicles, as well as the challenges and opportunities

Offered by Department	Credits	Status	Code
Electrical Engineering	3-0-0, (3)	Open Elective	EL106306EL

Course Objectives

- To develop a solid understanding of electric vehicular technology and its underlying principles.
- To explore the components and systems of electrified vehicles, including propulsion, energy storage, control strategies and charging infrastructure etc.
- To investigate emerging trends and future developments in electric vehicular technology.

Course Content

Unit-1 :Vehicular Technology

History of modern transportation system, classification, and configuration of vehicular technology: Basics of vehicle dynamics,propulsion system, transmission system and braking system, drivetrain analysis, Overview of internal combustion engine and its characteristics. Social and environmental impact of ICE vehicle and Electric vehicles. Comparison of ICE vehicle and electric vehicles.

Unit-2Electric Vehicle Technology

Introduction to electric vehicle technology, configuration, working principle and operations of battery electric vehicle, hybrid electric vehicle and its configuration, plug in electric vehicle and fuel cell electric vehicle. Comparison of different electrified vehicles.

Unit-3 : Electric Propulsion System

Introduction of Electric propulsion system and its constituent technologies. Energy source and storage system such as battery, Ultracapacitor, Flywheels and fuel cell. Electrical Motor like DC Motor, Induction Motor, Permanent Magnet Synchronous Motor and Switched Reluctance Motor, Power Electronic Converter like AC/DC, DC/AC and DC/DC converter and its control. Electronic control unit, control algorithms and optimization techniques.

Unit-4 :Electric Vehicle Charging System

Introduction to EV charging system. Fundamentals of EV battery charging and voltage levels, classification, configuration and architecture, Slow charging and fast charging, Ac Charging and DC Charging, Onboard charging and off board charging, EV charging system standards and guidelines, Wireless charging system, public charging station, Integration of renewable energy system and storage system with grid connected charging system.

Unit-5 :Emerging Trends and Challenges

Policy, Standard and guidelines for electrified vehicle, Vehicle-to-Grid (V2G) integration and smart grid interactions, vehicle to Concept, Battery Management System, Advancements in battery technology and energy storage, Autonomous and connected electric vehicles, V2V concept. Efficiency and power density improvements

Course Materials

Required Text: Text books

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press , 2003
2. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press , 2004

Optional Materials: Reference Books

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley , 2003
2. Chris Mi, M. Abul Masrur, David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, John Wiley & Sons Ltd. , 2011

Course Outcome (CO's)

Student will be able to,

1. Learn and understand configuration, dynamics and working of conventional vehicles and vehicle dynamics electric vehicle and hybrid electric vehicle and fuel cell vehicle.
2. Learn and understand configuration and operation of electric vehicle, hybrid vehicle and fuel cell vehicles.
3. Describe the role of electric propulsion system and its constituents in the development of Hybrid and Electric Vehicle.
4. Classify and understand the configuration, working and operation of electric vehicle charging stations.
5. Appraise and explain the emerging trends and challenges in hybrid and electric vehicle and constituent technologies.

Mapping of COs and POs

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	2	-	-	-	-	3
CO2	3	3	3	3	3	2	2	-	-	-	-	2
CO3	3	3	3	3	3	2	2	-	-	-	-	2
CO4	3	2	3	2	3	2	3	-	-	-	-	2
CO5	3	3	2	2	2	2	-	-	-	-	-	2

Power System Protection & Switchgear Laboratory

Course Description

Offered by Department	Credits	Status	Code
Electrical	0-0-2, (1)	EPR	EL106401EL

[Pre-requisites: None]
[6th Semester, Third Year]

Course Outcomes:

Students are able to:

1. Understand the operation of different protective relay.
2. Apply earth fault and overcurrent protection to line and equipment.
3. Understand the operation of static and microprocessor based relays.
4. Apply the sequence component analysis to identify the fault types.
5. Comprehend switching phenomenon of various types of circuit breakers and their duties.

LIST OF EXPERIMENTS

1. Location of cable faults using Varley Loop test.
2. To study the gas actuated Buchholz relay for transformer.
3. To perform CT polarity test and study the operating principle of current differential relay.
4. To check voltage and current condition for unsymmetrical and symmetrical fault in short, medium, and long transmission line
5. Simulation of various faults and verification of symmetrical components of currents.
6. To study the operating principle of Microcontroller based differential relay.
7. To study the operating principle of under frequency relay.
8. To study the operating principle of motor protection relay.
9. To study the operating principle of Reverse Power relay (Model No: RW 12).
10. Study of single-phase Directional Over current relay (Model No: JRP 011)
11. Study of Over current relay for three phase protection (IRI 1)
12. Study of Air circuit breaker

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	3	2	3	2	2	3
CO2	3	3	3	3	3	2	3	2	3	2	2	3
CO3	3	3	3	3	3	2	3	2	3	2	2	3
CO4	3	3	3	3	3	2	3	2	3	2	2	3
CO5	3	3	3	3	3	2	3	2	3	2	3	3

High Voltage Engineering LAB

[6th Semester, Third Year]

Course Description

Offered by Department	Credits	Status	Code
Electrical Engineering	0-0-2 (1)	Program Core	EL106402EL

[Pre-requisites: Electrical Machines – II (EL105102EL),Electrical Power System (EL103105EL)]

LIST OF EXPERIMENTS:

1. To study the Horn Gap Apparatus.
2. To determine the breakdown strength of Transformer Oil.
3. To study the components, control and operation of 100kV High voltage ac/dc test set.
4. To determine the breakdown characteristics of air under the influence of uniform and non-uniform AC field using sphere-sphere gap apparatus.
5. To determine the breakdown characteristics of air under the influence of uniform and non-uniform AC field using Rod-gap apparatus with different electrode configurations.
6. To determine the breakdown characteristics and study the effect of polarity of the high voltage DC in the Breakdown Strength of Air using sphere-sphere gap apparatus.
7. To determine the breakdown characteristics and study the effect of polarity of the high voltage DC on flashover characteristics between different types of electrodes using Rod-gap apparatus.
8. To determine the dissipation factor (Tan-Delta) and Resistivity of the oil sample using ODF Meter / IR Tester and Oil Heater.
9. To study the 100kV capacitance divider for measurement of High AC and DC voltage.
10. To study the components, control and operation of 150kV, 1.2/50µs, 225J Impulse Generator.
11. To study the flashover voltage in line insulators using Rod gap apparatus.
12. To study the flashover voltage in lightning arrestors using Rod gap apparatus.
13. Study of Schering Bridge for capacitance and tan δ measurement of insulating material.

LAB Outcomes:

After the completion of the LAB the student will be able to:

S.No	COs	
1.	**CO1**	Understand high voltage breakdown phenomena in insulating materials.
2.	**CO2**	Know the methods to generate different high voltages ac, dc and impulse.
3.	**CO3**	Know the measurement of high voltages.
4.	**CO4**	Analyze the test procedures as per the standards.

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3		1	2	1	2
CO2	3	3	3	3	3	3	3		1	2	1	2
CO3	3	3	3	3	3	3	3		1	2	1	2
CO4	3	3	3	3	3	3	3		1	2	1	2