SEMESTER VIII

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U40B	ELECTRICAL SYSTEM DESIGN AND ESTIMATION	PCC	2	1	0	3	2020

i) PRE-REQUISITE: EE1U30A: Power Systems I

ii) COURSE OVERVIEW: Electrical System Design would provide general awareness on IS Product standards / Codes of Practice, The Electricity Act 2003, CEA Regulations and Rules, NEC etc. related to Domestic, Industrial and Commercial Installations. It will also help in the design of Main and Sub Switchboards and distribution system for a medium class domestic and industrial electrical installations.

iii) COURSE OUTCOMES

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

CO1	Explain the standards and regulations in the design of components for medium and high voltage installations.	Understand
CO2	Design low/medium voltage domestic and industrial electrical installations.	Apply
CO3	Design, testing and commissioning of 11 kV transformer substation.	Apply
CO4	Design electrical installations in high rise buildings.	Apply

iv) SYLLABUS

General awareness of IS Codes- The Electricity Act 2003- National Electric Code (NEC 2011) - Scope – Wiring installation -Classification of voltages-standards and specifications.

Lighting design calculations - Coefficients of Utilisation (CoU)- Average lumen method - Space to mounting height ratio- Design of lighting systems for interior and exterior applications.

Design of electrical schematic and physical layout drawings for low and medium class domestic installation - Pre-commissioning tests.

Design of Industrial installations - Selection of 11kV indoor and outdoor transformer substations upto 630kVA - Pre-commissioning tests of 11kV indoor/outdoor substation of an HT consumer.

Electrical installations of high-rise buildings - Selection of standby Diesel Generator set- Automatic Power Factor Correction (APFC) panel - Solar PV Systems.

v) (a) TEXT BOOKS

1) K. B. Raina, S. K. Bhattacharya, “Electrical Design Estimating Costing”, New Age, Reprint Edition, 2010.
2) M. K. Giridharan, “Electrical Systems Design”, I K International Publishers, New Delhi, 2nd Edition, 2016.
3) J. B. Gupta, “A Course in Electrical Installation Estimating and Costing”, S.K. Kataria & Sons, Reprint 2013 Edition.

(b) REFERENCES

1) U.A.Bakshi, V.U.Bakshi, Electrical Technology, Technical publications, Pune, 1st Edition, 2020.
2) National Electrical Code 2011, Bureau of Indian Standards.
3) National Lighting Code 2010, Bureau of Indian Standards.
4) National Building Code of INDIA 2016 - Bureau of Indian Standards.
5) Narang K.L., A Text Book of Electrical Engineering Drawing, Tech India Publications, reprint 2005.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**General awareness of IS Codes**: IS 732 - IS 3043 –IS 2026- IS 3646-part 1&2 - IS 5216 part 1&2 - Electricity supply code-2014 (Relevance of each code in electrical installation applications only). The Electricity Act 2003- General introduction- Distribution of Electricity (Part VI)- Central Electricity Authority (Part IX)- Regulatory Commissions (Part IX). National Electric Code (NEC 2011) - Scope – Wiring installation (Section 9) Graphical symbols and signs as per NEC for electrical installations. Classification of voltages-standards and specifications, tolerances for voltage and frequency.	**6**
II	**Lighting Schemes and calculations:** Lighting design calculations - Definitions of luminous flux, Lumen, Luminous intensity/illuminance (Lux), Illumination calculations, factors affecting Coefficients of Utilisation (CoU) - and Light Loss Factor (LLF). Design of illumination systems – Average lumen method - Space to mounting height ratio - Design of lighting systems for a medium area seminar hall using LED luminaires Exterior lighting design- point to point method - road lighting and public area lighting- Space to mounting height ratio - selection of luminaires - Metal Halide - High & Low pressure Sodium vapour lamps – LED lamps.	**8**

III	**Domestic Installation:** General aspects as per NEC and IS 732 related to the design of domestic dwellings availing single phase supply (LV) and three phase supply (MV) for a connected load less than 15kW. Common power ratings of domestic gadgets- connected load-diversity factor-selection of number of sub circuits (lighting and power)-selection of MCB distribution boards to provide over load, short circuit and earth leakage protection. Principle of operation of MCB, MCB Isolator, ELCB/RCCB and RCBO. Design of electrical schematic and physical layout drawings for low and medium class domestic installation. Preparation of schedule of works and bill of quantities (cost estimation excluded). Pre-commissioning tests- Insulation resistance measurement, continuity test, polarity test, and earth resistance measurement as applicable to domestic installations.	**11**
IV	**Industrial Power and Lighting Installations:** Industrial installations –classifications- Design of electrical distribution systems with main switch board, sub switch boards and distribution boards with ACBs, MCCBs and MCBs as the case may be, for feeding power (mainly motors) and lighting loads of small and medium industries. Design of MSB & SSB including Motor Control Centre (MCC) for motor controls - selection of bus bars and switchgears. Selection of 11kV indoor and outdoor transformer substations upto 630kVA - selection of switchgears and protective devices. Short circuit calculations and earthing design for the HV and LV sides of an 11 kV substation of capacity up to 630 kVA. Pre-commissioning tests of 11kV indoor/outdoor substation of an HT consumer.	**11**
V	Electrical installations of high-rise buildings: Distribution systems – rising main, cable system - Installation of lifts, standby generators, fire pumps - electric schematic drawing. Selection of standby Diesel Generator set (DG set) –power rating - Continuous, Prime and Standby power ratings- installation and essential protections-Introduction to Automatic Mains failure (AMF) systems. Energy Conservation Techniques in electrical power distribution - Automatic Power Factor Correction (APFC) panel – Principle of operation and advantages. Introduction to Solar PV Systems, off-grid and on-grid systems, Solar panel efficiencies-design of a PV system for domestic application-Selection of battery for off-grid domestic systems.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42A	ROBOTICS	PEC	2	1	0	3	2020

i) PRE-REQUISITE: EE1U30C: Signals and Systems, EE1U30E: Linear Control Systems.

ii) COURSE OVERVIEW: This course provides an introduction to the robots types, Configurations and application; Coordinate frames and types, Transformations and types; Forward and Inverse Kinematics of manipulator's; all types of robotic sensors; Open loop and closed loop control systems.

iii) COURSE OUTCOMES

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

CO1	Identify the anatomy and specifications of robots for typical application.	Understand
CO2	Select the appropriate sensors and actuators for robots.	Apply
CO3	Identify robotic configuration and gripper for a particular application.	Apply
CO4	Solve forward and inverse kinematics of robotic manipulators.	Apply
CO5	Develop trajectories in joint space and Cartesian space.	Apply
CO6	Develop the dynamic model of a given robotic manipulator and its control strategy.	Apply

iv) SYLLABUS

Definitions, Types of Robots, Anatomy of a robotic manipulator, open kinematic vs closed kinematic chain, degrees of freedom, Robot considerations for an application, Robot Applications.

Sensors and Actuators Sensor classification, Internal sensors, External sensors, Selection of sensors.

Actuators for robots, Electric actuators, Linear actuators, selection of motors; Hydraulic actuators, Pneumatic Actuators.

Robot configurations, features of SCARA, PUMA Robots; Classification of robots based on motion control methods and drive technologies; 3R concurrent wrist; Classification of End effectors.

Kinematics and Motion Planning - Robot Coordinate Systems, Kinematic parameters, D-H representation, Direct Kinematics. The Arm equation- forward and inverse Kinematics of typical robots upto 3 DOF, Motion Planning.

Dynamics and Control of Robots - Dynamic model of a robot using Lagrange’s equation, dynamic modeling of 1 DOF robot, Transfer function and state space representation, Performance and stability of feedback control, PID control of a single link manipulator, selection of PID controller gains; nonlinear nature of manipulators, and need for nonlinear control techniques, Computed torque control.

v) (a) TEXT BOOKS

1) S K Saha, “Introduction to Robotics”, Mc Graw Hill Education, 2003.
2) Robert. J. Schilling, “Fundamentals of robotics – Analysis and control”, Prentice Hall of India 1996.
3) R K Mittal and I J Nagrath, “Robotics and Control”, Tata McGraw Hill, New Delhi, 2003.
4) John. J. Craig., “Introduction to Robotics (Mechanics and control)”, Pearson Education Asia, 2002.
5) Saeed B. Nikku, “Introduction to Robotics”, Pearson Education, 2001.
6) Rachid Manseur, “Robot Modeling and Kinematics”, Lakshmi publications, 2009.

(b) REFERENCES

1) Ashitava Ghosal, “Robotics-Fundamental concepts and analysis”, Oxford University press.
2) S. R. Deb, “Robotics Technology and Flexible Automation”, 2nd Edition.
3) Boltans W., “Mechatronics”, Pearson Education, 2009.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction** Definitions - Robots, Robotics; Types of Robots- Manipulators, Mobile Robots - wheeled & Legged Robots, Aerial Robots; Anatomy of a robotic manipulator - links, joints, actuators, sensors, controller; open kinematic vs closed kinematic chain; degrees of freedom. Robot specifications for an application - number of axes, work volume, capacity & speed, stroke & reach, Repeatability, Precision and Accuracy, Operating environment, point to point control or continuous path control. Robot Applications - medical, mining, space, defense, security, domestic, entertainment, Industrial Applications - Material handling, welding, Spray painting, Machining.	**8**
II	**Sensors and Actuators** Sensor classification - touch, force, proximity, vision sensors. Internal sensors - Position sensors, velocity sensors, acceleration sensors, Force sensors; External sensors-contact type, non-contact type.	**10**

	Vision - Elements of vision sensor, image acquisition, image processing; Selection of sensors. Actuators for robots - classification - Electric, Hydraulic, Pneumatic actuators; their advantages and disadvantages; Electric actuators- Stepper motors, DC motors, DC servo motors and their drivers, AC motors, Linear actuators, selection of motors; Hydraulic actuators - Components and typical circuit, advantages and disadvantages; Pneumatic Actuators - Components and typical circuit, advantages and disadvantages.	
III	**Robotic configurations and end effectors** Robot configurations - PPP, RPP, RRP, RRR; features of SCARA, PUMA Robots. Classification of robots based on motion control methods and drive technologies; 3R concurrent wrist. Classification of End effectors - mechanical grippers, special tools, Magnetic grippers, Vacuum grippers, adhesive grippers, Active and passive grippers, factors affecting selection of grippers.	**9**
IV	**Kinematics and Motion Planning** Robot Coordinate Systems- Fundamental and composite rotations, homogeneous coordinates and transformations. Kinematic parameters, D-H representation, Direct Kinematics. The Arm equation- forward Kinematic analysis of a typical robots up to 3 DOF. Motion Planning - joint space trajectory planning-cubic polynomial, linear trajectory with parabolic blends; Cartesian space planning, Point to point vs continuous path planning.	**9**
V	**Dynamics and Control of Robots** Dynamics - Dynamic model of a robot using Lagrange's equation, dynamic modeling of 1 DOF robot Control Techniques - Transfer function and state space representation, Performance and stability of feedback control. PID control of a single link manipulator, selection of PID controller gains; nonlinear nature of manipulators, and need for nonlinear control techniques, Computed torque control, Gravity control.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42B	ENERGY MANAGEMENT	PEC	3	0	0	3	2020

i) **PRE-REQUISITE:** Nil.

ii) **COURSE OVERVIEW**: This course is to expose the students to the fundamental concepts of energy management and auditing.

iii) **COURSE OUTCOMES**

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

CO1	Explain the significance of energy management and auditing.	Understand
CO2	Identify energy efficiency improvement opportunities for electrical loads.	Apply
CO3	Apply demand side management techniques.	Apply
CO4	Explain the energy management opportunities in industries.	Understand
CO5	Develop the economic feasibility of the energy conservation measures.	Apply

iv) **SYLLABUS**

Energy Management - General Principles and Planning. Energy Audit- need, types and methodologies. Instruments for energy audit, Energy audit report - Power quality audit Energy conservation in buildings: ECBC code, Building Management System.

Energy Efficiency in Electricity Utilization: Electricity transmission and distribution system, cascade efficiency. Lighting- energy conservation in lighting. Motors - energy conservation in motors. Present maximum efficiency standards for power and distribution transformers, design measures for increasing efficiency in electrical system components.

Demand side Management- techniques of DSM. Load management, load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient equipment Power factor improvement. DSM and Environment. Ancillary services: Introduction and Types of Ancillary services.

Energy Economics: Economic analysis: methods, cash flow model, time value of money, evaluation of proposals, pay-back period, average rate of return method, internal rate of return method, present value method, life cycle costing approach. Computer aided Energy Management Systems.

v) (a) **TEXT BOOKS**

1) Albert Thumann, William J. Younger, "Handbook of Energy Audits", CRC Press,9th Edition, 2013.

2) Charles M. Gottschalk, “Industrial energy conservation”, John Wiley & Sons, 1996.
3) Craig B. Smith, “Energy management principles”, Elsevier, 2nd Edition, 2015.
4) Energy Conservation Act – 2001 and Related Rules and Standards.
5) Publications of Bureau of Energy Efficiency (BEE).

(b) REFERENCES

1) D. Yogi Goswami, Frank Kreith, “Energy Management and Conservation Handbook”, CRC Press, 2007
2) G.G. Rajan, “Optimizing energy efficiencies in industry”, Tata McGraw Hill, Pub. Co., 2001.
3) IEEE recommended practice for energy management in industrial and commercial facilities.
4) IEEE std 739 -1995 (Bronze book).
5) M Jayaraju and Premlet, “Introduction to Energy Conservation and Management”, Phasor Books, 2008.
6) Paul O'Callaghan, “Energy Management”, McGraw Hill Book Co., 1992.
7) Wayne C. Turner, “Energy Management Hand Book”, The Fairmount Press, Inc., 1997.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Energy Management - General Principles and Planning:** General principles of energy management and energy management planning. **Energy Audit:** Definition, need, types and methodologies. Instruments for energy audit, Energy audit report - Power quality audit Energy conservation in buildings: ECBC code (basic aspects), Building Management System (BMS).	9
II	**Energy Efficiency in Electricity Utilization**: Electricity transmission and distribution system, cascade efficiency. Lighting: Modern energy efficient light sources, life and efficacy comparison with older light sources, energy conservation in lighting, use of sensors and lighting automation. **Motors**: Development of energy efficient motors and the present status, techniques for improving energy efficiency, necessity for load matching and selection of motors for constant and variable loads. Transformers: Present maximum efficiency standards for power and distribution transformers, design measures for increasing efficiency in electrical system components.	9
III	**Demand side Management**: Introduction to DSM, benefits of DSM, different techniques of DSM –time of day pricing, multi-utility power exchange model, time of day models for planning. Load management,	9

	load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient equipment. Power factor improvement, numerical examples. DSM and Environment. Ancillary services: Introduction of ancillary services – Types of Ancillary services	
IV	**Energy Management in Industries and Commercial Establishments:** Boiler - working principle - blow down, energy conservation opportunities in boiler. Steam: properties of steam, distribution losses, steam trapping. Identifying opportunities for energy savings in steam distribution. Furnace- General fuel economy measures, energy conservation opportunities in furnaces. **HVAC system:** Performance and saving opportunities in Refrigeration and Air conditioning systems. Heat Recovery Systems: Waste heat recovery system - Energy saving opportunities. **Cogeneration:** Types and schemes, optimal operation of cogeneration plants, combined cycle electricity generation.	**9**
V	**Energy Economics:** Economic analysis methods, cash flow model, time value of money, evaluation of proposals, pay-back period, average rate of return method, internal rate of return method, present value method, life cycle costing approach. Case Studies. Computer aided Energy Management Systems (EMS).	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42C	SMART GRID TECHNOLOGIES	PEC	2	1	0	3	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: This course introduces various advancements in the area of smart grid. It also introduces distributed energy resources and micro-grid. In addition, cloud computing, cyber security and power quality issues in smart grids are also introduced.

iii) COURSE OUTCOMES

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

CO1	Explain the basic concept of distributed energy resources, micro-grid and smart grid.	Understand
CO2	Choose appropriate Information and Communication Technology (ICT) in a smart grid.	Apply
CO3	Explain infrastructure and technologies for the consumer domain of smart grid.	Understand
CO4	Explain infrastructure and technologies for smart substation and distribution automation.	Understand
CO5	Develop cloud computing infrastructure for smart grid considering cyber security.	Apply
CO6	Identify power quality issues in smart grid context.	Apply

iv) SYLLABUS

Introduction to smart grid: Evolution, definition, need, function, opportunities, barriers, components and architecture.

Information and Communication Technology in Smart Grid: Wired and wireless communication, Communication Protocols in Smart grid, Introduction to IEC 61850 standard and benefits.

Introduction to smart meters, Electricity tariff, Real Time Pricing, Plug in Hybrid Electric Vehicles, Intelligent Electronic Devices and their application for monitoring & protection.

Smart substations, Substation automation, Feeder automation, Fault detection, Isolation, and Service Restoration. Introduction to Smart distributed energy resources and their grid integration, Smart inverters, Concepts of micro grid. Energy Management.

Cloud Computing in Smart Grid: Private, Public and hybrid cloud. Types of cloud computing services. Cloud architecture for smart grid, Cyber Security: Challenges and solution in smart grid.

Power Quality Management in Smart Grid: Power quality and Electromagnetic compatibility.

v) (a) TEXT BOOKS

1) Stuart Borlase "Smart Grid Infrastructure Technology and Solutions", CRC Press; 2nd Edition.
2) James Momoh, "Smart Grid: Fundamentals of Design and Analysis", Wiley, 2012.
3) S. Chowdhury, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 2009.
4) Chris Mi, M. Abul Masrur, David Wenzhong Gao, "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives", 2011, Wiley publication.

(b) REFERENCES

1) Danda B. Rawat; Chandra Bajracharya, "Cyber security for smart grid systems: Status, challenges and perspectives", IEEE Southeast Con 2015, DOI: 10.1109/SECON.2015.7132891.
2) Pillitteri, V. and Brewer, T. (2014), "Guidelines for Smart Grid Cyber security", NIST Interagency/Internal Report (NISTIR), National Institute of Standards and Technology, Gaithersburg, MD, [online], https://doi.org/10.6028/NIST.IR.7628r1.
3) Barker, Preston, Price, Rudy F., "Cyber security for the Electric Smart Grid: Elements and Considerations", Nova Science Publishers Inc, 2012.
4) Eric D. Knapp, Raj Samani, "Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure", Syngress; 1st Edition (26 February 2013).
5) Richard J. Campbell, "The Smart Grid and Cyber security: Regulatory Policy and Issues", Congressional Research Service, 2011.
6) Dariusz Kloza, Vagelis Papakonstantinou, Sanjay Goel, Yuan Hong, "Smart grid security", Springer.
7) Roger C. Dugan, "Electrical Power Systems Quality", McGraw-Hill Publication, 3rd Edition.
8) G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 2nd Edition.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Smart Grid**: Evolution of electric grid, definitions needed for smart grid, smart grid drivers, and functions of smart grid, opportunities and barriers of smart grid, difference between conventional grid and smart grid, concept of resilient and self- healing grid. Components and architecture, inter-operability, impacts of Smart Grid on system. Present development and international policies in smart grid, Smart grid standards.	7

II	**Information and Communication Technology in Smart Grid**: Wired and wireless communication -radio mesh, ZIGBEE, 3G, 4G and 5G, digital PLC, DSL, Wi-Max, LAN, NAN, HAN, Wi-Fi, Bluetooth. Bluetooth Low Energy (BLE), Light-Fi, substation event - GOOSE, IEC 61850 substation model. Communication protocols in smart grid, introduction to IEC 61850 standard and benefits, IEC Generic Object-Oriented Substation Event - GOOSE. IEC 61850, Substation model.	**8**
III	**Smart Grid Technologies Part I:** Introduction to smart meters, electricity tariff, real time pricing- Automatic Meter Reading (AMR) System, services and functions, components of AMR systems, Advanced Metering Infrastructure (AMI). Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Grid to Vehicle. Smart sensors, smart energy efficient end use devices, home & building automation, Intelligent Electronic Devices (IED) and their application for monitoring & protection, DFRA, DPRA, CBMA. Phasor Measurement Unit (PMU), standard for PMU. Time synchronization techniques, Wide Area Monitoring, control and protection systems - architecture, components of WAMS, and applications: voltage stability assessment, frequency stability assessment, power oscillation assessment, communication needs of WAMS, remedial action scheme.	**11**
IV	**Smart Grid Technologies Part II:** Smart substations, substation automation, feeder automation, fault detection, isolation, and service restoration, Geographic Information System (GIS), Outage Management System (OMS). Introduction to smart distributed energy resources and their grid integration, smart inverters. Concepts of micro grid, need & application of micro grid – Energy Management-Role of technology in demand response- Demand Side Management, Demand Side Ancillary Services, Dynamic Line rating.	**10**
V	**Cloud Computing in Smart Grid**: Public and hybrid cloud, cloud architecture of smart grid, types of cloud computing services- IaaS, SaaS, PaaS, DaaS. **Cyber Security -** Cyber security challenges and solutions in smart grid**,** cyber security risk assessment, and security index computation. **Power Quality Management in Smart Grid** - Fundamentals, power quality & EMC in Smart Grid. Power quality conditioners for smart grid.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42D	ELECTRICAL MACHINE DESIGN	PEC	2	1	0	3	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: The main goal of this course is to expose the students to the design of static machines like single phase and three phase transformers and rotating electrical machines such as DC machines, three phase Induction machines and Synchronous machines. It introduces students to cognitive learning and develops problem solving skills. It gives an insight into the general idea to the computer aided design of electrical machines.

iii) COURSE OUTCOMES

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

CO1	Enumerate the general design considerations of electrical machines.	Understand
CO2	Model armature and field system of DC machines.	Apply
CO3	Select suitable parameters to model transformers based on applications	Apply
CO4	Make use of suitable parameters to model stator and rotor of induction machines.	Apply
CO5	Make use of suitable parameters to model stator and rotor of synchronous machines.	Apply
CO6	Apply Software tools in electrical machine design.	Apply

iv) SYLLABUS

Magnetic circuit calculations, Magnetic Leakage Calculation, Unbalanced Magnetic Pull-Practical aspects of unbalanced magnetic pull.

Design of transformers - single phase and three phase transformers - distribution and power transformers, overall dimensions of core.

Design of DC machines - output equation, design of field winding, conductor cross section, design of inter pole, design of compensating winding.

Design of synchronous machines, Design of three phase induction motors, design of rotor bar, design of end ring, design of slip ring rotor winding.

v) (a) TEXT BOOKS

1) Sawhney A.K., A Course in Electrical Machine Design, Dhanpat Rai & Co. (P) Limited, New Delhi, 2016.

2) William T. Ryan, Design of Electrical Machinery, Creative Media Partners, LLC, 4th Edition, 2015.
3) Upadhay K.G., Design of Electrical Machines, New Age International, 2011.
4) Agarwal R.K., Principles of Electrical Machine Design, S. K. Kataria & Sons, 5th Edition 2014.
5) Say M.G., The Performance and Design of AC Machines, CBS Publishers, New Delhi, 3rd Edition, 2002.
6) Albert E Clayton & Hancock N.N., Performance and Design of DC Machines, Oxford and IBH Publishing CO& PVT Ltd, New Delhi, 3rd Edition,1971.

(b) REFERENCES

1) Rajani V., Nagarajan V.S., Electrical Machine Design, Pearson Publications, 3rd Edition, 2018.
2) Thomas A. Lipo, Introduction to AC machine design, Wiley-IEEE Press, 2017.
3) Deshpande M.V., Design and Testing of Electrical Machines, PHI Learning Pvt. Ltd., 2010.
4) Juha Pyrhonen, Valeria Hrabovcova, Tapani Jokinen, Design of Rotating Electrical Machines, John Wiley and Sons Inc., 2nd Edition 2013.
5) Ramamoorthy M, "Computer Aided Design of Electrical Equipment", East-West Press, 2nd Edition, January 2008.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Principles of electrical machine design:** General design considerations, types of enclosures - types of ventilation. Heating - cooling and temperature rise calculation – numerical problems. Continuous, short time and intermittent ratings. Insulation classes – Introduction to modern insulating materials, such as Nomex, Polyamide films and Silicone. Types of cooling in transformers and rotating electrical machines. **Magnetic system** - Carter's coefficient – real and apparent flux density. Unbalanced magnetic pull and its practical aspects.	**9**
II	**DC Machines**: Output equation - main dimensions - choice of specific electric and magnetic loadings corresponding to the insulating materials, magnetic material and type of cooling considered - choice of speed and number of poles - design of armature conductors, slots and winding - design problems. Design of air-gap - design of field system – design problems. Fundamental design aspects of interpoles, compensating winding, commutator and brushes.	**8**
III	**Transformers**: Design of transformers - single phase and three phase transformers - distribution and power transformers - output equation - core design with due consideration to percentage impedance required	**9**

	- window area - window space factor - overall dimensions of core – design problems. Windings - no. of turns - current density in consideration to the insulation scheme - conductor section. Design of cooling tank with tubes – design problems. Essential design features of cast resin dry type transformers. Fundamentals of K-factor rated transformer, ECBC standards for transformers, BEE Star rating of transformers.	
IV	**Induction machines**: Output equation - main dimensions - choice of specific electric and magnetic loadings corresponding to the insulating materials, magnetic material and type of cooling considered - design of stator and rotor windings - round conductor or rectangular conductor - design of stator and rotor slots, air-gap of slip ring and squirrel cage motors - calculation of rotor bar and end ring currents in cage rotor - design of slip ring rotor winding - design problems. Design aspects of induction motor for drive applications (basic principles only).	**9**
V	**Synchronous Machines:** Output equation - salient pole and turbo alternators - main dimensions - choice of specific electric and magnetic loadings corresponding to the insulating materials, magnetic material and type of cooling considered - significance of short circuit ratio - choice of speed and number of poles - design of armature conductors, slots and winding - round conductor or rectangular conductor - design of air-gap - design problems. Fundamental design aspects of the field system and damper winding. Features of brushless alternators. **Introduction to computer aided design:** Analysis and synthesis methods - hybrid techniques. Introduction to machine design software using Finite Element Method. Design, simulation and optimization using electromagnetic field simulation software (Assignment only).	**10**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42E	SWITCH MODE POWER CONVERTERS	PEC	3	0	0	3	2020

i) **PRE-REQUISITE:** EE1U30G: Power Electronics

ii) **COURSE OVERVIEW**: The main goal of this course is to expose the students to the analysis of different non-isolated, isolated DC-DC converters. It gives an insight to the design of DC-DC converters. It also includes the different PWM techniques of DC- AC converters and the concepts of Resonant converters.

iii) **COURSE OUTCOMES**

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

CO1	Develop the basic design for non-isolated DC-DC converter topologies.	Apply
CO2	Choose various isolated DC-DC converter topologies based on applications,	Apply
CO3	Describe the operation of Switched mode inverters and rectifiers.	Understand
CO4	Distinguish between inverter modulation strategies.	Understand
CO5	Describe the operation of soft switching resonant converters.	Understand

iv) **SYLLABUS**

Steady State Converter Analysis -Small-Ripple Approximation, Analysis of buck & boost converter in continuous & discontinuous conduction mode

Steady-State Equivalent Circuit modelling DC Transformer Model, Inductor voltage & capacitor voltage, inclusion of Semiconductor Conduction Losses in converters

AC Equivalent Circuit Modelling Small signal AC modelling of Buck Boost converter, Perturbation and Linearization, Construction of the Small-Signal Equivalent Circuit Model, Equivalent circuit model of a non-ideal flyback converter

State Space Averaging. State space averaging of non-ideal buck boost converter, Canonical Circuit Model of DC-DC converters, modelling of pulse width modulator

Converter Transfer Functions. Frequency response analysis, Transfer Functions of the Buck-Boost Converter, graphical construction of converter transfer functions, Controller Design.

v) (a) **TEXT BOOKS**

1) Ned Mohan, Tore M. Undeland, William P. Robbins, "Power Electronics Converters, Applications and Design", 3rd Edition, Wiley India Pvt Ltd, 2018.

2) Rashid M H, "Power Electronics – Circuits, Devices and Applications", Prentice Hall of India, New Delhi, 4th Edition, 2014.
3) Taylor Morey, Abraham Pressman, Keith Billings, "Switching Power Supply Design", McGraw Hill, 3rd Edition, 2009.

(b) REFERENCES

1) Daniel W Hart, "Power Electronics", Tata McGraw Hill, 2011.
2) Umanand L, "Power Electronics - Essentials and Applications", Wiley 2011.
3) Christophe P. Basso, "Switch-Mode Power Supplies Spice Simulations and Practical Designs", BPB Publication, 2010.
4) Muhammad Rashid, "Digital Power Electronics and Applications", 1st Edition, Elsevier, 2005.
5) Christophe Basso, "Switch-Mode Power Supplies", SPICE Simulations and Practical Designs, 2nd Edition 2014.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Linear Vs Switching Power Electronics. Buck, Boost, Buck-boost and Ćuk converters: Principles of steady-state analysis - Inductor volt-seconds balance and capacitor amp-seconds balance – Operation in Continuous Conduction Mode (CCM)-Voltage Gain – design of filter inductance & capacitance - boundary between continuous and discontinuous conduction – critical values of inductance/load resistance - Examples for buck and boost converters. Discontinuous Conduction Mode (DCM) of buck converter with constant output voltage – Output voltage ripple in DCM. Voltage Gain in DCM for buck converters. Synchronous Buck Converter	9
II	DC-DC converters with electrical isolation: High-frequency transformers for DC-DC converters: unidirectional magnetic core excitation & bidirectional core excitation. Fly back converter: Operation and waveforms in continuous & discontinuous conduction modes – Voltage gain. CCM operation of double ended fly-back converter. Forward converter in CCM: Basic forward converter with ideal transformer – practical forward converter with core reset – double ended forward converter Push-Pull, Half-Bridge and Full-Bridge converters: Operation in Continuous Conduction Mode (CCM) – Flux-walking in isolated converters. Current-source DC-DC converter.	9

III	Switched Mode DC to AC converters: Review of single-phase bridge inverters - 3-phase Sine-PWM inverter: – Linear Modulation, RMS fundamental line to line voltage & RMS fundamental line-to-line voltage – Overmodulation - Square wave operation in three-phase inverters - Switch utilization ratio of 1-phase & 3-phase full-bridge inverters. PWM Rectifiers: Generation of current harmonics in diode bridge rectifiers - Power factor - Improved single-phase utility interface - Active shaping of input line current through PFC boost converter - Single phase Switched mode rectifier.	**9**
IV	Modulation Schemes: Space Vector Modulation: Concept of space vector – space vector modulation – reference vector & switching (dwell) times – space vector sequence – comparison of sine PWM & space vector PWM. Programmed (selective) harmonic elimination switching in single phase inverters (Formulation example with elimination of two harmonics at a time) – current controlled voltage source inverter - Hysteresis current control.	**9**
V	Soft switching and resonant converters: Hard-switched Vs Soft-switched converters - Resonant Converters - Basic resonant circuit concepts – series resonant circuit – parallel resonant circuit – series-loaded and parallel loaded resonant converters (Operation in discontinuous conduction mode with $\omega s < 0.5\ \omega r$). Resonant Switch (Quasi-resonant) Converters: ZCS buck converter - L type - ZVS buck converter – comparison of ZCS & ZVS Resonant Converters.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42F	COMPUTER AIDED POWER SYSTEM ANALYSIS	PEC	2	1	0	3	2020

i) **PRE-REQUISITE:** EE1U20A: Circuits and Networks, EE1U30A: Power Systems I, EE1U30F: Power Systems II.

ii) **COURSE OVERVIEW**: The basic objective of this course is to familiarize the efficient computational techniques applied in analysing the power system.

iii) **COURSE OUTCOMES**

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

CO1	Develop the model of power system networks.	Apply
CO2	Solve linear systems using computationally efficient methods.	Apply
CO3	Solve load flow problems in power systems.	Apply
CO4	Develop optimal power flow problem in power system networks.	Apply
CO5	Analyse power system under short circuit conditions and infer the results to design a protective system.	Analyse

iv) **SYLLABUS**

Overview of graph theory: tree, co-tree and bus incidence matrix, development of network matrices from graph theoretic approach. Building algorithm for bus impedance matrix.

Review of solution of equations by Gauss-Jordan method, Gauss elimination, and LDU factorization. Inversion of Ybus for large systems.

Review of Load Flow analysis, Newton-Raphson method, Fast Decoupled Load Flow and DC Load Flow.

Review of economic load dispatch, formulation of optimal power flow with active power cost minimization, Solution of OPF using Gradient and Newton's methods.

Network fault calculations using Z bus, algorithm for calculating system conditions after fault – three phase to ground fault.

v) (a) **TEXT BOOKS**

1) Stagg and E l Abiad, "Computer Methods in Power System Analysis", McGraw Hill, 1968.
2) G. L. Kusic, “Computer Aided Power System Analysis”, PHI, 1989
3) John J. Grainger, William D. Stevenson, Jr., “Power System Analysis”, Tata McGraw-Hill Series in Electrical and Computer Engineering.

(b) REFERENCES

1) I. J. Nagrath and D. P. Kothari, "Modern Power System Analysis", Tata McGraw Hill, 1980.
2) J. Arriliga and N.R. Watson, Computer Modelling of Electrical Power Systems, 2nd Edition, John Wiley, 2001.
3) L. P. Singh, “Advanced Power System Analysis and Dynamics”, 3rd Edition, New Age Intl, 1996.
4) M. A. Pai, Computer Techniques in Power Systems Analysis, Tata McGraw-Hill, 2nd Edition 2005.
5) Arthur R. Bergen, Vijay Vittal, Power Systems Analysis (English) 2nd Edition, Pearson Higher Education
6) Wood, Allen J., Bruce F. Wollenberg, and Gerald B. Sheblé. Power generation, operation, and control. John Wiley & Sons, 2013.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction, Network Equation, Concept of Linear Graph – tree, co-tree, Bus Incidence matrix, A. Formation of Y_{bus} and Z_{bus} by singular transformation, Numerical problem. Z_{bus} building algorithm without mutual coupling (derivation not required), Numerical example.	**9**
II	Solution of linear system of equations by Gauss Jordan method and Gauss elimination method, Numerical problems. Triangular factorization –LDU factors, Numerical problems. Inversion of the Y_{BUS} matrix for large systems, Numerical problems. Tinney’s Optimally Ordering.	9
III	Review of Load Flow. Newton-Raphson method (Qualitative analysis only). Fast Decoupled Load Flow (Numerical problems up to 2 iterations) DC Load Flow (Numerical problems up to 2 iterations)	**9**
IV	Review of Economic Load Dispatch - Economic dispatch of generation without and with transmission line losses. Concept of optimal power flow – formulation with equality and inequality constraints (with active power cost minimization). Solution of OPF using Gradient and Newton method (Qualitative analysis only). Security Constrained Optimal Power Flow (concept only).	**9**

V	Symmetrical and Unsymmetrical fault calculations using Z_{BUS} – Numerical Problems (Symmetrical faults up to 3 bus systems). Algorithm for SC calculations for balanced 3 phase network – three phase to ground fault only – Numerical problem	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U42G	MACHINE LEARNING	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: The goal of this course to understand a wide variety of learning algorithms and how to evaluate models generated from data. The course also helps to apply the algorithms to a real-world problem, optimize the models learned and report on the expected accuracy that can be achieved by applying the models.

iii) COURSE OUTCOMES

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

CO1	Explain various basic learning techniques.	Understand
CO2	Compare parametric and non-parametric methods.	Understand
CO3	Apply machine learning solutions to classification, regression, and clustering problems.	Apply
CO4	Use Perceptron modelling-based learning techniques and Support Vector Machines to design solutions.	Apply

iv) SYLLABUS

Machine Learning, Examples - Learning Associations, Classification, Regression, Unsupervised Learning, Reinforcement Learning.

Supervised Learning: Learning a Class from Examples, Vapnik-Chervonenkis (VC) Dimension, Noise, Learning Multiple Classes, Regression, Model Selection and Generalization.

Parametric Methods: Maximum Likelihood Estimation, Bias and Variance, Parametric Classification, Regression, Tuning Model Complexity, Model Selection Procedures.

Multivariate Methods: Multivariate Data, Parameter Estimation, Multivariate Normal Distribution, Multivariate Classification, Multivariate Regression.

Clustering: Introduction, Mixture Densities, k-Means Clustering, Expectation-Maximization Algorithm, Choosing the number of clusters.

Nonparametric Methods: Nonparametric Density Estimation.

Decision Tree Based Learning: Univariate Trees, Pruning, Rule Extraction from Trees, Learning Rules from Data, Multivariate Trees.

Neural Networks: Perceptron, training a Perceptron, Learning Boolean functions, Multilayer Perceptrons, MLP as a Universal Approximator, Backpropagation Algorithm.

Local Models: Competitive Learning, Radial Basis Functions, Incorporating Rule-Based Knowledge.

v) (a) TEXT BOOKS

1) Ethem Alpaydın, “Introduction to Machine Learning”, Second Edition, The MIT Press, Cambridge, Massachusetts, London, England, 2010.
2) Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer, 2006. [CB-2006].
3) Tom Mitchell, “Machine Learning”, McGraw-hill, 1997.

(b) REFERENCES

1) Shai Shalev-Shwartz and Shai Ben-David, “Understanding Machine Learning”, Cambridge University Press, 2017.
2) Simon Haykin, “Neural networks and learning machines”, 3rd Edition. Pearson Education India, 2010.
3) Trevor Hastie, Robert Tibshirani and Jerome Friedman, “The Elements of Statistical Learning”, 2nd Edition, 2009.
4) Avrim Blum, John Hopcroft and Ravindran Kannan, “Foundations of Data Science”, January 2017.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction:** What Is Machine Learning, Examples of Machine Learning Applications - Learning Associations, Classification, Regression, Unsupervised Learning, Reinforcement Learning. **Supervised Learning:** Learning a Class from Examples, Vapnik-Chervonenkis (VC) Dimension, Noise, Learning Multiple Classes, Regression, Model Selection and Generalization.	9
II	**Parametric Methods:** Maximum Likelihood Estimation, Evaluating an Estimator: Bias and Variance, Parametric Classification, Regression, Tuning Model Complexity, Model Selection Procedures. **Multivariate Methods:** Multivariate Data, Parameter Estimation, Multivariate Normal Distribution, Multivariate Classification, Multivariate Regression.	9
III	**Clustering:** Introduction, Mixture Densities, k-Means Clustering, Expectation-Maximization Algorithm, Choosing the number of clusters. **Nonparametric Methods:** Nonparametric Density Estimation, Histogram Estimator, Kernel Estimator, k-Nearest Neighbour Estimator. **Decision Tree Based Learning:** Univariate Trees, Pruning, Rule Extraction from Trees, Learning Rules from Data, Multivariate Trees.	9

IV	**Neural Networks:** Understanding the Brain, Neural Networks as a Paradigm for Parallel Processing, Perceptron, Training a Perceptron, Learning Boolean functions, Multilayer Perceptrons, MLP as a Universal Approximator, Backpropagation Algorithm. **Local Models:** Competitive Learning, Radial Basis Functions, Incorporating Rule-Based Knowledge.	**9**
V	**Kernel Machines:** Optimal Separating Hyperplane, The Non separable Case: Soft Margin Hyperplane, ν-SVM, Kernal Trick, Kernel Machines for Regression. **Reinforcement Learning:** K-Armed Bandit, Elements of Reinforcement Learning, Q Learning. **Deep Learning**: Fundamentals, Basic Deep Learning Architectures.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43A	NONLINEAR SYSTEMS	PEC	2	1	0	3	2020

i) PRE-REQUISITE: EE1U30E: Linear Control Systems and EE1U40A: Advanced Control Systems.

ii) COURSE OVERVIEW: Most of the systems that we come across are nonlinear. Nonlinear systems exhibit interesting oscillatory behaviour and indeed unexpected phenomena like limit cycles, bifurcation, chaos etc. The course aims in understanding the basic phenomena of limit cycles, determine their existence and non-existence in systems using various theorems. This course also aims to investigate the behaviour of nonlinear systems, analyze their stability using the Lyapunov direct/indirect methods, frequency-domain methods and design various control schemes. For understanding the concepts, a basic mathematical foundation is also built throughout the course. The course will provide the basis for designing controllers for various applications such as aerospace, power systems, robotics, electric drives etc.

iii) COURSE OUTCOMES

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

CO1	Analyse the qualitative behaviour of nonlinear systems about their equilibrium points.	Analyse
CO2	Identify the existence and uniqueness of solutions of nonlinear differential equations, the existence of periodic orbits/limit cycles for nonlinear systems.	Apply
CO3	Analyse the stability of nonlinear systems.	Analyse
CO4	Develop feedback control systems for nonlinear systems.	Apply

iv) SYLLABUS

Non-linear system characteristics and mathematical modelling of a non-linear system, Stability of a nonlinear system based on equilibrium points, Bifurcation, Phase plane analysis of nonlinear systems.

Periodic solution of nonlinear systems and existence of limit cycle, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria, Existence and uniqueness of solutions to nonlinear differential equations, Lipschitz condition.

Lyapunov stability theorems, the direct method of Lyapunov, Construction of Lyapunov functions.

Passivity and loop transformations, KYP Lemma, Absolute stability, Circle Criterion, Popov Criterion.

Feedback linearization, Stabilization.

v) (a) TEXT BOOKS

1) Khalil H. K., “Nonlinear Systems”, 3rd Edition, Pearson, 2002
2) Gibson J. E., “Nonlinear Automatic Control”, Mc Graw Hill, 1963
3) Slotine J. E. and Weiping Li, “Applied Nonlinear Control”, Prentice-Hall, 1991.

(b) REFERENCES

1) Alberto Isidori, “Nonlinear Control Systems: An Introduction”, Springer-Verlag, 1985.
2) M. Vidyasagar, “Nonlinear Systems Analysis”, Prentice-Hall, India, 1991.
3) Shankar Sastry, “Nonlinear System Analysis, Stability and Control”, Springer, 1999.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Non-linear system characteristics and mathematical modelling of a non-linear system, Classification of equilibrium points, Stability of a nonlinear system based on equilibrium points, Bifurcation (construction not included), Phase plane analysis of nonlinear systems.	**9**
II	Periodic solution of nonlinear systems and existence of limit cycle, Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria, Existence and uniqueness of solutions to nonlinear differential equations (Proofs not required), Lipschitz condition.	**9**
III	Lyapunov stability theorems (Proofs not required)- local stability - local linearization and stability in the small- region of attraction, the direct method of Lyapunov, Construction of Lyapunov functions - Variable gradient and Krasovskii’s methods, La Salles's invariance principle.	**9**
IV	Passivity and loop transformations, KYP Lemma (Proof not required), Absolute stability, Circle Criterion, Popov Criterion.	**9**
V	Feedback linearization, Input state linearization method, Input-output linearization method, Stabilization - regulation via integral control- gain scheduling.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43B	SPECIAL ELECTRIC MACHINES	PEC	3	0	0	3	2020

i) PRE-REQUISITE: EE1U20D: DC Machines and Transformers, EE1U30D: Synchronous and Induction Machines, EE1U30E: Linear Control Systems.

ii) COURSE OVERVIEW: The goal of this course is to get an overview of special electrical machines for control and industrial applications.

iii) COURSE OUTCOMES

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

CO1	Illustrate the principle of PMDC, BLDC motor and its drive circuits.	Understand
CO2	Classify various types of stepper motors with their static and dynamic characteristics and its drive circuits.	Understand
CO3	Explain the principle of reluctance motors and various power converter circuits used in switched reluctance motors.	Understand
CO4	Describe the different types of AC and DC servomotors and list its applications	Understand
CO5	Explain the principle of various single-phase motors and linear motors by enumerating their advantages	Understand

iv) SYLLABUS

Permanent Magnet DC Motors - Brushless DC motor – construction – principle of operation

Stepper motors – Basic principle – different types - modes of excitation – characteristics – applications.

Reluctance motors, Synchronous Reluctance Motor – principle of operation- torque equation –characteristics – applications; Switched reluctance motors – principle of operation – power converter circuits– applications.

AC Servomotors, DC servomotors - principle of operation – types – comparison- applications

Single Phase Special Electrical Machines: AC series Motor, Repulsion Motor, Hysteresis Motor, Universal Motor.

Linear Electric Machines- Linear Induction Motor, Linear Synchronous Motor, Linear Reluctance Motor, Linear Levitation Machines.

v) (a) TEXT BOOKS

1) E. G. Janardanan, “Special Electrical Machines”, PHI Learning Private Limited, 2014.

2) T. J. E. Miller, "Brushless Permanent Magnet and Reluctance Motor Drives", Clarendon Press, Oxford, 1989.

(b) REFERENCES

1) Irving L. Kosow, "Electrical Machinery and Transformers", Pearson, 2nd Edition 2007.
2) Theodore Wildi, "Electric Machines, Drives and Power Systems", Pearson Education, 5th Edition, 2013.
3) Veinott & Martin, "Fractional & Subfractional Horsepower Electric Motors", McGraw Hill, 4th Edition, 1986.
4) Paul Acamley, "Stepping Motor – A Guide to Theory and Practice", IEE London, 2002.
5) B. K. Bose, "Modern power electronics and AC drives", Prentice Hall of India, N J, 2002.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Permanent Magnet DC Motors** – construction – principle of operation. **Brushless DC motor** – construction – principle of Operation – advantages - trapezoidal type - sinusoidal type – comparison – applications - drive circuits.	9
II	**Stepper motors:** Basic Principle - different types – variable reluctance-permanent magnet-hybrid type-comparison-theory of operation-modes of operation-Open loop control of Stepper Motor, Closed loop Control of Stepper Motor, Microprocessor based control of stepper motor- static and dynamic characteristics-applications.	9
III	**Reluctance motors** – principle of operation – torque equation –torque-slip characteristics -applications. **Switched reluctance motors** – principle of operation – power converter circuits – Control of SRM, Rotor Position Sensors, Current Regulators, Microprocessor – Based Control of SRM, Sensorless Control of SRM- torque equation – different types – comparison – applications. **Synchronous Reluctance Motor (SyRM):** Construction of SyRM, Working - Phasor Diagram and Torque Equation - Control of SyRM - Advantages and Applications	10
IV	**AC Servomotors-** Construction - principle of operation - operation– performance characteristics – damped AC servomotors – Drag cup servomotors – applications.	8

	DC servomotors – field and armature-controlled DC servomotors– permanent magnet armature controlled – series split field DC Servomotor.	
V	**Single Phase Special Electrical Machines:** AC series Motor, Repulsion Motor, Hysteresis Motor, Universal Motor- Construction-principle of operation – applications. **Linear Electric Machines:** Linear Induction Motor - Types of forces, Thrust Equation, Thrust speed characteristics, End effect and Transverse Edge effect; Linear Synchronous Motor, Linear Reluctance Motor, Linear Levitation Machines: - Advantages, Disadvantages, Application.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43C	POWER QUALITY	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: The objective of this course is to introduce the fundamental concepts of power quality. This course covers different power quality issues and its mitigation methods.

iii) COURSE OUTCOMES

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

CO1	Classify the sources and effects of power quality problems.	Understand
CO2	Apply Fourier Transform concepts for harmonic analysis.	Apply
CO3	Explain the important aspects of power quality monitoring.	Understand
CO4	Illustrate power quality mitigation techniques.	Understand
CO5	Explain power quality issues in grid connected renewable energy systems.	Understand

iv) SYLLABUS

Power quality phenomenon, Sources and effects of power quality problems, classification and origin of power quality disturbances.

Harmonics mechanism of harmonic generation, Harmonic sources, Harmonic analysis using Fourier series and Fourier transforms.

Harmonic indices, Power quality Monitoring

Mitigation of Power quality problems, passive filters, active filters, hybrid filters, DVR, DSTATCOM and UPQC.

Power factor correction, Single phase active power factor converter, Power Quality issues of Grid connected Renewable Energy Systems, Grounding and wiring.

v) (a) TEXT BOOKS

1) R. C. Dugan, M. F. Me Granaghen, H. W. Beaty, “Electrical Power System Quality”, McGraw-Hill, 2012.
2) C. Sankaran, “Power Quality”, CRC Press, 2002.
3) G. T. Heydt, “Power Quality”, Stars in circle publication, Indiana, 1991.
4) Jose Arillaga, Neville R. Watson, “Power System Harmonics”, Wiley, 1997.
5) Math H. Bollen, ‘Understanding Power Quality Problems’ Wiley-IEEE Press, 1999.
6) Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, “Power Quality problems and Mitigation Techniques”, John Wiley and Sons Ltd, 2015.

(b) REFERENCES

1) Surajit Chattopadhyay, ‘Electric power quality’ – Springer, 2011
2) Angelo Baggini (Ed.) Handbook of Power Quality, Wiley, 2008.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Power quality phenomenon** - Sources and effects of power quality problems, Need for concern of Power quality, types of power quality disturbances –Transients – classification and origin, Short duration voltage variation – interruption, sag, swell, Long duration voltage variation, voltage unbalance, waveform distortion - notching, harmonics and voltage flicker.	9
II	**Harmonics** - mechanism of harmonic generation, Triplen harmonics, Harmonic sources – switching devices, arcing devices and saturable devices, Effects of harmonics on power system equipment and loads – transformers, capacitor banks, motors and telecommunication systems, Effect of triplen harmonics on neutral current, line and phase voltages. Harmonic analysis using Fourier series and Fourier transforms – simple numerical problems.	10
III	**Harmonic indices** (CF, DF, THD, TDD, TIF, DIN, C – message weights), Displacement and total power factor. Overview of power quality standards: IEEE 519, IEEE 1433 and IEC 61000. Power quality Monitoring: Objectives and measurement issues, different monitoring instruments – Power quality analyzer, harmonic spectrum analyzer, flicker meters.	9
IV	**Mitigation of Power quality problems** - Harmonic elimination - Design simple problems and analysis of passive filters to reduce harmonic distortion – demerits of passive filters –description of active filters - shunt, series, hybrid filters, sag and swell correction using DVR. Power quality conditioners - DSTATCOM and UPQC - Configuration and working.	9
V	**Power factor correction** – Single phase active power factor converter – circuit schematic and control block diagram. Power Quality issues of Grid connected Renewable Energy Systems – operating conflicts. Grounding and wiring– reasons for grounding – wiring and grounding problems - solutions to these problems.	8
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43D	COMPUTER NETWORKS	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: The course introduces main concepts of networking; application areas; classification; reference models; transmission environment; technologies; routing algorithms; OSI and TCP/IP protocols; Functions and purposes of various layers in networking: reliable data transferring methods; application protocols; network security; management systems; perspectives of communication networks.

iii) COURSE OUTCOMES

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

CO1	Explain the computer networks, layered architecture, protocols and physical media used for setting up a network.	Understand
CO2	Compare the role of Data link layer, role of the MAC sub layer and networking devices in Ethernets and wireless LANs	Understand
CO3	Illustrate routing algorithms and congestion control algorithms and explain ways to achieve good quality of service.	Understand
CO4	Illustrate the IP address classes, ICMP protocols and other external routing protocols.	Understand
CO5	Explain the services provided by the transport layer and application layer.	Understand

iv) SYLLABUS

Uses of computer networks, Network hardware, Network software, Reference models, Physical Layer, Performance indicators

Data link layer, Medium Access Control (MAC) sublayer, Multiple access protocols, Ethernet, Wireless LANs.

Network layer design issues. Routing algorithms, Congestion control algorithms, Quality of Service (QoS), Requirements and techniques.

IPv4 protocol, IPv6, Internet Control Protocols, Internet multicasting.

Transport service, User Datagram Protocol (UDP), Transmission Control Protocol (TCP), Application Layer –Domain Name System (DNS), Electronic mail, World Wide Web (WWW).

v) (a) TEXT BOOKS

1) Andrew S. Tanenbaum, David J. Wetherall, “Computer Networks”, 5th Edition, Pearson Education, 2010.

2) Behrouz A Forouzan, "Data Communication and Networking", 5th Edition, McGraw Hill Higher Education, 2012.

(b) REFERENCES

1) Larry L Peterson and Bruce S Dave, "Computer Networks – A Systems Approach", 5th Edition, Elsevier, 2012.
2) Fred Halsall, "Computer Networking and the Internet", 5th Edition, Pearson Education, 2005.
3) James F. Kurose, Keith W. Ross, "Computer Networking: A Top-Down Approach", 6th Edition, Pearson Education, 2013.
4) Keshav, "An Engineering Approach to Computer Networks", Addison Wesley, 1998.
5) W. Richard Stevens. TCP/IP Illustrated Volume 1, Addison-Wesley, 2005.
6) William Stallings, Computer Networking with Internet Protocols, Prentice-Hall, 2004.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction and Physical Layer:** Introduction – Uses of computer networks, Uses of computer networks, Network hardware, Network software - Protocol hierarchies – Design issues for the layers – Connection oriented versus connectionless service. Reference models – The OSI reference model, The TCP/IP reference model, Comparison of OSI and TCP/IP reference models. Physical Layer – Transmission media overview – Twisted pair and fiber optics. Performance indicators – Bandwidth, Throughput, Latency, Bandwidth–Delay product.	9
II	**Data Link Layer:** Data link layer - Data link layer design issues, Error detection and correction, Sliding window protocols, Medium Access Control (MAC) sublayer, Channel allocation problem, Multiple access protocols – CSMA, Collision free protocols. Ethernet – Switched Ethernet, fast Ethernet and gigabit Ethernet. Wireless LANs - 802.11 – Architecture and protocol stack, Use of Bridges, Repeaters, Hubs, Switches, Routers and Gateways.	9
III	**Network Layer:** Network layer design issues, Routing algorithms, The Optimality Principle, Shortest path routing, Flooding, Distance Vector Routing, Link State Routing, Routing for mobile hosts, Congestion control algorithms – Approaches to congestion control (Details not required). Quality of Service (QoS) - Requirements, Techniques for achieving good QoS – Traffic shaping, Packet scheduling.	9

IV	**Network Layer in the Internet:** Internet Protocol (IP) - IPv4 protocol, IP addresses, IPv6, Internet Control Protocols - Internet Control Message Protocol (ICMP), Address Resolution Protocol (ARP), Dynamic Host Configuration Protocol (DHCP), Open Shortest Path First (OSPF) Protocol, Border Gateway Protocol (BGP), Internet multicasting.	**9**
V	**Transport Layer and Application Layer:** Transport service – Services provided to the upper layers Transport service primitives. User Datagram Protocol (UDP) – Introduction, Remote procedure call Transmission Control Protocol (TCP) – Introduction, TCP service model, TCP protocol, TCP segment header, Connection establishment & release Application Layer –Domain Name System (DNS) – overview of DNS name space and Name servers, Electronic mail – Architecture and services- SMTP – IMAP - POP3, World Wide Web (WWW) - Architectural overview, HTTP, File Transfer Protocol (FTP).	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43E	DESIGN OF POWER ELECTRONIC SYSTEMS	PEC	2	1	0	3	2020

i) PRE-REQUISITE: EE1U30G: Power Electronics.

ii) COURSE OVERVIEW: The course mainly deals with the design of various power semiconductor switches, protection circuits and magnetic component for power electronic circuits. Design and selection of appropriate passive components and filters for converters is analysed in detail in this course.

iii) COURSE OUTCOMES

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

CO1	Design gate drive circuits for various power semiconductor switches.	Apply
CO2	Design protection circuits for various semiconductor devices.	Apply
CO3	Select appropriate passive components for power electronic circuits.	Apply
CO4	Design the magnetic components for power electronic circuits.	Apply
CO5	Design signal conditioning circuits and passive filters for converters.	Apply

iv) SYLLABUS

Gate drive requirements and gate/base drive design for SCRs, BJTs, MOSFETs, IGBTs, Gate drive design using discrete components, use of ICs such as DS0026, TLP250Boot-strap technique for gate drives using gate drive IC IR 2110.

Design of protection elements - Snubber circuits, Snubber design for step-down converter, Short-circuit and over-current protection in IGBTs, desaturation protection, Thermal protection, cooling, design and selection of heat sinks.

Inductors, Capacitors, Design of filters, Resistors, Resistors for special purpose.

Magnetic materials and cores: amorphous, ferrite and iron cores-Inductor and transformer design based on area-product approach. Magnetic characteristics and selection based on loss performance and size. Thermal considerations, leakage inductance.

Design of current transformers for power electronic applications, resistive shunts, typical design based on hall-effect sensors, signal conditioning circuits. Minimizing stray inductance in drive circuit, shielding and portioning of drive circuit.

v) (a) TEXT BOOKS

1) Mohan N., T. M. Undeland and W. P. Robbins., Power Electronics, Converters, Applications & Design, Wiley-India, 2002.
2) L. Umanand, Power Electronics – Essentials & Applications, Wiley-India, 2009.

(b) REFERENCES

1) V. Ramanarayanan, Course material on ‘Switched mode power conversion’ 2007.
2) Daniel W. Hart, Power Electronics, Tata McGraw-Hill Education, 2011.
3) Erickson, Robert W., and Maksimovic, Dragan, Fundamentals of Power Electronics, 1997.
4) Krein P. T., Elements of Power Electronics, Oxford University Press, 1998.
5) Joseph Vithayathil, Power Electronics: Principles and Applications, McGraw-Hill College; International Edition, 1995.
6) Singh M. D. and K. B. Khanchandani, Power Electronics, Tata McGraw Hill, New Delhi, 2008.
7) Muhammad H. Rashid, Power Electronics Circuits, Devices and Applications, Pearson Education, 2014.
8) P.S. Bimbhra, Power Electronics, Khanna Publishers, New Delhi, 1990.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Gate and base drive design**: Gate drive requirements and gate/base drive design for SCRs, BJTs, MOSFETs, IGBTs-Gate drive design using discrete components - open collector, totem pole, non-isolated and isolated- optocoupler, pulse transformer based, use of ICs such as DS0026, TLP250- High side and low side switch driving using isolated gate drivers. Boot-strap technique for gate drives using gate drive IC IR 2110.	10
II	**Design of protection elements**: Snubber circuits: Function and types of Snubber circuits, design of turn -off and turn-on snubber. Snubber design for step-down converter. Short-circuit and over-current protection in IGBTs, desaturation protection. Thermal protection, cooling, design and selection of heat sinks (natural cooling only).	9
III	**Passive elements in Power electronics**: Inductors: types of inductors and transformer assembly-. Capacitors: types of capacitors used in power electronic circuits, selection of capacitors, dc link capacitors in inverters, filter capacitors in dc-dc and inverter circuits, equivalent series resistance and equivalent series Inductance of capacitors and their effects in converter operation. Design of filters - input and output filters - typical filter design for single phase and three phase inverters - LC filter - corner frequency selection - harmonic filtering performance – design constraints. Resistors: power resistors, use in	9

	snubbers. Resistors for special purpose: high voltage resistors and current shunts.	
IV	**Magnetics design**: Magnetic materials and cores: amorphous, ferrite and iron cores-Inductor and transformer design based on area-product approach. Magnetic characteristics and selection based on loss performance and size, eddy current and hysteresis loss. Thermal considerations, leakage inductance, comparison of sizes of transformer and inductor, wire selection and skin effect.	**9**
V	**Measurements and signal conditioning:** Design of current transformers for power electronic applications, resistive shunts, hall-effect based voltage and current sensors, typical design based on hall-effect sensors, signal conditioning circuits - level shifters, anti-aliasing filters. Minimizing stray inductance in drive circuit, shielding and portioning of drive circuit, reduction of stray inductance in bus bar. Introduction to Intelligent Power Module.	**8**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43F	HVDC & FACTS	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: This course introduces HVDC concepts and analysis of HVDC systems. It also provides a detailed study of FACTS devices.

iii) COURSE OUTCOMES

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

CO1	Explain current source and voltage source converters for HVDC systems.	Understand
CO2	Illustrate the control schemes for HVDC systems.	Understand
CO3	Explain the need for FACTS devices.	Understand
CO4	Classify reactive power compensators in power system.	Understand
CO5	Interpret series and shunt connected FACTS devices for power system applications.	Understand

iv) SYLLABUS

Introduction to HVDC System - Types of HVDC system, Current Source Converters (CSC), Voltage Source Converters (VSC).

HVDC Controls- Functions of HVDC Controls - Current Margin Control Method - Current Control at the Rectifier - Inverter Extinction Angle Control.

Introduction to FACTS - Needs and emergence of FACTS - Types of FACTS controllers

Shunt and Series Facts Devices (Principle of operation and schematic) - Static shunt Compensator and STATCOM. Static Series compensator and switching converter type Series Compensators.

UPFC AND IPFC- Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC) (Principle of operation and schematic).

v) (a) TEXT BOOKS

1) Vijay K Sood, “HVDC and FACTS Controllers”, Springer, 2004
2) N.G. Hingorani and L.Gyugyi, “Understanding FACTS”, IEEE Press 2000.

(b) REFERENCES

1) Surajit Chattopadhyay, ‘Electric power quality’ – Springer, 2011.
2) Angelo Baggini (Ed.) Handbook of Power Quality, Wiley, 2008.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to HVDC System** Comparison of AC and DC Transmission - Types of HVDC system - Current Source Converters - Analysis without and with overlap period. Voltage Source Converters (VSC) - VSC with AC current control and VSC with AC voltage control.	8
II	**HVDC Controls** Functions of HVDC Controls - Equivalent circuit for a two terminal DC Link - Control Basics for a two terminal DC Link - Current Margin Control Method - Current Control at the Rectifier - Inverter Extinction Angle Control - Hierarchy of Controls.	9
III	**Introduction to FACTS** Power flow in Power Systems – Voltage regulation and reactive power flow control in Power Systems - Power flow control -Constraints of maximum transmission line loading - Needs and emergence of FACTS - Types of FACTS controllers-Advantages and disadvantages Transmission line compensation- Uncompensated line -shunt compensation - Series compensation -Phase angle control.	8
IV	**Shunt and Series Facts Devices** Static shunt Compensator - Objectives of shunt compensations - Variable impedance type VAR Generators -TCR, TSR, TSC, FC-TCR (Principle of operation and schematic) and -STATCOM (Principle of operation and schematic). Static Series compensator - Objectives of series compensations-Variable impedance type series compensators - GCSC. TCSC, TSSC (Principle of operation and schematic) Switching converter type Series Compensators-(SSSC) (Principle of operation and schematic).	11
V	**UPFC AND IPFC** Unified Power Flow Controller: Circuit Arrangement, Operation of UPFC- Basic principle of P and Q control- independent real and reactive power flow control – Applications. Introduction to interline power flow controller (IPFC) (Principle of operation and schematic). Thyristor controlled Voltage and Phase angle Regulators (Principle of operation and schematic).	9
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U43G	ADVANCED ELECTRONIC DESIGN	PEC	2	1	0	3	2020

i) **PRE-REQUISITE:** EE1U20C: Analog Electronics, EE1U30B: Microprocessors and Microcontrollers.

ii) **COURSE OVERVIEW**: This course makes a student capable to design a system that senses a physical quantity, condition the sensed signal and digitally measure it.

iii) **COURSE OUTCOMES**

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

CO1	Explain the frequency response characteristics of op-amps along with its circuit properties.	Understand
CO2	Develop advanced op-amp circuits which serve as building blocks to more complex digital and analog circuits.	Apply
CO3	Choose active filters as per situational and system demands.	Apply
CO4	Develop sensor circuits for physical quantity measurements.	Apply
CO5	Analyse the performance of microcontroller interfacing with analog domain for real world applications.	Analyse

iv) **SYLLABUS**

Op-amp Frequency response - compensating networks, non-compensated Op-Amps, High-frequency Op-amp equivalent circuit, open loop voltage gains as a function of frequency, closed loop frequency response.

Advanced Op-amp applications, voltage-to-current converters, current-to-voltage converters, voltage-to-frequency and frequency-to-voltage converters, Sample and hold circuit, performance characteristics, Phase Locked Loop (PLL).

Filters, Realisation of Active filters - Transfer function synthesis, Introduction to VCVS filters, First order low pass Butterworth filter design and frequency scaling, second order low pass Butterworth filter design.

IC Sensors, MEMS.

ADC, DAC and sensor interfacing to a typical Microcontroller, ADC programming / interfacing in Atmega 32.

v) (a) **TEXT BOOKS**

1) L. K. Maheswari, M.M.S Anand, "Analog Electronics", Prentice Hall India Learning Private Limited, 2005.

2) Muhammad Ali Mazidi, Sarmad Naimi, Sepehr Naimi, “The AVR Microcontroller and Embedded Systems: Using Assembly and C”, Pearson Education India, 1st Edition, 2013.

(b) REFERENCES

1) Ramakant A Gayakwad, “Op-amps and Linear Integrated Circuits”, Pearson Education; 4th Edition, 2015
2) D Roy Choudhury, “Linear Integrated Circuits”, New Age International Publishers; 5th Edition, 2018
3) Sergio Franco, “Design with operational amplifier and analog circuits” 3rd Edition, McGraw Hill, 2001
4) Elliot Williams, “Make: AVR Programming-Learning to write software for hardware”, 1st Edition, Shroff/Maker Media, 2014.
5) Data sheets and application notes of relevant ICs mentioned in the syllabus.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Op-amp Frequency response**-compensating networks, frequency response of internally compensated Op-Amps, frequency response of non-compensated Op-Amps, High-frequency Op-amp equivalent circuit, open loop voltage gains as a function of frequency, closed loop frequency response, circuit stability, slew rate, slew rate equation, effect of slew rate.	9
II	**Advanced Op-amp applications**-Precision rectifier, peak detector and log-converter, antilog amplifier, current mirror, voltage-to-current and current-to-voltage converters, voltage-to-frequency and frequency-to-voltage converters, Sample and hold circuit- Basic Circuits, practical sample and hold circuits, performance characteristics. Phase Locked Loop (PLL)- Operating principles, block diagrams, monolithic PLL, IC 565 PLL applications.	9
III	**Filters** -Introduction to basic theory of filters: Filter responses - Active vs passive filters, Low pass, Band-pass, high-pass, band-stop filters and their characteristics - first order vs higher order filters - Realisation of Active filters - Transfer function synthesis, Introduction to VCVS filters - Sallen Key based (VCVS) filters - Butterworth filters- First order low pass butterworth filter design and frequency scaling, second order low pass butterworth filter design.	10
IV	**IC Sensors**- IC sensors for different energy forms, thermal energy sensors, mechanical energy sensors, radiant energy sensors, magnetic	8

	energy sensors, chemical energy sensors. MEMS-typical IC sensors, temperature energy sensors- LM35 and AD590, pressure sensors-MPX2010, accelerometer-ADXL202E, ultrasonic sensor-873P, infrared thermometer modules-MLX90601 family, Hall effect direction detection sensor - A3422xka.	
V	**ADC, DAC and sensor interfacing to a typical Microcontroller-** Review of ADC and DAC characteristics-resolution, conversion time, parallel versus serial ADC with ADC0848 and MAX1112 examples, sampling requirements, ADC programming / interfacing in Atmega 32, interfacing temperature sensor LM35 with Atmega32, DAC 0808 interfacing with Atmega 32.	**9**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44A	ELECTRIC AND HYBRID VEHICLES	PEC	3	0	0	3	2020

i) PRE-REQUISITE: EE1U20E: DC Machines and Transformers, EE1U30G: Power Electronics, EE1U30C: Synchronous and Induction machines.

ii) COURSE OVERVIEW: The main goal of this course is to expose the students to the fundamental concepts and trends in electric, hybrid and autonomous vehicles and it also discusses how to choose proper energy storage devices for vehicle applications. It gives an insight into the electric machines used and its control for application of electric vehicles. It also intends to deliver various charging systems and various communication protocols.

iii) COURSE OUTCOMES

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

CO1	Explain the basic concepts of Conventional, Electric, Hybrid Electric and Autonomous Vehicles.	Understand
CO2	Compare various configurations of Electric and Hybrid Electric drive trains based on application	Understand
CO3	Explain the propulsion unit for electric and hybrid vehicles.	Understand
CO4	Choose various energy storage devices based on their performance requirements for EV application and explain EV charging systems.	Apply
CO5	Select drive systems and various communication protocols for Electric Vehicles.	Apply

iv) SYLLABUS

Conventional Vehicles, Basics of vehicle performance, Basic Architecture of hybrid traction, Power flow control.

Electric Propulsion unit, Configuration and control of DC motor drives, Induction Motor drives, PM and SRM motor drives.

Energy Storage Requirements in Hybrid and Electric Vehicles, Battery, fuel cell, flywheel and supercapacitor-based energy storage.

Design of electric and hybrid electric vehicle, sizing of components.

Communication Systems, Energy Management Strategies, EV charging technologies and policies.

v) (a) TEXT BOOKS

1) Iqbal Husain: Electric and Hybrid vehicles: Design Fundamentals, CRC press, 3rd Edition 2003.

2) Ehsani M., Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2005.
3) Gianfran C O Pistoia, Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market, Elsevier,2010.
4) Chan C. C. and Chau K. T., Modern Electric Vehicle Technology, OXFORD University Press, 2001.

(b) REFERENCES

1) James Larminie, John Lowry, Electric Vehicle Technology Explained, 2nd Edition Wiley 2003.
2) Fuhs A. E., Hybrid Vehicles and the Future of Personal Transportation, CRC Press, 2009.
3) Chris Mi, Abul Masrur M., Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, 2^{nd} Edition, John Wiley & Sons Ltd,2017.
4) Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, 2013.

(c) ONLINE RESOURCES

1) NPTEL courses/Materials (IITG, IITM, IITD) – Electric and Hybrid vehicles
   https://nptel.ac.in/courses/108/103/108103009/ (IIT Guwahati)
   https://nptel.ac.in/courses/108/102/108102121/ (IIT Delhi)
   https://nptel.ac.in/courses/108/106/108106170/ (IIT Madras)
2) FOC Control - video lecture by Texas Instruments
   https://training.ti.com/kr/field-oriented-control-permanent-magnet-motors
3) Sensored and sensorless FOC control of PMSM motors – Application notes (TI, MATLAB)
   https://www.ti.com/lit/an/sprabz0/sprabz0.pdf?ts=1620018267996&ref_url=https%253A%252F%252Fwww.google.com%252F
   https://in.mathworks.com/help/physmod/sps/ref/pmsmfieldorientedcontrol.html
4) Electric Vehicle Conductive AC Charging System
   https://dhi.nic.in/writereaddata/UploadFile/REPORT%20OF%20COMMITTEE636469551875975520.pdf
   Electric Vehicle Conductive AC Charging System

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Hybrid Electric Vehicles**: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. **Conventional Vehicles**: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance. **Autonomous Vehicles:** Levels of automation, significance & effects of automation in vehicles	9
II	**Hybrid Electric Drive-trains**: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. **Electric Drive-trains:** Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.	9
III	**Electric Propulsion unit:** Introduction to electric components used in hybrid and electric vehicles **DC Drives**: Review of Separately excited DC Motor control – Speed and torque equations - Independent control of orthogonal flux and torque - Closed loop control of speed and torque (block diagram only) **PMSM Drives**: PMSM motor basics – Independent control of orthogonal flux and torque (concept only)- Field Oriented Control (FOC) – Sensored and sensorless control (block diagram only)	10
IV	**Energy Storage**: Introduction to energy storage requirements in Hybrid and Electric Vehicles- Battery based energy storage systems, Battery Management System, Types of battery- Fuel Cell based energy storage systems- Supercapacitors-Hybridization of different energy storage devices **Overview of Electric Vehicle Battery Chargers** - On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams. Types of charging stations - AC Level 1 & 2, DC - Level 3 –V2G concept-Types of Connectors - CHAdeMO, CCS Type1 and 2, GB/T - PIN diagrams and differences	10
V	**Sizing the drive system:** Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics **Vehicle Communication protocols**: Need & requirements - Functions of Control Pilot (CP) and Proximity Pilot (PP) pins, Communication Protocols - CAN, LIN, FLEXRAY (Basics only)- Power line communication (PLC) in EV	7
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44B	INTERNET OF THINGS	PEC	3	0	0	3	2020

i) **PRE-REQUISITE:** EE1U30B: Microprocessors and Microcontrollers.

ii) **COURSE OVERVIEW**: The goal of this course is to introduce students to the different architectures used for connected smart devices. This course will enable students to program embedded devices used in different levels of IoT application. It also aims to expose students to design and develop Internet of Things based solution.

iii) **COURSE OUTCOMES**

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

CO1	Explain the role of computer networks in IoT.	Understand
CO2	Classify the different communication standards for IoT applications.	Understand
CO3	Relate suitable sensors to get the data from the "things" and upload to cloud	Understand
CO4	Develop programs for IoT devices using micropython language.	Apply
CO5	Develop an IoT based solution for the problem at hand.	Apply

iv) **SYLLABUS**

Physical Design of IoT, Logical design of IoT, Design Challenges.

Internet Protocols and standards, IP addressing, Physical layer components, Sizing of networks.

IoT and M2M Communications, Big Data Analytics.

Sensor technologies for IoT, data acquisition using embedded devices, data logging to cloud services-protocols and programming.

Embedded devices for IoT: Sensor interfacing and data acquisition using target boards like Raspberry Pi 4B, ARM EMBED, ESP32, Arduino boards.

IoT Applications.

v) **(a) TEXT BOOKS**

1) Simone Cirani, Internet of things: Architecture, protocols and standards, Wiley, 2019.
2) Charles Bell, MicroPython for the Internet of Things: A Beginner's Guide to programming with Python on Microcontrollers, Apress, 2017.
3) B.K Thripathy, J Anuradha, Internet of things (IoT) - technologies, applications, challenges and solutions, CRC press, 2018.
4) Raj Kamal, Internet of Things: Architecture and Design Principles, McGraw Hill (India) Private Limited, 2017.

5) Peter Waher, Mastering Internet of Things: Design and create your own IoT applications using Raspberry Pi 3, 1st Edition, Packt Publishing, 2018.

(b) REFERENCES

1) Qusay F. Hassan, Internet of Things A to Z: Technologies and applications, IEEE press, 2018
2) Gary Smart, Practical Python Programming for IoT: Build advanced IoT projects using Raspberry Pi 4, MQTT, RESTful APIs, Web Sockets, and Python 3, Packt Publishing Ltd, 2020
3) Gaston C. Hillar, MQTT Essentials - A Lightweight IoT Protocol, Packt Publishing Ltd, 2017.
4) Alasdair Gilchrist, Industry 4.0 The Industrial Internet of Things, Apress, 2016.
5) David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry, IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, First Edition, Cis CO Press, 2017.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction**: Definition and Characteristics of IoT, Physical Design of IoT: Things in IoT, IoT Protocols, Logical Design of IoT: IoT Functional Blocks, IoT Communication Models, IoT Communication APIs, IoT Enabling Technologies. Design challenges – power consumption and security issues. **Computer networks**: Internet-protocols and standards-OSI model-TCP/IP protocol suite. IP addressing – IPv4 and IPv6, Physical layer components- Switch, Router, Access point, station, Server, Client, Port, Gateway. Sizing of network- LAN, MAN, WAN	8
II	**IoT and M2M Communications:** Introduction, M2M, M2M applications, Differences between M2M and IoT, M2M standards- Bluetooth-LE, Zigbee, NFC, Wifi and LoRaWAN. Data logging and cloud services- CoAP, MQTT and JSON. Big data analytics (concepts only)	8
III	**Sensor technologies for IoT-** Wireless sensor network. Voltage, Current, Speed, Temperature and humidity sensors and data acquisition using embedded devices- block diagram. Data logging to cloud services- protocols and programming.	9
IV	**Embedded devices for IoT.** Introduction to Python programming and embedded programming using micropython. Sensor interfacing and data acquisition using target boards like Raspberry Pi 4B, ARM EMBED, ESP32, Arduino boards. Programming examples for data	10

	logging to cloud using micropython. (Assignments on hardware implementation using these or similar boards may be given.)	
V	**IoT applications:** Energy management and smart grid applications. IoT based home automation, Smart metering for electricity consumers. IoT based weather stations, Agriculture- smart farming, Automobile IoT- Electric vehicles-platform and software, Industrial IoT.	**10**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance : 10 marks

CA Exams (2 numbers) : 25 marks

Assignment/Project/Case study etc. : 15 marks

Total : 50 marks

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44C	ENERGY STORAGE SYSTEMS	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: This course is to expose the students to the fundamental concepts of energy storage systems used in different applications.

iii) COURSE OUTCOMES

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

CO1	Interpret the role of energy storage in power systems.	Understand
CO2	Classify thermal, kinetic and potential storage technologies and their applications.	Understand
CO3	Compare Electrochemical, Electrostatic and Electromagnetic storage technologies.	Understand
CO4	Apply energy storage technology in renewable energy integration.	Apply
CO5	Enumerate energy storage technology applications for smart grids.	Understand

iv) SYLLABUS

Introduction to energy storage in power systems- General considerations

Overview on Energy storage technologies - Thermal energy, Potential energy: Pumped hydro-Compressed Air, Kinetic energy: Mechanical- Flywheel, Power to Gas

Overview on Energy storage technologies- Batteries- Parameters, Fuel cells, Electrostatic energy Electromagnetic energy, Comparative analysis, Environmental impacts.

Energy storage and renewable power sources- Wave - Wind – Tidal – Hydroelectric - Solar thermal technologies and Photovoltaics, Storage role in isolated and integrated power systems with renewable power sources.

Energy storage Applications - Smart grid, Smart house, Mobile storage system- Electric vehicles – Grid to Vehicle (G2V)-Vehicle to Grid (V2G), Battery SCADA, Hybrid energy storage systems.

v) (a) TEXT BOOKS

1) Osaka T., Datta M., “Energy Storage Systems in Electronics-New Trends in Electrochemical Technology”, CRC Press 2000.
2) Rand D.A.J., Moseley P.T., Garche J. and Parker C.D., “Valve regulated Lead–Acid Batteries”, Elesevier 2004.

(b) REFERENCES

1) Broussely M. and Pistoia G., “Industrial Applications of Batteries from Cars to Aerospace and Energy Storage”, Elsevier, 2007

2) Nazri G. A. and Pistoia G., "Lithium Batteries – Science and Technology", Kluwer Academic Publishers, 2004
3) Larminie J., Dicks A. and Wiley-Blackwell, "Fuel Cell Systems Explained", 2^{nd} Edition, Wiley Publications, 2013.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to energy storage in power systems:** Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, comparison of storages and applications, Energy storage in the power and transportation sectors. Importance of energy storage systems in electric vehicles, Current electric vehicle market. Need and role of energy storage systems in power systems, General considerations, Energy and power balance in a storage unit.	9
II	**Overview on Energy storage technologies:** Thermal energy: General considerations - Storage media- Containment- Thermal energy storage in a power plant, Potential energy: Pumped Hydro-Compressed Air, Kinetic energy: Mechanical - Flywheel, Power to Gas - Hydrogen - Synthetic methane	9
III	**Overview on Energy storage technologies:** Electrochemical energy -Batteries- Battery parameters: C-rating -SoC- DoD- Specific Energy-Specific power (numerical examples), Fuel cells, Electrostatic energy (Super Capacitors), Electromagnetic energy (Super conducting Magnetic Energy Storage), Comparative analysis, Environmental impacts of different technologies.	9
IV	**Energy storage and renewable power sources:** Types of renewable energy sources: Wave - Wind – Tidal – Hydroelectric - Solar thermal technologies and Photovoltaics, Storage role in isolated power systems with renewable power sources, Storage role in an integrated power system with grid-connected renewable power sources.	9
V	**Energy storage Applications:** Smart grid, Smart microgrid, Smart house, Mobile storage system: Electric vehicles – Grid to Vehicle (G2V)-Vehicle to Grid (V2G), Management and control hierarchy of storage systems - Aggregating energy storage systems and distributed generation (Virtual Power Plant Energy Management with storage systems), Battery SCADA, Hybrid energy storage systems: configurations and applications.	9
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44D	ROBUST AND ADAPTIVE CONTROL	PEC	2	1	0	3	2020

i) PRE-REQUISITE: EE1U30E: Linear Control Systems and EE1U40A: Advanced Control Systems.

ii) COURSE OVERVIEW: This course provides a mathematical introduction to the field of robust and adaptive control. The concepts in this course are considered advanced in the field of modern control theory.

iii) COURSE OUTCOMES

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

CO1	Develop the norms of transfer functions and transfer function matrices.	Apply
CO2	Interpret the robustness of the control system using Robust Stability and Robust Performance measures.	Understand
CO3	Explain the synthesis of stabilizing controllers in H_2 and H_∞.	Understand
CO4	Construct sliding mode controllers for a system.	Apply
CO5	Construct adaptive controllers for a system.	Apply

iv) SYLLABUS

Introduction to robust control, Computing of H2 and Hinf norms (transfer function and transfer matrices), Computing of L2 and Linf Norms, singular value decomposition. Proper systems, Controllability and Observability Grammians, Concept of Minimal Realisation, Stabilizability and Detectability, Packed form notation.

Single degree and two degree of freedom Robust Control Systems - System Sensitivity, Sensitivity and Complementary Sensitivity peak selection, Well-Posedness of Feedback Loop, Internal Stability. Model Uncertainty, linear fractional transformation. Nominal Performance, Nominal Stability, Robust Performance and Robust Stability.

Introduction to Regulator problem, Standard LQR and LQG problem, Introduction to H2 control, Hinf control, mu Synthesis.

Introduction to Variable Structure Systems (VSS), Introduction to sliding mode control, Design of sliding mode controllers using pole placement, LQR method.

Adaptive Control, effects of process variation, Real Time Parameter Estimation, Self Tuning Regulators, Model Reference Adaptive systems (MRAS).

v) (a) TEXT BOOKS

1) Sigurd Skogestad and Ian Postewaite, “Muti-variable Feedback Design” 2nd Edition, John Wiley, 2005.
2) Kemin Zhou and Doyle J.C, “Essentials of Robust Control”, Prentice-Hall, 1998.
3) C Edwards and Sarah Spurgeon, “Sliding Mode Control: Theory and Applications”, Taylor and Francis,1998.
4) K. J. Astrom and B. Wittenmark, “Adaptive Control”, 2nd Edition, Addison-Wesley, 1995.

(b) REFERENCES

1) P C Chandrasekharan, “Robust Control of Linear Dynamical Systems”, Academic Press, 1996.
2) Richard C. Dorf, Robert H. Bishop, “Modern Control Systems”, Pearson Education, 2008.
3) S. Sastry and M. Bodson, “Adaptive Control”, Prentice-Hall, 1989.
4) John C. Doyle, Bruce A. Francis, Allen R. Tannenbaum, “Feedback Control Theory”, Macmillan Pub. Co, 1992.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to robust control- Vector space, linear subspaces, Norm and inner product of real vectors and matrix, Hilbert Spaces, H_2 and H_{inf} Spaces - Computing of H_2 and H_{inf} norms (transfer function and transfer matrices), Computing of L_2 and L_{inf} Norms, singular value decomposition. Proper systems, Controllability and Observability Grammians, Concept of Minimal Realisation, Stabilizability and Detectability, Packed form notation- various configurations.	**9**
II	Single degree and two degree of freedom Robust Control Systems - System Sensitivity, Relation between Sensitivity and disturbance inputs in a feedback system, Sensitivity and Complementary Sensitivity function. Sensitivity and Complementary Sensitivity peak selection- its relation to gain and phase margin - Weighted Sensitivity and weighted complementary sensitivity. Well-Posedness of Feedback Loop, Internal Stability. Model Uncertainty - Classification of uncertainties -parametric, structured and unstructured-m-delta configuration- linear fractional transformation-examples. Nominal Performance, Nominal Stability, Robust Performance and Robust Stability-Small Gain Theorem, Concept of loop shaping.	**9**
III	Introduction to Regulator problem, Standard LQR and LQG problem, control-Lack of Robustness, Introduction to H2 control, Hinf control, mu Synthesis.	**9**

IV	Introduction to Variable Structure Systems (VSS) - examples, Introduction to sliding mode control- -sliding surface- examples of dynamical systems with sliding modes, reaching laws-reachability condition, Invariance conditions- chattering - equivalent control, Design of sliding mode controllers using pole placement, LQR method.	**9**
V	Adaptive Control, effects of process variation - Adaptive Schemes - Adaptive Control problem - Applications – Real Time Parameter Estimation: Introduction - Regression Models - Recursive Least Squares, Self Tuning Regulators introduction, pole placement design, Model Reference Adaptive systems (MRAS) - the need for MRAS, MIT rule, MRAS for first order system.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44E	SOLAR PV SYSTEMS	PEC	2	1	0	3	2020

i) **PRE-REQUISITE:** Nil.

ii) **COURSE OVERVIEW**: This course introduces solar PV system and its grid integration aspects. It also gives insight to basic knowhow for the implementation of Solar PV system utilizing modern simulation software.

iii) **COURSE OUTCOMES**

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

CO1	Describe the basics of solar energy conversion systems.	Understand
CO2	Design a standalone PV system.	Apply
CO3	Demonstrate the operation of a grid interactive PV system and its protection against islanding.	Understand
CO4	Utilize life cycle cost analysis in the planning of Solar PV System.	Apply

iv) **SYLLABUS**

Source of Solar Energy Solar Constant - Solar Radiation on a Horizontal Surface - Solar Radiation on an Inclined Surface - T Monthly Average Daily Solar Radiation on Inclined Surfaces.

Solar Thermal System - Solar thermal collectors, Solar concentrators - Solar heating system, Air conditioning and Refrigeration system, Pumping system, solar cooker, Solar Furnace, Solar Greenhouse -Design of solar water heater.

Solar PV Systems - Solar Cell (Photovoltaic) Materials - Photovoltaic (PV) Module and PV Array, Packing Factor of the PV Module - Effect of shadowing - MPPT Techniques - MPPT using buck-boost converter.

Solar PV Systems Design, Design of Standalone System with Battery and AC or DC Load. A Grid Interactive PV System Overview of IEEE - 2018 Standard for Interconnecting Distributed Resources with Electric Power Systems.

Protection Against Islanding and Reverse Power Flow – AC Modules Design of EMI Filters. Overcurrent protection of solar PV power system, Life cycle costing, Growth models. Introduction to simulation software for solar PV system design.

v) (a) **TEXT BOOKS**

1) D.P. Kothari, M Jamil, “Grid Integration of Solar Photovoltaic Systems”, CRC Press 2018
2) Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, 3rd Edition, PHI.

3) G.N. Tiwari: “Solar Energy: Fundamentals, Design, Modelling and Applications”, Narosa Publishers ,2002.
4) A.A.M. Saigh (Ed), “Solar Energy Engineering”, Academic Press, 1977.

(b) REFERENCES

1) Masters, Gilbert M., “Renewable and Efficient Electric Power Systems”, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004.
2) A. Duffie and W.A. Beckman, “Solar Energy Thermal Processes”, J. Wiley, 1994.
3) Thomas E. Kissell, David M. Buchla, Thomas L. Floyd, “Renewable Energy Systems”, Pearson, 2017.
4) G. N. Tiwari, Arvind Tiwari, Shyam, “Handbook of Solar Energy: Theory, Analysis and Applications”, Springer, 2016.
5) F. Kreith and J.F. Kreider, “Principles of Solar Engineering”, McGraw Hill, 1978.
6) Khan B. H., “Non-Conventional Energy Resources”, Tata McGraw Hill, 2009.
7) D.P. Kothari, K.C. Singal, Rakesh Ranjan, “Renewable Energy Sources and Emerging Technologies”, Prentice Hall of India, New Delhi, 2009.
8) Rao S. and B. B. Parulekar, “Energy Technology”, Khanna Publishers, 1999.
9) Sab S. L., “Renewable and Novel Energy Sources”, MI. Publications, 1995.
10) Sawhney G. S., “Non-Conventional Energy Resources”, PHI Learning, 2012.
11) Abbasi S. A. and N. Abbasi, “Renewable Energy Sources and their Environmental Impact”, Prentice Hall of India, 2001.
12) Boyle G. (ed.), “Renewable Energy: Power for Sustainable Future”, Oxford University Press, 1996.
13) Johansson T. B., H. Kelly, A. K. N. Reddy and R. H. Williams, “Renewable Energy –Sources for Fuel and Electricity”, Earth scan Publications, London, 1993.
14) Tara Chandra Kandpal, Hari Prakash Garg, “Financial evaluation of Renewable Energy Technologies”, Mac Millam India Limited, 2003.
15) "IEEE Application Guide for IEEE Std 1547(TM), IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems," in IEEE Std 1547.2-2008, vol., no., pp.1-217, 15 April 2009, doi: 10.1109/IEEESTD.2008.4816078.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction - Basic Concept of Energy -Source of Solar Energy - Formation of the Atmosphere - Solar Spectrum. Solar Constant - Air Mass - Solar Time - Sun–Earth Angles - Solar Radiation - Instruments to Measure Solar Radiation-Pyrheliometer – Pyranometer - Sunshine Recorder - Solar Radiation on a Horizontal Surface - Extra-terrestrial Region - Terrestrial Region - Solar Radiation on an Inclined Surface - Conversion Factors - Total Solar Radiation on an Inclined/Tilted Surface -Monthly Average Daily Solar Radiation on Inclined Surfaces	9

II	Solar Thermal system - Principle of Conversion of Solar Radiation into Heat, – Solar thermal collectors – General description and characteristics – Flat plate collectors – Heat transfer processes – Solar concentrators (parabolic trough, parabolic dish, Central Tower Collector) – performance evaluation. Applications - Solar heating system, Air conditioning and Refrigeration system, Pumping system, solar cooker, Solar Furnace, Solar Greenhouse -Design of solar water heater.	**9**
III	Solar PV Systems-Introduction - Fundamentals of Semiconductor and Solar Cells - Photovoltaic Effect - Solar Cell (Photovoltaic) Materials - Basic Parameters of the Solar Cell -Generation of Solar Cell (Photovoltaic) Materials-.Photovoltaic (PV) Module and PV Array – Single - Crystal Solar Cell Module, Thin-Film PV Modules, III – V Single Junction and Multifunction PV Modules - Emerging and New PV Systems - Packing Factor of the PV Module - Efficiency of the PV Module - Energy Balance Equations for PV Modules -Series and Parallel Combination of PV Modules.- Effect of shadowing-MPPT Techniques - P&O, incremental conductance method-Maximum Power Point Tracker (MPPT) using buck-boost converter.	**9**
IV	Solar PV Systems – stand-alone and grid connected -Design steps for a Stand-Alone system – Storage batteries and Ultra capacitors. Design PV powered DC fan and pump without battery - Design of Standalone System with Battery and AC or DC Load. A Grid Interactive PV System - Phase, Frequency Matching and Voltage Consideration – Operation of a Grid Interactive Inverter –Grid Forming, Grid tracking, Concepts of Hybrid inverter technologies and power quality issues, Overview of IEEE - 2018 Standard for Interconnecting Distributed Resources with Electric Power Systems.	**9**
V	Protection Against Islanding and Reverse Power Flow – AC Modules Design of EMI Filters. Overcurrent protection of solar PV power system, Selective fuse links for PV String protection, PV fuse selection flow chart, Fuse rating for PV Applications. Life cycle costing, Growth models, Annual payment and present worth factor, payback period, LCC with examples. Introduction to simulation software for solar PV system design.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44F	INDUSTRIAL INSTRUMENTATION AND AUTOMATION	PEC	3	0	0	3	2020

i) **PRE-REQUISITE:** EE1U20C: Analog Electronics, EE1U20F: Digital Electronics, EE1U30E: Linear Control Systems.

ii) **COURSE OVERVIEW**: This course introduces basic terms and techniques applicable to instrumentation and various automation activities related to the industry and power sector. It also provides a basic idea of the recent developments in communication techniques and process control in industrial automation.

iii) **COURSE OUTCOMES**

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

CO1	Identify the sensors/transducers suitable for industrial applications.	Apply
CO2	Model the signal conditioning circuits for industrial instrumentation and automation.	Apply
CO3	Explain the concepts of data transmission and virtual instrumentation related to automation.	Understand
CO4	Develop the logic for the process control applications using PLC programming.	Apply
CO5	Explain the fundamental concepts of DCS and SCADA systems.	Understand

iv) **SYLLABUS**

Introduction to Process Control, Sensor time response, Transducers, Applications of Transducers, Phase measurement - Analog and digital.

Signal conditioning circuits and Final control, Noise problem in instrumentation and its minimization. Final control operation - signal conversion - actuators- control elements.

Data transmission and Virtual instrumentation system, Process control Network, Virtual instrumentation system, concepts of graphical programming.

Programmable logic controllers (PLC) – Organization - Hardware details - Standards Programming aspects - Ladder programming - the concept of latching, Introduction to Timer/Counters.

SCADA and DCS systems, Human-Machine Interface (HMI), Remote Terminal Unit (RTU) and Supervisory Stations, Protocols - IEC 60870-5-101 and DNP3, DCS.

v) **(a) TEXT BOOKS**

1) Curtis D Johnson, “Process Control Instrumentation Technology”, PHI Learning Pvt Ltd New Delhi, 1997.

2) Doeblin E.O, "Measurement Systems: Application and Design", 4th Edition, McGraw Hill, Newyork, 1992.
3) DVS. Murty, "Transducers and Instrumentation", 2nd Edition, PHI Learning Pvt Ltd New Delhi, 2013.
4) Jovitha Jerome, "Virtual instrumentation using LabVIEW", Prentice Hall of India, 2010.
5) William Bolton, "Programmable Logic Controllers", 5th Edition, ELSEVIER INDIA Pvt Ltd New Delhi, 2011.
6) Stuart A. Boyer, "SCADA: Supervisory Control and Data Acquisition", Fourth Edition, International Society of Automation, 2010.

(b) REFERENCES

1) G.K.McMillan, "Process/Industrial Instrument and control and hand book", McGraw Hill, New York,1999.
2) Michael P. Lucas, "Distributed Control system", Van Nastrant Reinhold Company, New York.
3) Patranabis, D., "Principles of Industrial Instrumentation", 2nd Edition, Tata McGraw Hill Publishing Co. Ltd. New Delhi.
4) Robert B. Northrop, "Introduction to instrumentation and measurements", CRC, Taylor and Francis, 2005.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Sensors and Transducers-**Introduction to Process Control - block diagram of the process control loop, definition of elements. Sensor time response - first and second-order responses. Transducers-Characteristics and Choice of the transducer. Applications of Transducers- Displacement measurement using Resistance Potentiometer- Capacitive differential pressure measurement, Flow measurement using Hot wire anemometer, speed measurement-Variable reluctance tachometers, Phase measurement- Analog and digital.	9
II	**Signal conditioning circuits and Final control -** Electronic amplifiers - Differential Amplifier, Instrumentation Amplifiers, Precision rectifiers, Log amplifiers, Carrier Amplifiers, Lock-In Amplifiers, Isolation Amplifiers, Charge amplifiers, Phase-sensitive detectors. Noise problem in instrumentation and its minimization. Final control operation - signal conversion - actuators - control elements. Actuators- Electrical, Pneumatic, Hydraulic, Control elements – mechanical, electrical, fluid valves.	9

III	**Data transmission and Virtual instrumentation system-** Cable transmission of analog and digital data, Fiber optic data transmission, Pneumatic transmission. Process control Network- Functions- General characteristics- Fieldbus and Profibus, radio-wireless communication, WLAN architecture. Virtual instrumentation system: The architecture of virtual instruments – Virtual instruments and traditional instruments – concepts of graphical programming.	**9**
IV	**Programmable logic controllers (PLC)-** Introduction to Sequence Control, Programmable logic controllers (PLC)- Organization- Hardware details- I/O- Power supply - CPU- Standards Programming aspects- Ladder programming- realization of AND, OR logic, the concept of latching, Introduction to Timer/Counters, Exercises based on Timers and Counters.	**9**
V	**SCADA and DCS systems**-SCADA: Introduction, SCADA Architecture, Common System Components, Supervision and Control, Human-Machine Interface (HMI), Remote Terminal Unit (RTU) and Supervisory Stations, Protocols-IEC 60870-5-101 and DNP3.DCS: Introduction, DCS Architecture, Control modes.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U44G	BIG DATA ANALYTICS	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: This course is offered to introduce fundamental algorithmic ideas in processing data. The preliminary concepts of Hadoop and Map Reduce are included as part of this course.

iii) COURSE OUTCOMES

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

CO1	Explain the key concepts of data science.	Understand
CO2	Describe big data and use cases from selected business domains	Understand
CO3	Apply Hadoop and related tools like Pig and Hive to perform big data analytics	Apply
CO4	Apply R language on simple data sets to perform preliminary analytics.	Apply
CO5	Choose various learning approaches in machine learning to process data, and to interpret the concepts of supervised and unsupervised learning.	Apply

iv) SYLLABUS

Data science in a big data world, Facets of data, Data science process, Retrieving data, Data Exploration-Data modelling

Big Data Overview - The five V's of big data, State of the Practice in Analytics, Apache Hadoop and the Hadoop Ecosystem, HDFS Concepts, Managing File system Metadata, Map Reduce

Analysing the Data with Hadoop using Map and Reduce-Developing a Map Reduce Application, Scheduling, Task execution, Big data Management Tools: PIG, HIVE, Introduction to NoSQL.

Review of Basic Analytic methods using R - Introduction to R, Descriptive Statistics, Exploratory Data Analysis, statistical models in R, Graphical Procedures

Machine learning - Introduction to Machine Learning, Supervised Learning - Regression, Classification, Unsupervised Learning, Model Selection and validation, Measuring classifier performance.

v) (a) TEXT BOOKS

1) Davy Cielen, Arno D. B. Meysman, and Mohamed Ali ,"Introducing Data Science - Big data, machine learning, and more, using Python tools", Dreamtech Press, 2016.

2) Tom White, "Hadoop: The Definitive Guide”, 3rd Edition, O'Reilley, 2012.
3) Matloff, Norman,”The art of R programming: A tour of statistical software design”, No Starch Press, 2011.

(b) REFERENCES

1) Michael Minelli, Michelle Chambers, and Ambiga Dhiraj, "Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses", Wiley, 2013
2) EMC Education Services, “Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data”, Wiley, January 2015.
3) Eric Sammer, "Hadoop Operations", O'Reilly Media, Inc, 2012.
4) E. Capriolo, D. Wampler, and J. Rutherglen, "Programming Hive", O'Reilley, 2012.
5) Alan Gates, "Programming Pig", O’Reilley,2011.
6) Ethem Alpaydın, “Introduction to Machine Learning (Adaptive Computation and Machine Learning)”, MIT Press, 2004.
7) Shai Shalev-Shwartz, Shai Ben-David, “Understanding Machine Learning: From Theory to Algorithms”, Cambridge University Press, 2014.
8) Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer, 2007.
9) Crawley, Michael J., “The R book”, John Wiley & Sons, 2012.
10) Sourabh Mukherjee, Amit Kumar Das and Sayan Goswami, “Big Data Simplified”, Pearson, 1st Edition, 2019.
11) Murtaza Haider, “Getting Started with Data Science”, 1st Edition, Kindle Edition, IBM Press, 2015.
12) Thomas Erl, Wajid Khattak and Paul Buhler “Big Data Fundamentals: Concepts, Drivers and Techniques”, Prentice Hall, Pearson Service, 2016.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Data science in a big data world:** Benefits and uses of data science and big data-Facets of data-the big data ecosystem and data science - Data science process-roles - stages in data science project- Defining research goals - Retrieving data - Cleansing, integrating, and transforming data - Data Exploration - Data modelling - Presentation and automation.	**9**
II	**Big Data Overview:** The five V’s of big data-State of the Practice in Analytics - Examples of Big Data Analytics - Apache Hadoop and the Hadoop Ecosystem – HDFS - Design of HDFS, HDFS Concepts-Daemons-Reading and Writing Data - Managing File system Metadata- Map Reduce - The Stages of Map Reduce - Introducing Hadoop Map Reduce – Daemons - YARN.	**9**

III	**Analysing the Data with Hadoop using Map and Reduce:** Developing a Map Reduce Application-Anatomy of a Map Reduce Job- Scheduling-Shuffle and Sort - Task execution. Big data Management Tools: PIG - Introduction to PIG, Execution Modes of Pig, Pig Latin, HIVE: Hive Architecture, HIVEQL, Introduction to NoSQL. (Introduction only).	**9**
IV	**Review of Basic Analytic methods using R:** Introduction to R -Data Import and Export -Attribute and Data Types - ordered and unordered factors-arrays and matrices- lists and data frames -Descriptive Statistics-Exploratory Data Analysis-Dirty Data-Visualizing a Single Variable-Examining Multiple Variables-statistical models in R-Graphical Procedures-High-level plotting commands-Low-level plotting commands.	**9**
V	**Machine learning:** Introduction to Machine Learning, Examples of Machine Learning Applications-Supervised Learning- Regression – Single variable, Multi variable- Classification – Logistic Regression-Unsupervised Learning - Clustering: K-means-Reinforcement Learning - Model Selection and validation - k-Fold Cross Validation-Measuring classifier performance - Precision, recall.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U40C	COMPREHENSIVE COURSE VIVA	PCC	1	0	0	1	2020

i) PREREQUISITE: EE1U30H: Comprehensive Course Work.

ii) COURSE OVERVIEW: The objective of this course viva is to ensure the basic knowledge of each student in the most fundamental core courses in the curriculum. The viva voce shall be conducted based on the core subjects studied from third to eighth semester. This course helps the learner to become competent in placement tests and other competitive examinations.

iii) COURSE OUTCOMES

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

CO1	Summarize the fundamental aspects of any engineering problem or situation relevant to the branch of study.	Understand

iv) SYLLABUS

The comprehensive course work will be conducted covering the following core courses studied from third to eighth semester.

Sl. No.	Course Code	Course Name
1	EE1U20A	Circuits and Networks
2	EE1U20B	Measurements and Instrumentation
3	EE1U20C	Analog Electronics
4	EE1U20D	DC Machines and Transformers
5	EE1U20E	Electromagnetic Theory
6	EE1U20F	Digital Electronics
7	EE1U30A	Power Systems I
8	EE1U30B	Microprocessors and Microcontrollers
9	EE1U30C	Signals and Systems
10	EE1U30D	Synchronous and Induction Machines
11	EE1U30E	Linear Control Systems
12	EEE1U30F	Power Systems II
13	EE1U30G	Power Electronics
14	EE1U40A	Advanced Control Systems
15	EE1U40B	Electrical System Design and Estimation

v) GUIDELINES

1) The course should be mapped with a faculty and classes shall be arranged for practicing questions based on the core courses listed in the curriculum.
2) The viva voce shall be conducted by the same three-member committee assigned for final project phase II evaluation. It comprises Project coordinator, expert from industry/ research institute and a senior faculty from a sister department.
3) The mark will be treated as internal.
4) Comprehensive viva shall be conducted along with the final project evaluation by the three-member committee.

vi) ASSESSMENT PATTERN

Only Continuous Internal Evaluation (CIE).

Total Marks : 50

Minimum required to pass : 25

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U49C	PROJECT PHASE II	PWS	0	0	12	4	2020

i) PRE-REQUISITE: EE1U49B: Project Phase-I.

ii) COURSE OVERVIEW: The goal of this course is to enable students to apply engineering knowledge in practical problem solving. It equips them to foster innovation in design of products, processes or systems. Also creates an urge to develop creative thinking in finding viable solutions to engineering problems. It also aims to provide a good training for the student(s) in R&D work and technical leadership.

iii) COURSE OUTCOMES

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

CO1	Extend knowledge in solving the real-life engineering problems	Understand
CO2	Plan the project effectively (Analysis / modelling / simulation / design / problem solving / experiment).	Apply
CO3	Validate the prototype / process. (Demonstration and testing)	Analyse
CO4	Comprehend and write effective reports, make effective presentations.	Apply
CO5	Develop professional ethics and communicate effectively.	Apply

iv) GUIDELINES

1. Detailed Analysis /Modelling /Simulation /Problem Solving / for implementation as needed.
2. Final development of product/process, testing, results, inferences, conclusions and future directions.
3. Preparing a paper for Conference presentation/Publication in Journals, based on the quality/quantity of work as adjudged by the evaluation committee.
4. Preparing a report in the standard format for being evaluated by the dept. evaluation committee.
5. Preparing presentations for assessments at various stages.

v) ASSESSMENT PATTERN

Only Continuous Internal Evaluation (CIE), minimum required to pass is 75 marks.

Project Supervisor	:	30
Interim evaluation by the evaluation committee (2 times in the semester by the evaluation committee)	:	50
Quality of the report evaluated by the above committee	:	30
Final evaluation by a three-member committee	:	40
Total marks	**:**	**150**

The interim evaluation committee comprises HoD or a senior faculty member, Project coordinator and Project supervisor.

The final evaluation committee comprises Project coordinator, expert from Industry/research Institute and a senior faculty from a sister department. The same committee will conduct comprehensive course viva for 50 marks.

vi) EVALUATION BY GUIDE

The guide/supervisor must monitor the progress being carried out by the project groups on regular basis. In case it is found that progress is unsatisfactory, it should be reported to the Department Evaluation Committee for necessary action. The presence of each student in the group and their involvement in all stages of execution of the project shall be ensured by the guide.

Project evaluation by the guide: 30 marks

This mark shall be awarded to the students in his/her group by considering the following aspects.

i) **Project Scheduling and Distribution of work among team members: 5 marks**
Detailed and extensive scheduling with timelines provided for each phase of project. Work breakdown structure well defined.

ii) **Literature Survey: 4 marks**
Outstanding investigation in all aspects

iii) **Student’s diary/Daily log: 7 marks**
The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students’ thought process and reasoning abilities. The students should record in the daily/weekly activity diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches and drawings related to the observations made by the students. The daily/weekly activity diary shall be signed after every day/week by the guide.

iv) **Individual Contribution: 9 marks**
The contribution of each student at various stages.

v) **Completion of the project: 5 marks**

The students should demonstrate the project to their respective guide. The guide shall verify the results and see that the objectives are met.

EVALUATION RUBRICS for PROJECT Phase II: Interim Evaluation - 1						
No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
PHASE-II INTERIM EVALUATION - 1 (25 MARKS)						
2-a	Novelty of idea, and Implementation scope [CO1] [Group Evaluation]	**5**	• The project does not involve elements of creativity and innovation and it's a non-implementable idea. • The work presented so far is not at all the original contribution by the team.	• No major contributions in innovative aspects. Some of the aspects of the proposed idea can be implemented. • There is still lack of originality in the work done so far by the team. • No improvements.	• The project involves some elements of creativity and innovation. It's an implementable project idea. • There is some evidence for the originality of the work done by the team. • The team is doing some independent learning.	• The objective is highly innovative and involves creativity. • Original work done by the team is not yet stated anywhere else and could be a patentable / publishable work.
			(0 - 1 Mark)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-b	Effectiveness of task distribution among team members. [CO2] [Group Evaluation]	**5**	• No task distribution among team members and do not have any awareness on what to do. • The students did not have any idea on what materials / resources to be used in the project.	• Some indication on task allocation among the team members but not effectively distributed, • Some team members do not have any idea of the responsibilities assigned. • Some identified tasks were not followed independently well.	• Good evidence of planning done. Materials were listed and thought out, but needs improvement. • Better task allocation among group members but some group members heavily loaded. • Mostly the duty is being tracked by the individual members.	• Excellent means of task identification and each member knows well about their individual tasks. • All members are assigned tasks in an equal manner. • The individual members are ensuing the tasks in an outstanding manner.
			(0 - 1 Mark)	(2 - 3 Marks)	(4 Marks)	(5 Marks)

2-c	Adherence to project schedule. [CO3] [Group Evaluation]	**5**	• No weekly discussion with the faculty supervisor. • No indication of sustained planning or scheduling of the project. • They do not have any idea on the budget required even after the phase I. • Project log book not maintained. –	• Maintains a log book and some of the project details were documented. Regular updating is not satisfactory. • There is some improvement in the primary plan prepared during phase I. • The students have not formalized a budget plan. • Schedules were not prepared. –	• Maintains a log book and most of the project details were documented but needs improvement. • Good sign of planning done and being trailed up to a good extent after phase I. • Detailed Schedules were not prepared and needs improvement.	• Good adherence to action plan and organization of activities effectively within the time frame. • Excellent indication of widespread project planning and follow-up since phase I. • Tasks are restructured and incorporated in the schedule. • Weekly discussion with the faculty supervisor and proper maintenance of log book.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-d	Interim Results. [CO2] [Group assessment]	**5**	• No interim results to show.	• The team showed some interim results, but they are not complete needs improvements.	• The interim results showed were good and mostly reliable with respect to the current stage but still needs upgrading.	• There were substantial interim results which evidently shows the progress of work.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-e	Presentation [CO4, CO5] [Individual assessment]	**5**	• The presentation was light in content and dull in appearance. • Very poor presentation. • No interim results.	• Presentation is average. • The student has only a weak idea about the task.	• Good overall presentation. • Presentation is clearly structured and quality is good. • Student has good idea about the team's project.	• Excellent presentation. • The presentation is done professionally and with great clarity. • Student has excellent knowledge of the project.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
Total – 25 marks						

EVALUATION RUBRICS for PROJECT Phase II: Interim Evaluation 2						
No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
PHASE-II INTERIM EVALUATION - 2 (25 MARKS)						
2-f	Application of engineering knowledge [CO2] [Individual Assessment]	**10**	• Have very little idea as how to choose and use modern engineering tools. • The student does not know how to apply engineering knowledge on the design and the methodology adopted. • Application of engineering knowledge in the project is poor.	• Difficulty to identify the skills and modern engineering tools that could be used in achieving the objectives. • The student able to apply some basic knowledge and not able to show the design procedure and the methodologies adopted.	• Able to correctly identify the skills and modern engineering tools applicable to the project work. • The student is able to show application of engineering knowledge in the design and methodologies to a good extent possible.	• Proper selection and effective use of possible techniques, skills and modern engineering tools applicable to the project work. • Excellent knowledge in design procedure. • The student is able to apply engineering knowledge to the problem and develop solutions.
			(0 3 Marks)	(4 6 Marks)	(7 - 9 Marks)	(10 Marks)
2-g	Involvement of individual members [CO3] [Individual Assessment]	**5**	• No active involvement in the project. • The student does not show any interest. • No Individual participation in the project work.	• The student shows some extent of individual contribution. • Limited to some of the tasks.	• Provide productive suggestions for the betterment of the project. • The individual contribution is obvious. • The student has good volume of contribution in main activities of the project.	• Active involvement and provide productive suggestions in interactions with the supervisor. • Student acting as the prime technical lead and has excellent contribution to the project.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-h	Results and inferences upon execution [CO3] [Group Assessment]	**5**	• Expected outcomes are not achieved yet. • The team is incapable to originate any inferences on the issues observed. • Any kind of remarks or	• Only a few of the expected outcomes are achieved. • Limited inferences are made on the observed issues. • No additional work suggested.	• Many of the expected outcomes are achieved. • Many observations and inferences are made and attempts are taken to identify the issues.	• Most of the specified outcomes are met. • Extensive studies are done and inferences drawn. Most of the issues are addressed and solutions suggested.

			studies are not made.		• Some suggestions are made for further work.	• Clear and effective suggestions made for further work.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-i	Documentation and presentation. [CO4] [Individual assessment]	**5**	• Presentation lacks clarity. • The individual student has no idea on the presentation. • The presentation is of poor quality.	• Overall presentation quality needs to be improved • Individual performance desires to be enhanced. • Performance is satisfactory.	• Presentation is clearly structured and appropriate to the audience. • The individual presentation and performance are very good.	• Presentation is well structured and follows the conventions in the field. • The individual's presentation is done professionally and the performance is excellent.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
Total – 25 marks						

EVALUATION RUBRICS for PROJECT Phase II: Final Evaluation						
No	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
PHASE-II FINAL EVALUATION (40 MARKS)						
2-j	Engineering knowledge. [CO1] [Group Assessment]	10	• Have very little idea as how to choose and use modern engineering tools. • The student does not know how to apply engineering knowledge on the design and the methodology adopted. • Application of engineering knowledge in the project is poor.	• Difficulty to identify the skills and modern engineering tools that could be used in achieving the objectives. • The student able to apply some basic knowledge and not able to show the design procedure and the methodologies adopted.	• Able to correctly identify the skills and modern engineering tools applicable to the project work. • The student is able to show application of engineering knowledge in the design and methodologies to a good extent possible.	• Proper selection and effective use of possible techniques, skills and modern engineering tools applicable to the project work. • Excellent knowledge in design procedure. • The student is able to apply engineering knowledge to the problem and develop solutions.
			(0 - 3 Marks)	(4 - 6 Marks)	(7 - 9 Marks)	(10 Marks)
2-k	Relevance of the project with respect to societal and/or industrial needs. [Group Assessment] [CO2]	5	• The project has neither social nor industrial relevance.	• The project has some relevance with respect to social/ industrial application. • The team has not taken much effort to explore further,	• The project is relevant to the society /industry. • The team is mostly fruitful in interpreting the problem into an engineering requirement.	• The project is exceptionally relevant to society/industry. • The team has made outstanding contribution in resolving the problem.
			(0 - 1 Mark)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-i	Innovation / novelty / Creativity [CO2] [Group Assessment]	5	• The project does not involve elements of creativity and innovation and it's a non-implementable idea. • The work presented so far is not at all the original contribution by the team.	• No major contributions in innovative aspects. Some of the aspects of the proposed idea can be implemented. • There is still lack of originality in the work done so far by the team.	• The project involves some elements of creativity and It's an implementable project. • Some sign for the originality of the work done by the team. • Could be transformed into a product.	• The objective is highly innovative and involves creativity. • Original work done by the team is not yet stated anywhere else and could be a patentable / publishable work.
			(0 - 1 Mark)	(2 - 3 Marks)	(4 Marks)	(5 Marks)

2-m	Quality of results / conclusions / solutions. [CO3] [Group Assessment]	10	• Expected outcomes are not achieved yet. • The team is incapable to originate any inferences on the issues observed. • Any kind of remarks or studies are not made.	• Only a few of the expected outcomes are achieved. • Limited inferences are made on the observed issues. • No additional work suggested.	• Many of the expected outcomes are achieved. • Many observations and inferences are made and attempts are taken to identify the issues. • Some suggestions are made for further work.	• Most of the specified outcomes are met. • Extensive studies are done and inferences drawn. Most of the issues are addressed and solutions suggested. • Clear and effective suggestions made for further work.
			(0 - 3 Marks)	(4 - 6 Marks)	(7 - 9 Marks)	(10 Marks)
2-n	Presentation - Part I Preparation of slides. [CO4] [Group Assessment].	5	• Presentation lacks clarity and not in proper format. • The individual student has no idea on the presentation. • The presentation is of poor quality.	• Overall presentation follows proper style formats to some extent. • Language needs to be improved. • All references are not cited properly. • Presentation slides needs to be more professional.	• Presentation is clearly structured and follows proper style format. • Organization of the slides is good. • Most of references are cited properly. • Some of the results are not clearly shown. There is scope for improvement.	• Presentation is well structured and slides are exceptionally good. • The presentation Neatly organized. • All references cited properly. • Figures, Tables and equations are properly numbered, Results are clearly highlighted and its readable
			(0 - 1 Mark)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
	Presentation - Part II: Individual Communication [CO5] [Individual Assessment].	5	• The student is not communicating properly. • Poor response to questions.	• The student is able to explain some of the content. • The student requires a lot of efforts to get to the idea. • There are language issues.	• Good presentation/ communication by the student. • The student is able to explain most of the content very well. • A few areas where the student shows lack of preparation. • Language is better.	• Clear and concise communication showed by the student. • Presentation is outstanding. • Very confident and tackles all the questions without hesitation. • Exceptional qualities of a good communicator.
			(0 - 1 Mark)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
Total – 40 marks						

EVALUATION RUBRICS for PROJECT Phase II: Report Evaluation						
Sl. No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
PHASE-II PROJECT REPORT (30 MARKS)						
2-o	Report [CO4]	30	• The prepared report is shallow and not as per standard format. • Lack of effort in preparation.	• Project report follows the standard format to some extent. • Language needs to be improved. • All references are not cited properly.	• Systematic documentation and is following the standard format. • Organization of the report is good. • Most of references are cited properly.	• The report is very well organized. • All referencescited properly. • Language is excellent and follows standard styles.
			(0 - 11 Marks)	(12 - 18 Marks)	(19 - 28 Marks)	(29 - 30 Marks)
Total – 30 marks						

B.TECH HONOURS MINI PROJECT

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1H49A	Mini Project	PWS	0	1	6	4	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: A Project topic must be selected either from research literature or the students themselves may propose suitable topics in consultation with their guides. The objective of Mini Project Work is to enable the student to take up investigative study in the broad field of Electrical and Electronics Engineering, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a supervisor. This is expected to provide a good initiation for the student(s) in R&D work.

The assignment to normally include:

♦ Survey and study of published literature on the assigned topic;

♦ Preparing an Action Plan for conducting the investigation, including team work;

♦ Working out a preliminary Approach to the Problem relating to the assigned topic;

♦ Block level design documentation

♦ Conducting preliminary Analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility;

♦ Preparing a Written Report on the Study conducted for presentation to the Department.

iii) COURSE OUTCOMES

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

CO1	Extend knowledge in solving the real-life engineering problems	Understand
CO2	Prepare work plan and liaison with the team in completing as per schedule.	Apply
CO3	Validate the prototype / process. (Demonstration and testing)	Analyse
CO4	Comprehend and write effective reports, make effective presentations.	Apply
CO5	Develop professional ethics and communicate effectively.	Apply

iv) GUIDELINES

1. Detailed Analysis /Modelling /Simulation /Problem Solving / for implementation as needed.

2. Final development of product/process, testing, results, inferences, conclusions and future directions.
3. Preparing a paper for Conference presentation/Publication in Journals, based on the quality/quantity of work as adjudged by the evaluation committee.
4. Preparing a report in the standard format for being evaluated by the dept. evaluation committee.
5. Preparing presentations for assessments at various stages.

v) ASSESSMENT PATTERN

Only Continuous Internal Evaluation (CIE), minimum required to pass is 50 marks.

Project Supervisor	:	30
Interim evaluation by the evaluation committee (2 times in the semester by the evaluation committee)	:	20
Quality of the report evaluated by the above committee	:	20
Final evaluation by a three-member committee	:	30
Total marks	**:**	**100**

The interim evaluation committee comprises HoD or a senior faculty member, Project coordinator and Project supervisor.

The final evaluation committee comprises Project coordinator, expert from Industry/research Institute and a senior faculty from a sister department.

vi) EVALUATION BY GUIDE

The guide/supervisor must monitor the progress being carried out by the project groups on regular basis. In case it is found that progress is unsatisfactory, it should be reported to the Department Evaluation Committee for necessary action. The presence of each student in the group and their involvement in all stages of execution of the project shall be ensured by the guide.

Project evaluation by the guide: 30 marks

This mark shall be awarded to the students in his/her group by considering the following aspects.

i) **Project Scheduling and Distribution of work among team members: 5 marks**
Detailed and extensive scheduling with timelines provided for each phase of project. Work breakdown structure well defined.

ii) **Literature Survey: 4 marks**
Outstanding investigation in all aspects

iii) **Student’s diary/Daily log: 7 marks**
The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students’ thought process and reasoning abilities. The students should record in the daily/weekly activity diary the day to day account of the observations, impressions, information gathered and suggestions given,

if any. It should contain the sketches and drawings related to the observations made by the students. The daily/weekly activity diary shall be signed after every day/week by the guide.

iv) Individual Contribution: 9 marks

The contribution of each student at various stages.

v) Completion of the project: 5 marks

The students should demonstrate the project to their respective guide. The guide shall verify the results and see that the objectives are met.