VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examinations and Syllabus

M.Tech ENERGY SYSTEMS ENGINEERING (ESE)

(Effective from Academic year 2020 - 21)

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examinations – 2020 - 21
M.Tech ENERGY SYSTEMS ENGINEERING (ESE)
Choice Based Credit System (CBCS) and Outcome Based Education(OBE)

I SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours per Week			Examination				Credits
				Theory	Practical	Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	20EEE11	Mathematical Methods in Control	03	--	02	03	40	60	100	4
2	PCC	20ESE12	Energy Resources and the Environmental Impacts	03	--	02	03	40	60	100	4
3	PCC	20ESE13	Energy Production, Conversion and Conservation	03	--	02	03	40	60	100	4
4	PCC	20ESE14	Energy Conversion Technologies	03	--	02	03	40	60	100	4
5	PCC	20ESE15	Power System Operation	03	--	02	03	40	60	100	4
6	PCC	20ESEL16	Energy Laboratory -1	--	04	--	03	40	60	100	2
7	PCC	20RMI17	Research Methodology and IPR	01	--	02	03	40	60	100	2
			TOTAL	**17**	**04**	**12**	**21**	**280**	**420**	**700**	**24**

Note: PCC: Professional core.

Skill development activities:
Students and course instructor/s to involve either individually or in groups to interact together to enhance the learning and application skills.
The students should interact with industry (small, medium and large), understand their problems or foresee what can be undertaken for study in the form of research/ testing / projects, and for creative and innovative methods to solve the identified problem.
The students shall
(1) Gain confidence in modelling of systems and algorithms.
(2) Work on different software/s (tools) to Simulate, analyse and authenticate the output to interpret and conclude. Operate the simulated system under changed parameter conditions to study the system with respect to thermal study, transient and steady state operations, etc.
(3) Handle advanced instruments to enhance technical talent.
(4) Involve in case studies and field visits/ field work.
(5) Accustom with the use of standards/codes etc., to narrow the gap between academia and industry.
All activities should enhance student's abilities to employment and/or self-employment opportunities, management skills, Statistical analysis, fiscal expertise, etc.

Internship: All the students have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination shall be conducted during III semester and the prescribed internship credit shall be counted for the same semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as fail in internship course and have to complete the same during the subsequent University examination after satisfying the internship requirements.

Note: (i) Four credit courses are designed for 50 hours Teaching – Learning process.
(ii) Three credit courses are designed for 40 hours Teaching – Learning process.
(iii) Two credit courses are designed for 25 hours Teaching – Learning process.

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II SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ seminar	Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	20ESE21	Integration of Distributed Generation	03	--	02	03	40	60	100	4
2	PCC	20ESE22	Industrial Energy and Management	03	--	02	03	40	60	100	4
3	PCC	20ESE23	Power System Planning	03	--	02	03	40	60	100	4
4	PEC	20ESE24X	Professional elective 1	04	--	--	03	40	60	100	4
5	PEC	20ESE25X	Professional elective 2	04	--	--	03	40	60	100	4
6	PCC	20ESEL26	Energy Laboratory - 2	--	04	--	03	40	60	100	2
7	PCC	20ESE27	Technical Seminar	--	02	--	--	100	--	100	2
TOTAL				**17**	**06**	**06**	**18**	**340**	**360**	**700**	**24**

Note: PCC: Professional core, PEC: Professional Elective.

Professional Elective 1		Professional Elective 2	
Course Code under 20ESE24X	**Course title**	**Course Code under 20ESE25X**	**Course title**
20ESE241	Solar Energy Technologies	20ESE251	Wind Energy Systems
20ESE242	Photovoltaics	20ESE252	Power System Harmonics
20ESE243	Introduction to Nuclear Power	20ESE253	Carbon Capture and Storage
20ESE244	Environmental Impacts of Renewable Energy	20ESE254	Intelligent Energy Demand Forecasting

Note:

1. Technical Seminar: CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a senior faculty of the department. Participation in the seminar by all postgraduate students of the programme shall be mandatory.

The CIE marks awarded for Technical Seminar, shall be based on the evaluation of Seminar Report, Presentation skill and performance in Question and Answer session in the ratio 50:25:25.

2. Internship: All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination shall be conducted during III semester and the prescribed internship credit shall be counted in the same semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as fail in internship course and have to complete the same during the subsequent University examination after satisfying the internship requirements.

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III SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ Mini –Project/ Internship	Skill Development activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	20ESE31	Energy Audit	03	--	02	03	40	60	100	4
2	PEC	20ESE32X	Professional elective 3	03	--	--	03	40	60	100	3
3	PEC	20ESE33X	Professional elective 4	03	--	--	03	40	60	100	3
4	Project	20ESE34	Project Work phase -1	--	02	--	--	100	--	100	2
5	PCC	20ESE35	Mini-Project	--	02	--	--	100	--	100	2
6	Internship	20ESEI36	Internship	(Completed during the intervening vacation of I and II semesters and /or II and III semesters.)			03	40	60	100	6
TOTAL				**09**	**04**	**02**	**12**	**360**	**240**	**600**	**20**

Note: PCC: Professional core, PEC: Professional Elective.

Professional elective 3		Professional elective 4	
Course Code under 20ESE32X	**Course title**	**Course Code under 20ESE33X**	**Course title**
20ESE321	Solar Hydrogen Energy Systems	20ESE331	Energy Storage in Power Grids
20ESE322	Energy Management Strategies for EV/PHEV	20ESE332	High-Power Battery Technologies
20ESE323	Energy Pricing – Economics and Principles	20ESE333	Piezoelectric Energy
20ESE324	Data Analytics for the Smart Grid	20ESE334	Cybersecurity in the Electricity Sector

Note:

1. Project Work Phase-1: Students in consultation with the guide/co-guide if any, shall pursue literature survey and complete the preliminary requirements of selected Project work. Each student shall prepare relevant introductory project document, and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide if any, and a senior faculty of the department. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill and performance in Question and Answer session in the ratio 50:25:25.

SEE (University examination) shall be as per the University norms.

2. Internship: Those, who have not pursued /completed the internship shall be declared as fail in internship course and have to complete the same during subsequent University examinations after satisfying the internship requirements. Internship SEE (University examination) shall be as per the University norms.

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IV SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination					Credits
				Theory	Practical/ Field work	Duration in hours	CIE Marks	SEE Marks Viva voce	Total Marks		
				L	P						
1	Project	20ESE41	Project work phase -2	--	04	03	40	60	100	20
			TOTAL	--	**04**	**03**	**40**	**60**	**100**	**20**

Note:

1. Project Work Phase-2:

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a Senior faculty of the department. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report subjected to plagiarism check, Project Presentation skill and performance in Question and Answer session in the ratio 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

MATHEMATICAL METHODS IN CONTROL			
Course Code	20EEE11	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Introduction to vector spaces and sub-spaces, definitions, illustrative example. Linearly independent and dependent vectors- Basis-definition and problems. Linear transformations-definitions. Matrix form of linear transformations-Illustrative examples.■

Module-2

Solution of Systems of Linear Equations: Direct methods-Relaxation method, Partition method, Croute's Triangularisation method. Eigen values and Eigen vectors. Bounds on Eigen Values. Jacobi method & Givens method for symmetric matrices.■

Module-3

Orthogonal vectors and orthogonal bases. Gram-Schmidt orthogonalization process. SVD and Applications.■

Module-4

Probability: Random variables, Probability distributions: Binomial, Poisson, Normal distributions, Joint probability distribution (discrete and continuous)-Illustrative examples. ■

Module-5

Moments, central moments, characteristic functions, probability generating and moment generating functions-illustrations. Poisson, Gaussian and Erlang distributions-examples. ■

Course outcomes:

At the end of the course the student will be able to:

1. Understand the fundamentals of vector space and bases in reference to transformations.
2. Solve system of linear equations using direct and iterative methods.
3. Use the idea of Eigen values and Eigen vectors for the application of SVD.
4. Describe the basic notions of discrete and continuous probability distributions.
5. Find out responses of linear systems using statistical and probability tools.■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbooks

1. Linear Algebra and its Applications, David C.Lay et al, Pearson, 5th Edition,2015.

2. Numerical Methods for Scientific and Engineering Computation, M. K. Jain et al, New Age International, 9th

Reference Books

1. Signals, Systems, and Inference, Alan V. Oppenheim and George C. Verghese, Pearson, 2012.

2. Numerical methods for Engineers, Steven C Chapra and Raymond P Canale, McGraw-Hill 7th Edition, 2015.

3. Higher Engineering Mathematics, B.S. Grewal, Khanna Publishers, 44th Edition, 2017.

ENERGY RESOURCES AND THE ENVIRONMENTAL IMPACTS			
Course Code	20ESE12	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Energy Issues: Introduction, Energy Terms, Conservation Law for Energy, Enthalpy, Heat Transfer, Net Energy Analysis, Developing a National Energy Policy.

Thermodynamic Principles: Introduction, Qualitative Review of the Second Law, Describing Equations, The Heat Exchanger Dilemma, Applications.

Energy Demand: Introduction, Early History, The First Humans, The Industrial Revolution, Recent Years, Effect of Demand of Energy Resources, Canada, Energy Needs, Energy Resources, Tar Sands, Future Energy Demands.

Sustainability and Green Science/Engineering: Introduction, Sustainability, Green Science/ Engineering. ■

Module-2

Energy Regulations: Introduction, The Regulatory System, Laws and Regulations: The Differences, The Role of the States, The Department of Energy (DOE), The Federal Energy Regulatory Commission (FERC), Energy Information Administration (EIA), The Environmental Protection Agency (EPA), The 2013 New York State Energy Plan, Overview of New York's State Energy Plan.

The Modern Energy Matrix: Introduction, Energy System Components, Energy Matrix Overview.

Energy Resources – (a) Coal: Introduction, Early History, Availability/Distribution and Characterization, Extraction, Processing, and Transportation/ Transmission, Environmental Issues, Future Prospects and Concerns. ■

Module-3

Energy Resources (continued)

(b) Oil, (c) Natural Gas, (d) Shale Oil, (e) Tar Sands, (f) Solar Energy: Introduction, Early History, Availability/Distribution and Characterization, Extraction, Processing, and Transportation/ Transmission, Environmental Issues, Future Prospects and Concerns. ■

Module-4

Energy Resources (continued)

(g)Nuclear Energy, (i) Hydroelectric Energy, (j) Wind Energy (k) Geothermal Energy (l) Hydrogen Energy, (m) Biomass Energy: Introduction, Early History, Availability/Distribution and Characterization, Extraction, Conversion, and Transportation/ Transmission, Environmental Issues, Future Prospects and Concerns. ■

Module-5

Other Energy Sources: Introduction, Fuels Derived from Coals and Oils, Hydrocarbons, Hydrokinetic Energy, Ocean Thermal Energy, Wave Energy.

Energy Demand and Distribution Systems: Introduction, The Evolution of Energy Demand, Energy Stakeholders, The Role of Distribution Systems.

Conservation, Sustainability, and Green Engineering: Introduction, Energy Conservation, Sustainability Approaches, Green Engineering.

Environmental Considerations: Introduction, Environmental Management Topics, Environmental Factors, The Health Risk Evaluation Process, The Hazard Risk Assessment Process.

Economic Considerations: Introduction, Operating Costs, Energy Cost Data, Hidden Economic Factors, Project Evaluation and Optimization, Principles of Accounting, Concluding Remarks. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain energy management including engineering principles, regulations to energy conservation, sustainability and green engineering.
- Explain different energy resources both conventional and non-conventional.
- Analyze different energy management issues such as energy demand and distribution, conservation, sustainability, environmental and economic considerations. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Energy Resources Availability, Management, and Environmental Impacts, Kenneth J. Skipka, Louis Theodore,

ENERGY PRODUCTION, CONVERSION AND CONSERVATION			
Course Code	20ESE13	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Basic Definitions: System, Property and Variables, Dimensions and Units, Measures of Amounts and Fractions, Force, Temperature, Pressure, Volume, State, Process, Problems.
Energy and Energy Types: Energy, Energy Types, Non Renewable Energy Sources, Heating Value of Fuel, Renewable Energy Resources, Hydrogen, Electric Energy, Magnetic Energy, Chemical Energy, Energy and Global Warming, Tackling the Global Warming. ■

Module-2

Mechanical Energy and Electrical Energy: Mechanical Energy, Kinetic Energy, Potential Energy, Pressure Energy, Surface Energy, Sound Energy, Mechanical Work, Electric Energy, Other Forms of Work.
Internal Energy and Enthalpy: Internal Energy, Enthalpy, Heat, Effect of Temperature on the Heat of Reaction, Standard Enthalpy Changes, Adiabatic Flame Temperature, Air Pollution from Combustion Processes, Heat of Mixing, Heat Measurements by Calorimeter, Psychrometric Diagram, Heat Transfer, Entropy, Energy, Fluid-Flow Work. ■

Module-3

Energy Balances: Balance Equations, Mass Balance, Energy Balance, Entropy Balance, Energy Balance, Fluid-Flow Processes, Energy Balance in a Cyclic Process.
Energy Production: Energy Production, Electric Power Production, Transmission of Energy, Power Producing Engine Cycles, Improving the Power Production in Steam Power Plants, Geothermal Power Plants, Cogeneration, Nuclear Power Plants, Hydropower Plants, Wind Power Plants, Solar Power Plants, Hydrogen Production, Fuel Cells, Biomass and Bioenergy Production, Other Energy Production Opportunities, Levelized Energy Cost, Thermodynamic Cost, Ecological Cost. ■

Module-4

Energy Conversion: Energy Conversion, Series of Energy Conversions, Conversion of Chemical Energy of Fuel to Heat, Thermal Efficiency of Energy Conversions, Ideal Fluid-Flow Energy Conversions, Lost Work, Efficiency of Mechanical Conversions, Conversion of Thermal Energy by Heat Engines, Improving Efficiency of Heat Engines, Hydroelectricity, Wind Electricity, Geothermal Electricity, Ocean Thermal Energy Conversion, Thermoelectric Effect, Efficiency of Heat Pumps and Refrigerators, Efficiency of Fuel Cells, Energy Conversions in Biological Systems. ■

Module-5

Energy Storage: Energy Storage and Regulation, Types of Energy Storage, Thermal Energy Storage, Electric Energy Storage, Chemical Energy Storage, Mechanical Energy Storage.
Energy Conservation: Energy Conservation and Recovery, Conservation of Energy in Industrial Processes, Energy Conservation in Home Heating and Cooling. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain different types of systems, properties, variables energy and types of energy.
- Explain different forms of external and internal energy and compute different forms of energy.
- Explain about energy balance and energy production by different means.
- Explain different methods of energy conversion, storage and conservation. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Energy Production, Conversion, Storage, Conservation, and Coupling, Yasar Demirel, Springer, 2012.

ENERGY CONVERSION TECHNOLOGIES			
Course Code	20ESE14	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Energy and Energy Efficiency: Energy Sources, Energy Efficiency and Contemporary Trends. **Storage and Usage of Energy:** Overview, Storage of Energy as Electrochemical Energy, Storage of Energy as Electromagnetic Energy, Storage of Energy as Electrostatic Energy, Storage of Energy as Mechanical Energy, Using the Energy as Electrical Energy.

Power Electronics and Its Role in Effective Conversion of Electrical Energy: Overview, Principles of Conversion of Electrical Energy, Computer-Aided Design of Power Electronic Converters in Power Electronics. ■

Module-2

AC/DC Conversion: Basic Indicators in Respect to the Supply Network, Single-Phase and Three-Phase Uncontrolled Rectifiers, Single-Phase and Three-Phase Controlled Rectifiers, Bidirectional AC/DC Conversion, Methods to Improve Power Efficiency in AC/DC Conversion. ■

Module-3

AC/AC Conversion: Basic Indicators in Respect to the Supply Network, Single-Phase and Three-Phase AC Regulators, Methods to Improve Power Efficiency in AC/AC Conversion.

DC/DC Conversion: Basic Indicators, Conversion Without Galvanic Isolation, Conversion with Galvanic Isolation, Bidirectional DC/DC Conversion, Methods to Improve Power Efficiency in DC/DC Conversion. ■

Module-4

DC/AC Conversion: Basic Indicators, Single-Phase and Three-Phase Converters, Methods to Improve Power Efficiency in DC/AC Conversion.

Conversion of Electrical Energy in the Processes of Its Generation and Transmission:
Conversion in the Process of Electrical Generation, Static VAR Compensators, (SVC),Static Synchronous Compensator (STATCOM), Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Controller (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC), High Voltage DC Transmission. ■

Module-5

Conversion of Electrical Power from Renewable Energy Sources: Overview, Conversion of Solar Energy, Conversion of Wind Energy, Conversion of Water Energy.

Uninterruptible Power Supply Systems: Introduction, Basic Schemas and Their Indicators, Methods to Increase the Reliability, Communication between UPS Systems and Different Systems.

Other Applications of Converters and Systems of Converters: Industrial Applications, Transport Applications, Home Appliances, Elevators, Applications in Communication, Medical Applications. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain present state and trends of the use of electrical energy in the country, its storage and usage and the role of power electronic converters in the conversion of energy
- Explain schemes and operational principles of single-phase and three-phase AC rectifiers.
- Explain schemes and operational principles of single-phase and three-phase AC regulators, operational characteristics of convertors with and without galvanic isolation.
- Explain schemes and operational principles of single-phase and three-phase inverters and the role of power electronic converters in conversion of electrical energy in the process of generation and transmission.
- Discuss the use of energy of renewable sources – sun and wind, its conversion, analysis of different schemes to insure uninterruptible supply and other applications of converters and system of converters. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Technologies for Electrical Power Conversion, Efficiency, and Distribution: Methods and Processes, Mihail Hristov Antchev, Engineering science reference, 2010.

POWER SYSTEM OPERATION			
Course Code	20ESE15	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Power System Operation: Overview, Operator, Process, Technology, Power System Operation Criteria.
Power System Monitoring: Operator Function in Power System Monitoring, Process for Power System Monitoring, Technology for Power System Monitoring, Bad Data Identification, Observability.
Power System Scenario Analysis: Operator Function in Power System Scenario Analysis, Process for Power System Scenario Analysis, Technology for Power System Control. ■

Module-2

Power System Posturing: Static Security: Operator's Question on Power System Posturing: Static Security, Process for Power System Posturing: Static Security, Technology for Power System Posturing: Static Security.
Power System Posturing: Angular Stability: Operator's Question on Power System Posturing: Angular Stability, Process for Power System Posturing: Angular Stability, Technology for Power System Posturing: Angular Stability, Implementation of Angular Stability Limits. ■

Module-3

Power System Posturing: Voltage Stability: Operator's Question on Power System Posturing: Voltage Stability, Process for Power System Posturing: Voltage Stability, Technology for Power System Posturing: Voltage Stability, Voltage Stability Limit Derivation and Implementation.
Power System Generation Load Balance: Operator's Question on Generation Load Balance, Process for Generation Load Balance, Technology for Generation Load Balance. ■

Module-4

Power System Operation Optimization: Operator's Question on Power System Operation Optimization, Process for Power System Generation Operation, Process for Generation Sufficiency, Technology for Generation Sufficiency.
System Operation Control Centers: Introduction, Modern Control Center Attributes, Control Center Redundancy Configuration, Modern Control Center Configuration, Modern Control Center Design Details. ■

Module-5

Energy Management Systems: Introduction, EMS Functionality Overview, Energy Management System Availability Criteria and Architecture.
Distribution Management System: Introduction, DMS Functionality Overview, Distribution Management System Architecture.
Evolving Power System Operation Solutions: Introduction, Evolving Operation Solutions. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain operator needs, processes for power system monitoring
- Explain function of operator in the power system scenario analysis.
- Explain the operator needs and processes on security and stability of power system
- Explain optimization of power system operation.
- Describe the control centers, energy management systems and distribution management systems.
- Develop state of art solution for power system operation. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Practical Power System Operation, Ebrahim Vaahedi, Wiley, 2014.

ENERGY LABORATORY -1			
Course Code	20ESEL16	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	0:4:0	SEE Marks	60
Credits	02	Exam Hours	03

Sl. NO	Experiments
1	Measurement of kinetic energy: Linear and rotational.
2	Determination of calorific values of coal, LPG.
3	Test on energy efficient motors and characteristics: Comparison of performance.
4	Measurement of solar radiation and sunshine hours.
5	Measurement of emissivity, reflectivity and transitivity.
6	Performance testing of solar flat water heater, forced flow and thermo syphon systems.
7	Measurement of V-I characteristics of solar panel at various levels of insulation and the identification of equivalent circuit parameters.
8	Performance testing of solar air heater and dryer and desalination unit.
9	Measurement of efficiency and concentration ratio of solar flat and linear parabolic thermal
10	Study of sun tracking system by mechanical movements.
11	Testing and performance analysis of solar PV operated pump.

Course outcomes:

At the end of the course the student will be able to:

- Measure the kinetic energy due to linear as well as rotational motion and the calorific values of fuels such as coal and LPG
- Measure of solar radiation and sunshine hours, emissivity, reflectivity and transitivity and efficiency of solar concentrators.
- Test the performance of energy efficient motors, solar water heaters, air heater, dryer, solar pump and desalination units.
- Explain the working of sun tracking system. ■

RESEARCH METHODOLOGY AND IPR			
Course Code	20RMI17	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	1:0:2	SEE Marks	60
Credits	02	Exam Hours	03

Module-1

Research Methodology: Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India.

Defining the Research Problem: Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration.

Module-2

Reviewing the literature: Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed.

Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.

Module-3

Design of Sampling: Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs.

Measurement and Scaling: Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale.

Data Collection: Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method.

Module-4

Testing of Hypotheses: Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis.

Chi-square Test: Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests.

Module-5

Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports.

Intellectual Property: The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers' Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organisation (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property Rights, UNSECO. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss research methodology and the technique of defining a research problem
- Explain the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.
- Explain various research designs, sampling designs, measurement and scaling techniques and also different methods of data collections.
- Explain several parametric tests of hypotheses, Chi-square test, art of interpretation and writing research reports
- Discuss various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks

1. Research Methodology: Methods and Techniques, C.R. Kothari, Gaurav Garg, New Age International, 4th Edition, 2018.
2. Research Methodology a step-by-step guide for beginners. (For the topic Reviewing the literature under module 2), Ranjit Kumar, SAGE Publications, 3rd Edition, 2011.
3. Study Material (For the topic Intellectual Property under module 5), Professional Programme Intellectual Property Rights, Law and Practice, The Institute of Company Secretaries of India, Statutory Body Under an Act of Parliament, September 2013.

Reference Books

1. Research Methods: the concise knowledge base, Trochim, Atomic Dog Publishing, 2005.
2. Conducting Research Literature Reviews: From the Internet to Paper, Fink A, Sage Publications, 2009.

*** END ***

INTEGRATION OF DISTRIBUTED GENERATION			
Course Code	20ESE21	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Distributed Generation: Introduction, Sources of Energy - Wind Power, Solar Power, Combined Heat-and-Power, Hydropower, Tidal Power, Wave Power, Geothermal Power, Thermal Power Plants. ■

Module-2

Distributed Generation (continued): Interface with the Grid.
Power System Performance: Impact of Distributed Generation on the Power System, Aims of the Power System, Hosting Capacity Approach, Power Quality, Voltage Quality and Design of Distributed Generation, Hosting Capacity Approach for Events, Increasing the Hosting Capacity.
Overloading and Losses: Impact of Distributed Generation, Overloading: Radial Distribution Networks, Overloading: Redundancy and Meshed Operation, Losses. ■

Module-3

Overloading and Losses (continued): Increasing the Hosting Capacity.
Voltage Magnitude Variations: Impact of Distributed Generation, Voltage Margin and Hosting Capacity, Design of Distribution Feeders, A Numerical Approach to Voltage Variations, Tap Changers with Line-Drop Compensation, Probabilistic Methods for Design of Distribution Feeders. ■

Module-4

Voltage Magnitude Variations (continued): Statistical Approach to Hosting Capacity, Increasing the Hosting Capacity.
Power Quality Disturbances: Impact of Distributed Generation, Fast Voltage Fluctuations, Voltage Unbalance. ■

Module-5

Power Quality Disturbances (continued): Low-Frequency Harmonics, High-Frequency Distortion, Voltage Dips, Increasing the Hosting Capacity. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain energy generation by wind power and solar power.
- Discuss the variation in production capacity at different timescales, the size of individual units, and the flexibility in choosing locations with respect to of wind and solar systems.
- Explain the performance of the system when distributed generation is integrated to the system.
- Discuss effects of the integration of DG: the increased risk of overload and increased losses.
- Discuss effects of the integration of DG: increased risk of overvoltages, increased levels of power quality disturbances.
- Discuss effects of the integration of DG: incorrect operation of the protection
- Discuss the impact the integration of DG on power system stability and operation. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Integration of Distributed Generation in the Power System, Math Bollen, Wiley, 2011.

INDUSTRIAL ENERGY AND MANAGEMENT			
Course Code	20ESE22	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Engineering Aspects of Industrial Energy Management: Introduction to Industrial Energy Systems.
Industrial Steam System: System Performance Definition, Principles of Performance Analysis, Analysis of Boiler Performance, Factors Influencing Boiler Performance, Opportunities for Boiler Performance Improvement, Software for Boiler Performance Analysis, Boiler Performance Monitoring, Steam Distribution and Condensate Return System, Condensate Return System, Environmental Impacts. ■

Module-2

Industrial Electric Power System: Introduction, Description of Industrial Electric Power Systems, Basic Terms, Tariff System, Main Components of Industrial Electric Power Systems, Performance Assessment of Industrial Electric Power Systems, Performance Improvement Opportunities, Maintenance Considerations, Performance Monitoring, Environmental Impacts. ■

Module-3

Compressed Air System: System Description, Performance Analysis, Performance Improvement Opportunities, Performance Monitoring, Example: Detailed Energy Audit of Compressed Air System, Example: Comparison of Load/Unload and Pump-up Tests.■

Module-4

Refrigeration System: Description of System, Performance Definitions, Performance Analysis, Performance Improvement Opportunities, Performance Monitoring, Example: Improvement of Chilled Water System Operation. ■

Module-5

Industrial Cogeneration: System Description, Principles of Operation, Types of Industrial Cogeneration Plants, Operational Modes of Cogeneration Systems, Performance Definition, Factors Influencing Performance, Economic Aspects of Cogeneration as a Performance Improvement Measure, Performance Assessment, Performance Monitoring and Improvement, Environmental Impacts, Case Study: Drying Kiln (Gas Turbine Operation Philosophy Improvement). ■

Course outcomes:

At the end of the course the student will be able to:

- Explain technical aspects of industrial energy and environmental performance management, and define industrial energy systems.
- Explain the performance analysis, performance improvement opportunities and monitoring of five industrial energy systems: (1) Industrial Steam System, (2) Electrical Energy System, (3) Compressed Air System, (4) Refrigeration System and (5) Industrial Cogeneration.
- Explain the environmental impacts of the considered industrial energy system. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Applied Industrial Energy and Environmental Management, Zoran K. Morvay et al, Wiley, 2008.

POWER SYSTEM PLANNING			
Course Code	20ESE23	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Power System Planning: Introduction, Power System Composition, The Planning Process, Power System Planning.
Factors Affecting the Future of Power Supply Industry: Introduction, Electricity Supply Industry Reform, Deregulation of Markets, Public Private Partnership Models, Environmental Considerations, Other Considerations Affecting the Power Industry Reform, Case Study.
Planning Criteria: Introduction, Planning Expansion, Power System Stability Concerns, Modeling and Performance Indicators, Power Quality (PQ) Considerations, Uncertainty Constraints and Risk Analysis Planning, Case Study: Generation Expansion Planning. ■

Module-2

Load Research: Introduction, Load Research Methodology, Sampling Design, Use of Load Research Results, Driving Factors, Load Modelling, Case Study.
Electricity Load Forecasting: Introduction, Classification Electrical Load Forecasting, Forecasting Perspectives, Forecasting Driving Factors, Forecasting Time Frames, Case Study.
Energy Efficiency: Introduction, Energy Efficiency Impact on Electricity Consumption, Appliance Efficiency, Building Efficiency, Improving Energy Efficiency, Incentives Mechanisms to Effect EE, Case Study. ■

Module-3

Demand Side Management: Introduction, Concepts and Characteristics of Demand Side Management (DSM), Alternatives of DSM, Benefits of DSM, Implementation of DSM, Evaluation of DSM Alternatives, Case Study.
Renewable Energy Technologies: Introduction, RE and Electric Power, Green Energy and Sustainable Energy Generation, Site Specificity, RE Pricing, Production Economics, Environmental Impacts, Promoting of RE.
System Expansion Studies: Introduction, Generation Expansion, Transmission and Distribution Expansion, Cost Considerations and Expansion Obligations, Regulatory Incentives, Case Study. ■

Module-4

Integrated Resource Planning: Introduction, Concept and Rationale, Supply and Demand Side Interaction, Uncertainty and Cost Implications, Benefits of IRP, Case Study.
Interconnected Systems: Introduction, AC and HVDC Interconnection, Benefits of Interconnection, Interconnection: Technical Factors, Economic and Financial Impacts, Environmental Concerns, Social Impacts, Legal Aspects, Political Aspect.
Financing of Power Projects: Introduction, Economic Feasibility of Projects, Factors Influencing Investment in Power Systems, Financial vs. Economic Analyses, Financial Analysis Tools, Major Factors Influencing Financing, Financing Requirements, Public Private Partnership (PPP). ■

Module-5

Tariff Studies: Introduction, Tariff Calculation Models, Social Tariff Impacts, Cost-Reflective Tariff, Regulations and Tariffs, Case Study: Electricity Tariffs in Jordan (ERC, 2005), Net Paid Up Capital: JEPCO Prior to 2011.
Planning Tools: Introduction, Data Collection, Group Thinking, Decision Support Analysis, Decision Aiding Tools, Strategic Planning. ■

Course outcomes:

At the end of the course the student will be able to:

- Define the power system, its components
- Discuss the planning process and different aspects related to this process.
- Discuss regulatory and market constraints in light of the new trends of privatization and market deregulation.
- Discuss the planning criteria, load research and explain the tools and methodologies for forecasting future energy and electrical loads.
- Discuss energy efficiency methods and techniques to decreases demand of consumers and demand side management in order to reduce future demand
- Discuss generation of electricity from renewable energy sources and the expansion planning studies.
- Discuss Integrated Resource Planning (IRP), tariff calculation models and impact of tariff on society
- Explain planning tools used in all phases of planning process. ■

Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module.
Textbook
1. Power System Planning Technologies and Applications: Concepts, Solutions, and Management, Fawwaz

<table>
<tr><td colspan="4">SOLAR ENERGY TECHNOLOGIES</td></tr>
<tr><td>Course Code</td><td>20ESE241</td><td>CIE Marks</td><td>40</td></tr>
<tr><td>Teaching Hours/Week (L:P:SDA)</td><td>4:0:0</td><td>SEE Marks</td><td>60</td></tr>
<tr><td>Credits</td><td>04</td><td>Exam Hours</td><td>03</td></tr>
<tr><td colspan="4">Module-1</td></tr>
<tr><td colspan="4">Solar Energy: History and Current Use, Advantages of Solar Energy, Solar Energy Project Delivery Process, Integration of Solar Energy into the Existing Infrastructure.
Solar Energy Resource: Structure of the Sun, Nuclear Fusion: The Source of the Sun’s Power, The Spectral Nature of Solar Radiation, Position of the Sun in the Sky, Direct Beam, Diffuse, and Global Solar Insolation in the Plane of a Solar Collector Surface, Incident Angle of Direct Beam Sun on a Surface, The Effect of Shade, Solar Resource Measurement, Solar Resource Maps and Data, Typical Meteorological Year (TMY) Weather Data, Forecasting the Solar Resource Hours or Days into the Future, Diagnosis of Solar Energy System Performance Using Solar Resource Data, Computer Tools for Analysis of Solar Position and Solar Resources, Standards Related to Solar Resource Assessment. ■</td></tr>
<tr><td colspan="4">Module-2</td></tr>
<tr><td colspan="4">Photovoltaics (PV, Solar Electricity): Photovoltaic Cells and Modules, Voltage and Current Characteristics of PV Devices (the i-v curve), Open-Circuit Voltage and Operating Voltage of a PV Cell, Dependence of Voltage and Current on Temperature, Different Types of Photovoltaic Devices, Standard Ratings and Performance Indicators for PV Modules, Energy Balance for a PV Module, Nominal Operating cell Temperature (NOCT), Power Output of a PV Module, Photovoltaic System Schematic Design, Photovoltaic System Components, Estimating the Cost of a Photovoltaic System, Estimating Electric Use and Solar Fraction, Recommended Applications, Simple Hand Calculation of Photovoltaic System Size and Energy Delivery, Estimating the Energy Cost Savings of a Photovoltaic (Solar Electric) System, Computer Tools for Analysis of Photovoltaic Systems, Codes and Standards for Photovoltaic Modules and Systems, Operation and Maintenance of Photovoltaic Systems, Case Studies of Photovoltaic System Installations Procurement Specifications for Grid-Tied Solar Electric (Photovoltaic) System. ■</td></tr>
<tr><td colspan="4">Module-3</td></tr>
<tr><td colspan="4">Solar Water Heating: Different Types of Water-Heating, Solar Collectors, Solar Water Heating System Schematic Design, Solar Water Heating System Components, Estimating the Cost of a Solar Water Heating System, Estimating Building Hot Water Use and Solar Fraction, Recommended Applications, Simple Hand Calculation of Solar Water Heating System Size and Energy Delivery, System Thermodynamics and Computer Tools for Analysis of Solar Water Heating Systems, Codes and Standards for Solar Water Heaters, Operation and Maintenance of Solar Water Heating Systems, Case Studies of Solar Water Heating System Installations, Procurement Specifications for a Solar Water Heating System. ■</td></tr>
<tr><td colspan="4">Module-4</td></tr>
<tr><td colspan="4">Solar Ventilation Air Preheating: Operating Principle of the Transpired Air-Heating
Solar Collector, Solar Ventilation Air Preheat System Schematic, Solar Ventilation Air Preheat System Components, Design Considerations, Recommended Applications, Estimating the Cost of a Solar Ventilation Air Preheat System, Simple Hand Calculations for Size and Performance of a Solar Ventilation Air Heating System, Computer Tools for Analysis of Solar Ventilation Preheat Systems, Codes and Standards related to Solar Ventilation Air Preheating, Maintenance of Solar Ventilation Air Preheating Systems, Case Studies of Solar Ventilation Air Preheating System Installations, Procurement Specifications for Solar Ventilation Preheat System. ■</td></tr>
<tr><td colspan="4">Module-5</td></tr>
<tr><td colspan="4">Solar Space Heating and Cooling: Site Issues, Building Heat Loss, Solar Heat Gain through Windows and Opaque Surfaces, Materials and Building Components for Passive Solar Space Heating Systems, Thermal Storage, Heat Distribution Systems, Solar Space Heating (Passive or Active), System Schematic Design, Estimating the Cost of a Solar Space Heating System, Estimating Energy Use and Solar Fraction, Calculation of Solar Space Heating System Sizing and Energy Delivery, Computer Tools for Analysis of Passive Solar Systems, Codes and Standards Related to Passive Solar Heating, Operation and Maintenance of Passive Solar heating Systems, Case Studies of Passive Solar Space Heating Systems, Procurement Specifications for Passive Solar Thermal Storage Wall. ■</td></tr>
</table>

Course outcomes: At the end of the course the student will be able to: • Explain the history and use of solar energy, the source of solar energy and calculation of power and timing of the solar energy resource available to the different types of solar energy conversion technologies • Discuss photovoltaic cell their characteristics and their operation, performance parameters and design of photovoltaic systems • Discuss different types of solar water heating, soar collectors, solar water heater components, estimation of cost of solar water heating system, etc., • Discuss applications of solar energy in solar ventilation air preheating space heating and cooling and their design considerations. ■
Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module.
Textbook
1. Solar Energy Technologies and the Project Delivery Process for Buildings, Andy Walker, Wiley, 2013.

PHOTOVOLTAICS			
Course Code	20ESE242	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Properties of Solar Radiation: Glossary of Key PV Terms, Sun and Earth, Extraterrestrial Radiation, Radiation on the Horizontal Plane of the Earth's Surface, Simple Method for Calculating Solar Radiation on Inclined Surfaces, Radiation Calculation on Inclined Planes with Three-Component Model, Approximate Annual Energy Yield for Grid-Connected PV Systems, Composition of Solar Radiation, Solar Radiation Measurement. ■

Module-2

Solar Cells: Their Design Engineering and Operating Principles, The Internal Photoelectric Effect in Semiconductors, A Brief Account of Semiconductor Theory, The Solar Cell: A Specialized Semiconductor Diode with a Large Barrier Layer that is Exposed to Light, Solar Cell Efficiency, The Most Important Types of Solar Cells and the Attendant Manufacturing Methods, Bifacial Solar Cells, Examples. ■

Module-3

Solar Modules and Solar Generators: Solar Modules, Potential Solar Cell Wiring Problems, Interconnection of Solar Modules and Solar Generators, Solar Generator Power Loss Resulting from Partial Shading and Mismatch Loss - Power Loss Induced by Module Shading, Mismatch Loss Attributable to Manufacturing Tolerances, Mismatch Loss Attributable to String Inhomogeneity, Examples on the above topics.■

Module-4

PV Energy Systems: Stand-alone PV Systems, Grid-Connected Systems -Grid-Connected Operation, Design Engineering and Operating Principles of PV System Inverters. ■

PV Energy Systems (continued): Standards and Regulations for Grid-Connected Inverters, Avoidance of Islanding and Stand-alone Operation in Grid Inverters, Operating Performance and Characteristics of PV Grid Inverters - Conversion Efficiency, MPP Tracking Efficiency and MPP

Module-5

PV Energy Systems (continued): Control Characteristics, Overall Inverter Efficiency, Dynamic MPP Tracking Test - Simple Dynamic MPP Tracking Test Using Quasi-square Test Patterns. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain discuss solar insolation on horizontal and tilted surfaces and compute the amount of insolation by different methods
- Explain the structure and functional principle of solar cells; the impact of various solar cell materials and technologies on solar cell efficiency; solar cell designs; the solar cell manufacturing process.
- Explain the construction of solar modules, laminates and solar generators, and wiring options of solar module particularly in scenarios involving partially shaded solar generators configuration.
- Explain the layout and configuration of PV installations, their design and operating principles.
- Explain the operation of grid-connected PV systems, and the problems that can arise when such installations are connected to the public grid and provide solutions for them. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Photovoltaics System Design and Practice, Heinrich Haberlin, Wiley, 2012.

INTRODUCTION TO NUCLEAR POWER			
Course Code	20ESE243	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

The Earth and Nuclear Power: Sources and Resources: Introduction, Earth's Internal Heat Generation, The Earth's Energy Flow, The Fission Process, Thermal Energy Resources.
How Reactors Work: Introduction, The Fission Process, Basic Components of a Nuclear Reactor, Thermal Reactors, Fast Reactors. ■

Module-2

Cooling Reactors: Introduction, General Features of a Reactor Coolant, Principles of Heat Transfer, Gaseous Coolants, Liquid Coolants, Boiling Coolants, Alternative Forms of Reactor Coolant Circuits.
Loss of Cooling: Introduction, The Electric Kettle, Pressurized-Water Reactor, Boiling-Water Reactor, CANDU Reactor, Gas-Cooled Reactors, Sodium- Cooled Fast Reactor. ■

Module-3

Loss-of-Cooling Accidents: Introduction, Incidents in light Water-Cooled Reactors, Heavy Water-Moderated Reactors, Gas-Cooled Reactors, Liquid Metal-Cooled Fas t Reactors, The International Nuclear Event Scale (INES). ■

Module-4

Postulated Severe Accidents Introduction: Introduction, Postulated Severe Accidents in Water-Cooled Reactors, Specific Phenomena relating to Severe Accidents, Severe Accidents in other Reactor Types, Fission Product Dispersion following Containment Failure.
Cooling during Fuel Removal and Processing: Introduction, Refuelling, Spent Fuel Storage and Transport, Reprocessing Plant. ■

Module-5

Cooling and Disposing of the Waste: Introduction, Classification of Waste Products, Fission Products and Their Biological Significance, Options for Nuclear Waste Disposal, Long-Term Storage and Disposal of Spent Nuclear Fuel, Storage and Disposal of Fission Products from Reprocessing Plants, Disposal of other Materials.
Fusion Energy - Prospect for the Future: Introduction, The Fusion Process, Confinement, Current Technical Position, Conclusions. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the fission process in nuclear materials and how the nuclear reactors work and the basic components of nuclear reactors and their types.
- Explanation about cooling of reactors, features of coolant, different types of coolants used in the reactors and the losses of cooling.
- Discussion on loss of cooling accidents in different reactors.
- Discussion on postulated severe accidents in water cooled reactors and other reactors and cooling of reactor during removal and processing.
- Discussion on cooling and disposing the nuclear waste and prospect of fusion energy in the future. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Introduction to Nuclear Power, Geoffrey F. Hewitt, Taylor & Francis, 2000.

ENVIRONMENTAL IMPACTS OF RENEWABLE ENERGY			
Course Code	20ESE244	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Energy Basics: Energy, Types of Energy, Non-renewable Energy, Renewable Energy, Measuring Energy, Heat Engines.
Wind Power: Introduction, Wind Power Basics, Wind Energy, Wind Power,
Wind Turbine Components, Wind Energy Site Evaluation Impacts, Wind Energy Construction Impacts. ■

Module-2

Wind Power(continued): Wind Energy Operations Impacts, Wind Energy Impacts on Wildlife, Wind Energy Impacts on Human Health, Power Transmission Lines, Energy Transmission Site Evaluation Impacts, Energy Transmission Construction Impacts, Energy Transmission Operations Impacts, Wind Turbine Operations and Maintenance Personnel Safety Concerns, Wind Power: The Bottom Line.
Solar Energy: Energy from the Sun, Environmental Impacts of Solar Energy, Ecological Impacts, Solar Energy Job Hazards. ■

Module-3

Hydropower: River, Historical Perspective, Key Definitions, Hydropower Basic Concepts, Advanced Hydropower Technology, Ecological Impacts of Hydropower, Biological Impacts of Flow Fluctuations, Low Water Levels and Evaporation of Reservoirs, Impacts on Human Health and Safety, Hydropower: The Bottom Line. ■

Module-4

Biomass/Bioenergy: Introduction, Biomass, Plant Basics, Feedstocks, Biomass for Biopower Biomass for Bioproducts. ■

Module-5

Biomass/Bioenergy(continued): Biodiesel, Biogas (Methane), Impacts of Biomass Construction, Production, and Operation, Impacts on Human Health and Safety, Fatalities and Incidents, Biofuels: The Bottom Line.
Fuel Cells: Introduction to Hydrogen Fuel Cells, Hydrogen Storage, How a Hydrogen Fuel Cell Works, Environmental Impacts of Fuel Cells, Properties of Hydrogen. ■

Course outcomes:
At the end of the course the student will be able to:

- Define energy, types of energy
- Discuss generation of energy from different renewable sources and their impact on environment.
- Discuss use of Fuel cells and their impact on environment.■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Environmental Impacts of Renewable Energy, Frank R. Spellman, CRC Press, 2015.

WIND ENERGY SYSTEMS			
Course Code	20ESE251	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Wind Energy Systems: Introduction, Overview of Wind Energy Conversion Systems, Wind Turbine Technology, Wind Energy Conversion System Configurations, Grid Code.
Fundamentals of Wind Energy Conversion System Control: Introduction, Wind Turbine Components, Wind Turbine Aerodynamics, Maximum Power Point Tracking (MPPT) Control. ■

Module-2

Wind Generators and Modelling: Introduction, Reference Frame Transformation, Induction Generator Models, Synchronous Generators.
Power Converters in Wind Energy Conversion Systems: Introduction, AC Voltage Controllers (Soft Starters), Interleaved Boost Converters, Two-Level Voltage-Source Converters. ■

Module-3

Power Converters in Wind Energy Conversion Systems (continued): Three-Level Neutral Point Clamped Converters, PWM Current Source Converters, Control of Grid-Connected Inverter.
Wind Energy System Configurations: Introduction, Fixed-Speed WECS, Variable-Speed Induction Generator WECS, Variable-Speed Synchronous Generator WECS. ■

Module-4

Fixed**-Speed Induction Generator WECS:** Introduction, Configuration of Fixed-Speed Wind Energy Systems, Operation Principle, Grid Connection with Soft Starter, Reactive Power Compensation.
Variable-Speed Wind Energy Systems with Squirrel Cage Induction Generators: Introduction,
Direct Field Oriented Control, Indirect Field Oriented Control, Direct Torque Control, Control of Current Source Converter Interfaced WECS. ■

Module-5

Doubly Fed Induction Generator Based WECS: Introduction, Super-and Subsynchronous Operation of DFIG, Unity Power Factor Operation of DFIG, Leading and Lagging Power Factor Operation, Stator Voltage Oriented Control of DFIG WECS, DFIG WECS Start-Up and Experiments. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the wind turbine technology, wind energy system classification, costs, and grid codes for wind power integration.
- Explain the fundamentals and control principles of wind energy systems, including wind turbine components, aerodynamics, stall and pitch controls, and maximum power point tracking schemes
- Explain commonly used wind generators,
- Develop the dynamic and steady-state models of generators for the analysis of wind energy systems.
- Discuss power converters and PWM schemes used in wind energy systems.
- Discuss configurations and characteristics of major practical Wind Energy Conversion Systems. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Power Conversion and Control of Wind Energy Systems, BinWu et al, Wiley, 2011.

POWER SYSTEM HARMONICS			
Course Code	20ESE252	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Fundamentals of Harmonic Distortion and Power Quality Indices in Electric Power Systems: Introduction, Basics of Harmonic Theory, Linear and Nonlinear Loads, Fourier Series, Power Quality Indices under Harmonic Distortion, Power Quantities under Nonsinusoidal Situations.

Harmonic Sources: Introduction, The Signature of Harmonic Distortion, Traditional Harmonic Sources, Future Sources of Harmonics. ■

Module-2

Standardization of Harmonic Levels: Introduction, Harmonic Distortion Limits.

Effects of Harmonics on Distribution Systems: Introduction, Thermal Effects on Transformers, Miscellaneous Effects on Capacitor Banks, Abnormal Operation of Electronic Relays, Lighting Devices, Telephone Interference, Thermal Effects on Rotating Machines, Pulsating Torques in Rotating Machines, Abnormal Operation of Solid-State Devices, Considerations for Cables and Equipment Operating in Harmonic Environments.

Harmonic Measurements: Introduction, Relevant Harmonic Measurement Questions, Measurement Procedure, Relevant Aspects.■

Module-3

Harmonic Filtering Techniques: Introduction, General Aspects in the Design of Passive Harmonic Filters, Single-Tuned Filters, Band-Pass Filters, Relevant Aspects to Consider in the Design of Passive Filters, Methodology for Design of Tuned Harmonic Filters, Example 1: Adaptation of a Power Factor Capacitor Bank into a Fifth Harmonic Filter, Example 2: Digital Simulation of Single-Tuned Harmonic Filters, Example 3: High-Pass Filter at Generator Terminals Used to Control a Resonant Condition, Example 4: Comparison between Several Harmonic Mitigating Schemes Using the University of Texas at Austin HASIP Program, Active Filters. ■

Module-4

Other Methods to Decrease Harmonic Distortion Limits: Introduction, Network Topology configuration, Increase of Supply Mode Stiffness, Harmonic Cancellation through Use of Multipulse Converters, Series Reactors as Harmonic Attenuator Elements, Phase Balancing.

Harmonic Analyses: Introduction, Power Frequency vs. Harmonic Current Propagation, Harmonic Source Representation, Harmonic Propagation Facts, Flux of Harmonic Currents, Interrelation between AC System and Load Parameters, Analysis Methods, Examples of Harmonic Analysis.

Fundamentals of Power Losses in Harmonic Environments: Introduction, Meaning of Harmonic-Related Losses, Relevant Aspects of Losses in Power Apparatus and Distribution Systems, Harmonic Losses in Equipment, Example of Determination of K Factor, Rotating Machines. ■

Module-5

The Smart Grid Concept: Introduction, Photovoltaic Power Generator, Harnessing the Wind, FACTS Technology Concept and its Extended Adoption in Distribution Systems, High-Voltage Direct Current (HVDC) Transmission.

Harmonics in the Present Smart Grid Setting: Introduction, Photovoltaic Power Converters, Conventional Wind Power Converters, Power Electronics Harmonics Inherent in FACTS Technology, HVDC Harmonics and Filtering.

Harmonics from Latest Innovative Electric Grid Technologies: Introduction, Electric Vehicles Connected to the Grid, Superconducting Fault Current Limiters, Electric Vehicle Charging Stations. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss harmonics, different types of sources of harmonics.
- Estimate electrical parameters under harmonic situations.
- Describe the industry standards of harmonic distortion levels and effects of harmonics.
- Characterize harmonic levels at a given facility using industry recommendations.
- Design filters for mitigation of harmonics
- Explain the operation of filters for harmonic elimination.
- Explain power losses in electrical equipment due to harmonic waveform distortion.
- Explain the concept of smart grid, the presence of harmonics and their characteristics in the smart grid.■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Harmonics, Power Systems and Smart Grids, Francisco C. DE La Rosa, CRC, 2nd Edition 2015.

CARBON CAPTURE AND STORAGE			
Course Code	20ESE253	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Introduction: The carbon cycle, Mitigating growth of the atmospheric carbon inventory, The process of technology innovation.
Overview of carbon capture and storage: Carbon capture, Carbon storage.
Power generation fundamentals: Physical and chemical fundamentals, Fossil-fueled power plant, Combined cycle power generation, Future developments in power-generation technology. ■

Module-2

Carbon capture from power generation: Introduction, Precombustion capture, Postcombustion capture, Oxyfuel combustion capture, Chemical looping capture systems, Capture-ready and retrofit power plant, Approaches to zero-emission power generation.
Carbon capture from industrial processes: Cement production, Steel production, Oil refining, Natural gas processing.
Absorption capture systems: Chemical and physical fundamentals, Absorption applications in postcombustion capture, Absorption technology RD&D status. ■

Module-3

Adsorption capture systems: Physical and chemical fundamentals, Adsorption process applications, Adsorption technology RD&D status.
Membrane separation systems: Physical and chemical fundamentals, Membrane configuration and preparation and module construction, Membrane technology RD&D status, Membrane applications in precombustion capture, Membrane and molecular sieve applications in oxyfuel combustion, Membrane applications in postcombustion CO_2 separation, Membrane applications in natural gas processing. ■

Module-4

Cryogenic and distillation systems: Physical Fundamentals, Distillation column configuration and operation, Cryogenic oxygen production for oxyfuel combustion, Ryan–Holmes process for CO_2 –CH_4 separation, RD&D in cryogenic and distillation technologies.
Mineral carbonation: Physical and chemical fundamentals, Current state of technology development, Demonstration and deployment outlook.
Geological storage: Introduction, Geological and engineering fundamentals, Enhanced oil recovery, Saline aquifer storage, Other geological storage options. ■

Module-5

Ocean storage: Introduction, Physical, chemical, and biological fundamentals, Direct CO_2 injection, Chemical sequestration, Biological sequestration.
Storage in terrestrial ecosystems: Introduction, Biological and chemical fundamentals, Terrestrial carbon storage options, Full GHG accounting for terrestrial storage, Current R&D focus in terrestrial storage.
Other sequestration and use options: Enhanced industrial usage, Algal biofuel production.
Carbon dioxide transportation: Pipeline transportation, Marine transportation. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss the impacts of climate change and the measures that can be taken to reduce emissions.
- Discuss carbon capture and carbon storage.
- Explain the fundamentals of power generation.
- Explain methods of carbon capture from power generation and industrial processes.
- Explain different carbon storage methods: storage in coal seams, depleted gas reservoirs and saline formations.
- Explain Carbon dioxide compression and pipeline transport. ■

Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module.
Textbook
1. Carbon Capture and Storage, Stephen A. Rackley, Elsevier, 2010.

INTELLIGENT ENERGY DEMAND FORECASTING			
Course Code	20ESE254	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Introduction: Traditional Approaches for Electric Load Forecasting, Artificial Intelligent Technology for Electric Load Forecasting, Support Vector Regression for Electric Load Forecasting, Feasible Approaches to Improve the Forecasting Accuracy Performance.

Modeling for Energy Demand Forecasting: Autoregressive Integrated Moving Average Model, Seasonal Autoregressive Integrated Moving Average Model,Holt–Winters Model, Seasonal Holt–Winters (SHW) Model, General Regression Neural Network Model, Back-Propagation Neural Networks Model, Support Vector Regression Model. ■

Module-2

Evolutionary Algorithms in SVR's Parameter Determination: Data Set and Forecasting Comparison Statistical Tests, Modeling and Forecasting Results of Alternative Models, Genetic Algorithm in SVR's Parameter Determination, Simulated Annealing Algorithm in SVR's Parameter Determination, Hybrid GA with SA in SVR's Parameter Determination, Particle Swarm Optimization Algorithm in SVR's Parameter Determination. ■

Module-3

Evolutionary Algorithms in SVR's Parameter Determination: Continuous Ant Colony Optimization Algorithm in SVR's Parameter Determination, Artificial Bee Colony Algorithm in SVR's Parameter Determination, Immune Algorithm in SVR's Parameter Determination.

Chaos/Cloud Theories to Avoid Trapping into Local Optimum (continued): Brief Introductions of Chaotic Sequence and Cloud Model, Chaotic Genetic Algorithm (CGA) in SVR's Parameters Determination, Chaotic Simulated Annealing Algorithm in SVR's Parameters Determination. ■

Module-4

Chaos/Cloud Theories to Avoid Trapping into Local Optimum (continued): Chaotic Cloud Simulated Annealing Algorithm in SVR's Parameters Determination, Chaotic GASA (CGASA) Algorithm in SVR's Parameters Determination, Chaotic PSO (CPSO) Algorithm in SVR's Parameters Determination, Chaotic Ant Swarm Optimization Algorithm in SVR's Parameters Determination, Chaotic Artificial Bee Colony Algorithm in SVR's Parameters Determination, Chaotic Immune Algorithm in SVR's Parameters Determination. ■

Module-5

Recurrent/Seasonal Mechanism to Improve the Accurate Level of Forecasting: Combined Mechanisms, Seasonal ARIMA Model and Seasonal HW (SHW) Model, Seasonal Mechanism in SVRCGA Model and Forecasting Results, Seasonal Mechanism in SVRCSA Model and Forecasting Results, Seasonal Mechanism in SVRCCSA Model and Forecasting Results, Seasonal Mechanism in SVRCGASA Model and Forecasting Results, Seasonal Mechanism in SVRCPSO Model and Forecasting Results, Seasonal Mechanism in SVRCAS Model and Forecasting Results, Seasonal Mechanism in SVRCABC Model and Forecasting Results, Recurrent and Seasonal Mechanisms in SVRCABC Model and Forecasting Results, Seasonal Mechanism in SVRCIA Model and Forecasting Results. ■

Course outcomes:

At the end of the course the student will be able to:

- Understand electrical load forecasting and different forecasting models.
- Use Evolutionary Algorithms to conduct intelligent searching around the solution range to determine suitable parameter combination of an SVR model.
- Apply hybrid chaos theory with evolutionary algorithms to overcome the shortcomings of trapping local optimum to improve forecasting performance. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Intelligent Energy Demand Forecasting, Wei-Chiang Hong, Springer-Verlag, 2013.

ENERGY LABORATORY - 2			
Course Code	20ESEL26	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	0:4:0	SEE Marks	60
Credits	02	Exam Hours	03

Sl. NO	**Experiments**
1	Study of storage battery: Charging & discharging characteristics and maintenance.
2	Determination of efficiency of DC-AC inverter and DC-DC converters.
3	Energy audit of following installations and payback analysis, financial work sheet with reference to a renewable energy project: i) Workshop ii) Building lighting and ventilation iii) Air conditioning systems iv) Ice factory v) Small chemical plant vi) Foundry vii) IT Company viii) Large scale hotels ix) Laboratory in academic institutions.
4	Series and parallel connection of solar panel and effect shading.
5	Modelling and simulation of solar photovoltaic arrays.
6	Effect of temperature on V-I characteristics of photovoltaic panels.
7	Calculation of parameters of solar panel: Fill factor, V_{OC}, I_{SC}, Losses.
8	Development of algorithm for MPPT of solar PV system using measured insolation.
9	Mathematical modelling of solar photovoltaic arrays: Different types.
10	Study of multi junction solar cells: Characteristics.

Course outcomes:

At the end of the course the student will be able to:

- Explain charging and discharging characteristics and maintenance of storage battery.
- Evaluate efficiency of inverter and converters.
- Perform Energy audit of different installations and payback analysis, financial worksheet with reference to a renewable energy project.
- Model and simulate solar panels and study series and parallel connection of panels and the effect of shading.
- Study the effect of temperature on V-I characteristics of photovoltaic panels and calculate different parameters of solar panel.
- Develop mathematical models and develop algorithm for MPPT of solar PV system using measured insolation.
- Study multi junction solar cells and their characteristics.■

TECHNICAL SEMINAR			
Course Code	20ESE27	CIE Marks	100
Number of contact Hours/week	2	SEE Marks	--
Credits	02	Exam Hours	--

Course objectives:

The objective of the seminar is to inculcate self-learning, face audience confidently, enhance communication skill, involve in group discussion and present and exchange ideas.

Each student, under the guidance of a Faculty, is required to

- Choose, preferably through peer reviewed journals, a recent topic of his/her interest relevant to the Course of Specialization.
- Carryout literature survey, organize the Course topics in a systematic order.
- Prepare the report with own sentences.
- Type the matter to acquaint with the use of Micro-soft equation and drawing tools or any such facilities.
- Present the seminar topic orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit two copies of the typed report with a list of references.

The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident.

The CIE marks for the seminar shall be awarded (based on the relevance of the topic, presentation skill, participation in the question and answer session and quality of report) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculties from the department with the senior most acting as the Chairperson.

Marks distribution for CIE of the course 20ESE27 seminar:

Seminar Report: 30 marks

Presentation skill:50 marks

Question and Answer:20 marks

*** END ***

ENERGY AUDIT			
Course Code	20ESE31	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Types of Energy Audits and Energy-Audit Methodology: Definition of Energy Audit, Place of Audit, Energy – Audit Methodology, Financial Analysis, Sensitivity Analysis, Project Financing Options, Energy Monitoring and Training.
Survey Instrumentation: Electrical Measurement, Thermal Measurement, Light Measurement, Speed Measurement, Data Logger and Data – Acquisition System, Thermal Basis.
Energy Audit of Boilers: Classification of Boilers, Parts of Boiler, Efficiency of a Boiler, Role of excess Air in Boiler Efficiency, Energy Saving Methods. ■

Module-2

Energy Audit of Furnaces: Parts of a Furnace, classification of Furnaces, Energy saving Measures in Furnaces, Furnace Efficiency.
Energy Audit of a Power Plant: Indian Power Plant Scenario, Benefit of Audit, Types of Power Plants, Energy Audit of Power Plant.
Energy Audit of Steam-Distribution Systems: Steam as Heating Fluid, Steam Basics, Requirement of Steam, Pressure, Piping, Losses in Steam Distribution Systems, Energy Conservation Methods. ■

Module-3

Compressed Air System: Classification of Compressors, Types of Compressors, Compressed Air – System Layout, Energy – Saving Potential in a Compressed – Air System.
Energy Audit of HVAC Systems: Introduction to HVAC, Components of Air – Conditioning System, Types of Air – Conditioning Systems, Human Comfort Zone and Psychrometry, Vapour – Compression Refrigeration Cycle, Energy Use Indices, Impact of Refrigerants on Environment and Global Warming, Energy – Saving Measures in HVAC, Star Rating and Labelling by BEE.
Electrical-Load Management: Electrical Basics, Electrical Load Management, Variable- Frequency Drives, Harmonics and its Effects, Electricity Tariff, Power Factor, Transmission and Distribution Losses. ■

Module-4

Energy Audit of Motors: Classification of Motors, Parameters related to Motors, Efficiency of a Motor, Energy Conservation in Motors, BEE Star Rating and Labelling.
Energy Audit of Pumps, Blowers and Cooling Towers: Pumps, Fans and Blowers, Cooling Towers. ■

Module-5

Energy Audit of Lighting Systems: Fundamentals of Lighting, Different Lighting Systems, Ballasts, Fixtures (Luminaries), Reflectors, Lenses and Louvres, Lighting Control Systems, Lighting System Audit, Energy Saving Opportunities.
Energy Audit Applied to Buildings: Energy – Saving Measures in New Buildings, Water Audit, Method of Audit, General Energy – Savings Tips Applicable to New as well as Existing Buildings. ■

Course outcomes:

At the end of the course the student will be able to:

- Understand the need of energy audit and energy audit methodology.
- Explain audit parameters and working principles of measuring instruments used to measure the parameters.
- Conduct energy audit of boilers, furnaces, power plant, steam distribution system and compressed air systems.
- Conduct energy audit HVAC systems, motors, pumps, blowers and cooling towers.
- Explain load management techniques, effects of harmonics, electricity tariff, improvement of power factor and losses in transmission.
- Conduct energy audit of lighting systems and buildings. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Handbook on Energy Audit, Sonal Desai, Mc Graw Hill, 2015.

SOLAR HYDROGEN ENERGY SYSTEMS			
Course Code	20ESE321	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Introduction: The Current Situation, The Peak Oil Theory, Forms of Energy Sources and Environmental Impact, Sustainability of an Energy System, A Hydrogen New Energy System, Scenarios for the Future, Alternatives to Hydrogen.

Hydrogen: Hydrogen as Energy Carrier, Properties, Production, Usage Degenerative Phenomena and Material Compatibility, Components: Pipes, Joints and Valves, Transport.■

Module-2

Electrolysis and Fuel Cells: Introduction, Chemical Kinetics, Thermodynamics, Electrode Kinetics, Energy and Exergy of the Cell, Electrolyser, Fuel Cell.

Solar Radiation and Photovoltaic Conversion: Solar Radiation, Photovoltaic Effect, Semiconductors and the p-n Junction, Crystalline Silicon Photovoltaic Cells, Other Cell Technologies, Conversion Losses, Changes in the I-U Curve, Photovoltaic Cells and Modules, Types of Photovoltaic Plants, Radiation on the Receiving Surface, Determination of the Operating Point.■

Module-3

Wind Energy: Introduction, Mathematical Description of Wind, Wind Classification, Mathematical Model of the Aerogenerator, Power Control and Design, Wind Turbine Rating, Electric Energy Conversion, Calculation Example, Environmental Impact.

Other Renewable Energy Sources for Hydrogen Production: Solar Thermal Energy, Hydroelectric Energy, Tidal, Wave and Ocean Thermal Energy Conversions, Biomasses. ■

Module-4

Hydrogen Storage: Issues of Hydrogen Storage, Physical Storage, Physical-Chemical Storage, Chemical Storage.

Other Electricity Storage Technologies: Introduction, Electrochemical Storage, Ultra-capacitors, Compressed Air, Underground Pumped Water, Pumped Heat, Natural Gas Production, Flywheels, Superconducting Magnetic Energy Storage. ■

Module-5

Study and Simulation of Solar Hydrogen Energy Systems: Solar Hydrogen Energy Systems, Control Logic, Performance Analysis, Simulation with PV Conversion and Compression Storage, Simulation with PV Conversion and Activated-Carbon Storage, Simulation with Wind Energy Conversion, Compression and Activated-Carbon Storage, Notes on Exergy Analysis, Remarks on the Simulation of Solar Hydrogen Energy Systems.

Real-Life Implementations of Solar Hydrogen Energy Systems: Introduction, The first Project, The Schatz Solar Hydrogen Project, The ENEA Project, The Zollbruck Full Domestic System, The GlasHusEtt Project, The Trois Rivi`ere Plant, The SWB Industrial Plant, The HaRI Project, Results from Real-Life Implementations. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the macro-economical, technical and historical aspects of the new hydrogen-based energy system.
- Describe the physical and chemical properties of hydrogen, its production, application, the degenerative phenomena and the compatibility of the materials employed to handle hydrogen storage and transportation.
- Explain the behaviour and the modeling of electrolysers and fuel cells.
- Describe the fundamentals of photovoltaic and wind energies.
- Explain other potential renewable energy sources for hydrogen production.
- Explain the process of the storage of hydrogen and the chemical storage in standard batteries and other advanced alternatives.
- Explain implementation of the hydrogen system and simulation of the system behaviour with the help of mathematical models. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Solar Hydrogen Energy Systems Science and Technology for the Hydrogen Economy, Gabriele Zini et al, Springer, 2012.

ENERGY MANAGEMENT STRATEGIES FOR EV/PHEV			
Course Code	20ESE322	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Introduction: Background, HEV Fundamentals, Simulation Platform: The Advanced Vehicle, Simulator (ADVISOR) Software.

Electric and Plug-in Hybrid Electric Vehicle Drive Train Topologies: Concept of Electric, Hybrid Electric and Plug-in Hybrid Electric Vehicles, Hybrid Electric Vehicle Drive Train Topologies, Plug-in Hybrid Electric Vehicle Drive Train Topologies, All-Electric Vehicle Drive Train Topology.

EV and PHEV Energy Storage Systems: Introduction, Batteries, Electrical Modelling of Ultracapacitors, Electrical Modelling of Flywheel Energy Storage Systems, Operating Principle of a Fuel Cell. ■

Module-2

Hybrid Electric and Fuel Cell Hybrid Electric Vehicles: HEV Fundamentals and Concepts, Efficiencies of Series and Parallel HEV Drive Trains, Varied Driving Patterns and Regenerative Braking Efficiency Analysis, Regenerative Braking Efficiency Analysis, Overall Electric Drive Train Efficiency Analysis, Fuel Cell HEV: Modelling and Control, Power Electronics Interface of Fuel Cell and Traction System, Concept of Fuel Cell Plug-in HEV (FC-PHEV).

EV and PHEV Battery Technologies: 5.1 Energy Storage Issues of PHEVs and EVs. ■

Module-3

On-Board Power Electronic Battery Management: Battery Cell Voltage Equalization Problem, Introduction to Classic and Advanced Battery Cell Voltage Equalizers, Economic Significance of Battery Cell Voltage Equalization, Design and Performance of a Novel Power Electronic Cell Equalizer, Controller Design for Developed Cell Equalizer, Experimental Results. ■

Module-4

EV and PHEV Battery Charging: Grid and Renewable Energy Interface: Introduction, Charging Regimes for Batteries, Charging from Grid, Charging from Renewable Energy Sources, Power Electronics for EV and PHEV Charging, Topologies for PV Inverters, Power Converters Topology. ■

Module-5

Power Electronic Converter Topologies for EV/PHEV Charging: Grid and Photovoltaic (PV) System for EV/PHEV Charging, DC/DC Converters and DC/AC Inverters for Grid/PV Interconnection, Novel Integrated DC/AC/DC Converter for EV/PHEV Charging, High Frequency Transformer-Based Isolated Charger Topology, Component Design, Comments, Transformer-Less Charger Topology, Comments, Modelling and Simulation Results of Test System, Conclusion, High Frequency Transformer-Isolated Topology with DC-Link, Transformer-Less Topology, Efficiency,

EVs and PHEVs for Smart Grid Applications: Introduction, Vehicle-to-Grid and Grid-to-Vehicle Issues, Ancillary Services from V2G, Vehicle-to-Home and Home-to-Vehicle Concept, Interconnection Requirements, Study Case.

EV and PHEV Well-to-Wheels Efficiency Analysis: Interest in Well-to-Wheels Efficiency Analysis, Theoretical Efficiency Calculations for Advanced Vehicular Drive Trains, Simulation Setup for the Vehicle Under Study, Overall Efficiency Analysis Based on Simulation Results of the HEV and FCV Drive Train Architectures, Acceleration Performance and Well-to-Wheels Greenhouse Gas Emissions for HEV and ECV Drive Trains, Prospective Future Work. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the practical issues for commercialization of current and future EVs/PHEVs.
- Explain advanced power electronics and motor drives solutions for both current as well as future EV/PHEV drive trains.
- Discuss EV/PHEV power system architectures, battery technologies on-board energy management issues.
- Discuss advanced power electronic converter topologies for current and future battery charging infrastructures.
- Discuss EV/PHEV battery interface with renewable energy as well as the AC grid and efficiency analysis of all existing and future more electric drive train topologies. ■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Energy Management Strategies for Electric and Plug-in Hybrid Electric, Vehicles Sheldon S. Williamson, Springer, 2013.

ENERGY PRICING – ECONOMICS AND PRINCIPLES			
Course Code	20ESE323	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Introduction: Distinguishing Between Cost and Price, Cost and Price in Our Daily Vocabulary, The Credibility of Cost, Total Cost of the Operation as a Whole, Joint-Product Costs, Price Relationships: The Baker Revisited - The Quantity Discount, The Economics of Fixed (Overhead) Costs, A Closer Look at Two-Part Pricing, Competitive Pricing (Value to the Purchaser), From Wonderland to Reality, Cost and Price-A Primer.

The Cost Approach to Pricing-The Direction of Cost: Preface, Fixed and Variable Costs, Decreasing, Constant, and Increasing Costs Conditions, Decreasing Costs, The Base System, Future Additions, The Small Base-Load Plant, The Peaking or Firming-Up Plant, Power Purchases by Electric Utilities from Non-utility Sources, Bypass, and Discounts, Variable Costs, Matters of Judgment, A Note on Generating Plants, A Note on the Level of Costs. ■

Module-2

The Cost Approach to Pricing - Joint Cost Allocations: Direct and Joint/Common Costs, Cost Causation, Utility Cost Allocation Theory, The Functionalization of Costs, Methods of Allocation, Distribution, Rate Schedule Divisions of Cost, Suballocations, The Total Cost and Incremental Cost Methods, The Separable Costs-Remaining Benefits Method of Cost Allocation in Federal Multi-purpose Projects, Limits on the Ascertainment of Costs, Definitions of Cost.

The Cost Approach to Pricing - The Tenneco Pattern: Tenneco Pattern, The Issues, The Regulatory Scheme in Brief, Assignment of Fixed and Variable Costs, The Demand Charge, Zoning, A Resume, The Minimum Bill, Tenneco Allocations for Rate Design. ■

Module-3

The Value Approach to Pricing - Demand Influence: Preface, Value of Service Defined, Cost vs. Value in Juxtaposition, The "Upper and Lower Limit of Rates" Concept, Economic Demand, Direct and Derived Demand, Option Demand, The Price Elasticity of Demand, The Crucial Importance of Price Elasticity, The Revenue Effects of Elasticity, Immediate, Short-Run and Long-Run Price Elasticities of Demand, Repression and Stimulation, The Principle of Diminishing Utility, Economics of Pricing on a Value of Service Basis, Monopoly Pricing, The Theory of Class Price, Bases of Rate Classes, The Cost and Value Approaches Compared, Unreasonable Discrimination, Predatory Pricing, Is There a Problem?, Concluding Observations on Cost vs. Value, Marketing and Advertising.

The Value Approach to Pricing - Planning for Demand: Units of Measurement, Procedure, Planning: Short-Run Demand Forecasts, Planning: Long-Range Demand Forecasts, Final Results, Public Policy Forecasts, Concluding Comments. ■

Module-4

The Public Policy/Social Engineering Approach to Pricing: California's Lifeline/ Baseline Rate, Cost Components of Rates, Timed Pricing, The Colour GREEN, Venture into Marginal Cost Regulation, Wind Rates on an Integrated Electric System.

Introduction to Rates: The Unregulated Marketplace, The Marketplace Under Regulation,
The Customer Viewpoint, The Management Viewpoint, The Public Viewpoint, Related Objectives, Some Expert Opinions, Definitions.

Elements of Rate Design: Frequent Features, The "Blocking" Principle, "Postage Stamp" vs. Zone Rates, All-Purpose vs. Special-Purpose Rates: Unbundling, Seasonal vs. Year-Round Rates, Rolled-in vs. Incremental Pricing/Old Customer vs. New Customer Rates, Rate-Level Changes Across-the-Board, The "Fine-Print" Provisions, Nota Bene. ■

Module-5

Traditional Types of Rate Forms: Introduction, Rate Elements Defined Again, Single-Part Rate Forms, Two-Part Rate Forms, Three-Part Rate Forms, Modifications of Rate Forms and Special Applications, Miscellany.

Tools of the Trade: Introduction, Knowing the Market: Load Curves, Gauging the Market: Analysis Factors, Capacity Factor, Utilization Factor, Demand Factor, Power Factor, A Note to the Rate maker ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the difference between cost and price and to explain different types of costs.
- Explain the Joint cost allocation and why and when fixed and variable costs should be assigned to the demand charges of multi-part rates and the different methods for assigning the rates.
- Explain two different value influenced pricing, one the value approach of pricing – demand and the other pricing – planning for demand.
- Explain public-policy/ social engineering approach to pricing, the environment surrounding utility prices by outlining the viewpoints brought to bear on the subject by customers, utility managements, and the public and introduction to non-price clauses which frequently are inserted into the rate to modify its price statements.
- Explain the types of rate forms for the energy industries such as single part, two part rate and the tools of the trade such as load curve, capacity factor, utilization factor, demand factor and power factor. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Energy Pricing - Economics and Principles, Roger L. Conkling, Springer, 2011.

DATA ANALYTICS FOR THE SMART GRID			
Course Code	20ESE324	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Putting the Smarts in the Smart Grid: Goal, The Imperative for the Data-Driven Utility, Big Data: We'll Know It When We See It, What Are Data Analytics? Starting from Scratch, Finding Opportunity with Smart Grid Data Analytics.

Building the Foundation for Data Analytics: Chapter Goal, Perseverance Is the Most Important Tool, Building the Analytical Architecture.

Transforming Big Data for High-Value Action: Goal, The Utility as a Data Company, Algorithms, Seeing Intelligence, Assessing the Business Issues. ■

Module-2

Applying Analytical Models in the Utility: Goal, Understanding Analytical Models, Using Descriptive Models for Analytics, Using Diagnostic Models for Analytics, Predictive Analytics, Prescriptive Analytics, An Optimization Model for the Utility, Toward Situational Intelligence.

Enterprise Analytics: Goal, Moving Beyond Business Intelligence.

Operational Analytics: Goal, Aligning the Forces for Improved Decision-Making, The Opportunity for Insight, Focus on Effectiveness, Distributed Generation Operations: Managing the Mix-Up, Grid Management, Resiliency Analytics, Extracting Value from Operational Data Analytics. ■

Module-3

Customer Operations and Engagement Analytics: Goal, Increasing Customer Value, What's in It for the Customer?

Analytics for Cybersecurity: Goal, Cybersecurity in the Utility Industry, The Role of Big Data Cybersecurity Analytics.

Sourcing Data: Goal, Sourcing the Data, Working with a Variety of Data Sources. ■

Module-4

Big Data Integration, Frameworks, and Databases: Goal, This Is Going to Cost, Storage Modalities, Data Integration, The Costs of Low-Risk Approaches, Let the Data Flow, Other Big Data Databases, The Curse of Abundance.

Extracting Value: Goal, We Need Some Answers Here, Mining Data for Information and Knowledge, The Process of Data Extraction, Stream Processing, Avoid Irrational Exuberance. ■

Module-5

Envisioning the Utility: Goal, Big Data Comprehension, Why Humans Need Visualization, The Role of Human Perception, The Utility Visualized, Making Sense of It All.

A Partnership for Change: Goal, With Big Data Comes Big Responsibility, Privacy, Not Promises, Privacy Enhancement, The Utility of the Future Is a Good Partner. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss the key role of data analytics; its architecture and the challenges of creating and implementing them.
- Discuss useful analytical models, traditional business functions and issues affecting how analytics are used in the control room.
- Discuss the methods to increase residential customer lifetime value, vulnerabilities, threats, and analytic approaches to responding to cyber warfare against the utility,
- Discuss the elements of big data infrastructure, their difficulties and benefits in adapting to the needs of high-volume and varied data types,
- Explain the basic concepts of data visualization and the importance of utility becoming trusted steward of big data. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Big Data Analytics Strategies for the Smart Grid, Carol L. Stimmel, CRC Press, 2015.

ENERGY STORAGE IN POWER GRIDS			
Course Code	20ESE331	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Electrical Energy Storage: Difficulties of storing electrical energy, Need for storing electrical energy, Value enhancement of storage in electrical grids, Storage management.
Recent Developments in Energy Storage: Introduction, Storage technologies, Characteristics of a storage system, Hydraulic storage, Compressed-air storage, Thermal storage, Chemical storage, Kinetic storage, Electrostatic storage, Electromagnetic storage, Compared performances of storage technologies. ■

Module-2

Applications and Values of Energy Storage in Power Systems: Introduction, Introduction to power systems and their operation, Services that can be provided by storage, Example of the contribution of storage to the treatment of congestion events. ■

Module-3

Applications and Values of Energy Storage in Power Systems (continued): Example of contribution of storage to dynamic support of frequency control in an island grid, General conclusion.
Introduction to Fuzzy Logic and Application to the Management of Kinetic Energy Storage in a Hybrid Wind-Diesel System: Introduction, Introduction to fuzzy logic, Wind-kinetic energy storage combination on an isolated site with a diesel generator. ■

Module-4

Supervisor Construction Methodology for a Wind power Source Combined with Storage: Introduction, Energetic system studied, Supervisor development methodology, Specifications, Supervisor structure, Identification of various operating states: functional graph, Membership functions, Operational graph, Fuzzy rules, Experimental validation. ■

Module-5

Design of a Hybrid Multisource/Multistorage Supervisor: Introduction, Methodology for the construction of a supervisor for a hybrid source incorporating wind power, Compared performance of different variants of hybrid source.
Management and Economic Enhancement of Adiabatic Compressed-Air Energy Storage Incorporated into a Power Grid: Introduction, Services provided by storage, Supervision strategy,
Economic value of services, Application. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss the need to store electrical energy.
- Explain electrical energy storage technologies used currently.
- Explain the general characteristics of the components making up an electrical system transport and distribution network management modes and the services that can be provided by storage.
- Explain the contribution of storage to the treatment of congestion and the dynamic frequency control in the event of sudden instability.
- Explain the basic concepts of fuzzy logic applied to the management of an inertial energy storage system.
- Explain the methodology to design of an electrical supervisor for a wind power system incorporating electrical energy storage using fuzzy rules.
- Explain the design methodology of hybrid supervisor for a multisource and multi-storage system and the management and economic enhancement of adiabatic compressed-air storage incorporated into an electrical network with renewable wind energy production. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Energy Storage in Electric Power Grids, Benoît Robyns et al, Wiley, 2015.

HIGH-POWER BATTERY TECHNOLOGIES			
Course Code	20ESE332	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Current Status of Rechargeable Batteries and Fuel Cells: Rechargeable Batteries, Fundamental Aspects of a Rechargeable Battery, Rechargeable Batteries Irrespective of Power Capability, Rechargeable Batteries for Commercial and Military Applications, Batteries for Low-Power Applications, Fuel Cells.

Batteries for Aerospace and Communications Satellites: Introduction, On-board Electrical Power System, Battery Power Requirements and Associated Critical Components, Cost-Effective Design Criterion for Battery-Type Power Systems for Spacecraft, Spacecraft Power System Reliability, Ideal Batteries for Aerospace and Communications Satellites, Performance Capabilities and Battery Power Requirements for the Latest Commercial and Military Satellite Systems, Military Satellites for Communications, Surveillance, Reconnaissance, and Target Tracking, Batteries Best Suited to Power Satellite Communications Satellites. ■

Module-2

Fuel Cell Technology: Introduction, Performance Capabilities of Fuel Cells Based on Electrolytes,
Low-Temperature Fuel Cells Using Various Electrolytes, Fuel Cells Using a Combination of Fuels, Fuel Cell Designs for Multiple Applications, Ion-Exchange Membrane Fuel Cells, Potential Applications of Fuel Cells, Fuel Cells for Aircraft Applications, Fuel Cells for Commercial, Military, and Space Applications, Fuel Cells Capable of Operating in Ultra-High-Temperature Environments, Fuel Cell Requirements for Electric Power Plant Applications. ■

Module-3

Batteries for Electric and Hybrid Vehicles: Introduction, Chronological Development History of Early Electric Vehicles and Their Performance Parameters, Electric and Hybrid Electric Vehicles Developed Earlier by Various Companies and Their Performance Specifications, Development History of the Latest Electric and Hybrid Electric, Vehicle Types and Their Performance Capabilities and Limitations, Performance Requirements of Various Rechargeable Batteries, Materials for Rechargeable Batteries, Rechargeable Batteries, Critical Role of Rare Earth Materials in the Development of EVs and HEVs. ■

Module-4

Low Power Rechargeable Batteries for Commercial, Space, and Medical Applications: Introduction, Low-Power Battery Configurations, Batteries for Miniaturized Electronic System Applications, Batteries for Medical Applications, Selection Criteria for Primary and Secondary (Rechargeable) Batteries for Specific Applications. ■

Module-5

Rechargeable Batteries for Military Applications: Introduction, Potential Battery Types for Various Military System Applications, Low-Power Batteries for Various Applications, High-Power Lithium and Thermal Batteries for Military Applications, High-Power Rechargeable Batteries for Underwater Vehicles, High-Power Battery Systems Capable of Providing Electrical Energy in Case of Commercial Power Plant Shutdown over a Long Duration, Batteries Best Suited for Drones and Unmanned Air Vehicles. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss the current status of primary and secondary (rechargeable) batteries and fuel cells for various applications, their performance capabilities and limitations.
- Explain the performance requirements for next-generation high-power rechargeable batteries suited for applications requiring high-energy and -power densities, their design configurations for specific applications with emphasis on safety, reliability, longevity, and portability.
- Explain fuel cells suitable for applications where electrical power requirements vary between several kilowatts (kW) to a few megawatts (MW).
- Explain the working of high-power batteries currently used by EVs and HEVs
- Discuss the design configurations and performance of high-power batteries.
- Explain low-power battery configurations best suited for compact commercial, industrial, and medical applications.
- Describe rechargeable batteries for military and battlefield applications. ■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module.
Textbook
1. Next-Generation Batteries and Fuel Cells for Commercial, Military, and Space Applications,A.R. JHA, CRC

PIEZOELECTRIC ENERGY			
Course Code	20ESE333	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Introduction to Piezoelectric Energy Harvesting: Vibration-Based Energy Harvesting Using Piezoelectric Transduction, An Example of a Piezoelectric Energy Harvesting System, Mathematical Modelling of Piezoelectric Energy Harvesters.

Base Excitation Problem for Cantilevered Structures and Correction of the Lumped-Parameter Electromechanical Model: Base Excitation Problem for the Transverse Vibrations of a Cantilevered Thin Beam, Correction of the Lumped-Parameter Base Excitation Model for Transverse Vibrations, Experimental Case Studies for Validation of the Correction Factor, Base Excitation Problem for Longitudinal Vibrations and Correction of its Lumped-Parameter Model, Correction Factor in the Electromechanically Coupled Lumped-Parameter Equations and a Theoretical Case Study. ■

Module-2

Analytical Distributed-Parameter Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvesters: Fundamentals of the Electromechanically Coupled Distributed-Parameter Model, Series Connection of the Piezoceramic Layers, Parallel Connection of the Piezoceramic Layers, Equivalent Representation of the Series and the Parallel Connection Cases, Single-Mode Electromechanical Equations for Modal Excitations, Multi-mode and Single-Mode Electromechanical FRFs, Theoretical Case Study. ■

Module-3

Experimental Validation of the Analytical Solution for Bimorph Configurations: PZT-5H Bimorph Cantilever without a Tip Mass, PZT-5H Bimorph Cantilever with a Tip Mass, PZT-5A Bimorph Cantilever.

Dimensionless Equations, Asymptotic Analyses, and Closed-Form Relations for Parameter Identification and Optimization: Dimensionless Representation of the Single-Mode Electromechanical FRFs, Asymptotic Analyses and Resonance Frequencies, Identification of Mechanical Damping, Identification of the Optimum Electrical Load for Resonance Excitation,

Identification and Optimization(continued): Intersection of the Voltage Asymptotes and a Simple Technique for the Experimental Identification of the Optimum Load Resistance, Vibration Attenuation/Amplification from the Short-Circuit to Open-Circuit Conditions, Experimental Validation for a PZT-5H Bimorph Cantilever. ■

Module-4

Approximate Analytical Distributed-Parameter Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvesters: Unimorph Piezoelectric Energy Harvester Configuration, Electromechanical Euler–Bernoulli Model with Axial Deformations, Electromechanical Rayleigh Model with Axial Deformations, Electromechanical Timoshenko Model with Axial Deformations, Modelling of Symmetric Configurations, Presence of a Tip Mass in the Euler–Bernoulli, Rayleigh,

Approximate Analytical Distributed-Parameter Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvesters (continued): and Timoshenko Models, Comments on the Kinematically Admissible Trial Functions, Experimental Validation of the Assumed-Modes Solution for a Bimorph Cantilever, Experimental Validation for a Two-Segment Cantilever.

Modelling of Piezoelectric Energy Harvesting for Various Forms of Dynamic Loading: Governing Electromechanical Equations, Periodic Excitation, White Noise Excitation, Excitation Due to Moving Loads, Local Strain Fluctuations on Large Structures, Numerical Solution for General Transient Excitation, Case Studies. ■

Module-5

Modelling and Exploiting Mechanical Nonlinearities in Piezoelectric Energy Harvesting: Perturbation Solution of the Piezoelectric Energy Harvesting Problem: the Method of Multiple Scales, Monostable Duffing Oscillator with Piezoelectric Coupling, Bistable Duffing Oscillator with Piezoelectric Coupling: the Piezomagnetoelastic Energy Harvester, Experimental Performance Results of the Bistable Piezomagnetoelastic Energy Harvester, A Bistable Plate for Piezoelectric Energy Harvesting.

Piezoelectric Energy Harvesting from Aeroelastic Vibrations: A Lumped-Parameter Piezoaeroelastic Energy Harvester Model for Harmonic Response, Experimental Validations of the Lumped-Parameter Model at the Flutter Boundary, Utilization of System Nonlinearities in Piezoaeroelastic Energy Harvesting, A Distributed-Parameter Piezoaeroelastic Model for Harmonic Response: Assumed-Modes Formulation, Time-Domain and Frequency-Domain Piezoaeroelastic Formulations with Finite-Element Modelling, Theoretical Case Study for Airflow Excitation of a Cantilevered Plate. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain vibration-based energy harvesting using piezoelectric transduction
- Discuss analytical distributed-parameter modeling of the transverse and longitudinal vibrations for cantilevered beams and bars under base excitation.
- Explain electromechanically coupled analytical solutions of symmetric bimorph piezoelectric energy harvester configurations under base excitation for the series and parallel connections of the piezoceramics layers.
- Solve the single-mode electromechanical equations for relatively complicated structural configurations which do not allow analytical solutions.
- Develop distributed-parameter electromechanical models for piezoelectric energy harvesting under various forms of dynamic loading.
- Explain modeling and exploiting mechanical nonlinearities in piezoelectric energy harvesting
- Explain harvesting piezoelectric energy from aeroelastic vibrations of structures with piezoceramic layers under airflow excitation. ■

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbook

1. Piezoelectric Energy Harvesting, Alper Erturk, Wiley, 2011.

CYBERSECURITY IN THE ELECTRICITY SECTOR			
Course Code	20ESE334	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-1

Introduction: Transformation, Dependence on the ICT, 8Cybersecurity, Priority Critical Infrastructure.
State of Cybersecurity in the Electricity Sector: Introduction, Vulnerabilities, Threats, Challenges, Initiatives, Future Directions. ■

Module-2

Cybersecurity Standards Applicable to the Electricity Sector: Introduction, Literature Search, Literature Analysis, Standards' Selection and Evaluation Criteria, Results, Most Relevant Standards, Standards' Limitations, Standards' Implementation and Awareness. ■

Module-3

A Systematic Approach to Cybersecurity Management: Introduction, Cybersecurity Management Approaches in Standards, The Systematic Approach to Cybersecurity Management in the Electricity Sector. ■

Module-4

Cost of Cybersecurity Management: Introduction, Economic Studies, Organisation Management Studies, Cost-Benefit Analysis, Cost Calculators, Costing Metrics, CAsPeA.
Cybersecurity Assessment: Introduction, Security Assessment Methods for the Electricity Sector, Cybersecurity Test beds for Power Systems, JRC Cybersecurity Assessment Method, Laboratory Infrastructure, MAlSim. ■

Module-5

Cybersecurity Controls: Introduction, Standard Technical Solutions, Information Sharing Platform on Cybersecurity Incidents for the Energy Sector, Situation Awareness Network. ■

Course outcomes:
At the end of the course the student will be able to:

- Discuss the current cybersecurity situation in the electricity sector and the relevant standards that can be employed for cybersecurity.
- Explain cybersecurity management approach and the methods for the electricity sector.
- Explain available solutions that support the cost-benefit analyses involved in cybersecurity management and cybersecurity assessment approach.
- Discuss cybersecurity controls, for reducing cyber risks. ■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Cybersecurity in the Electricity Sector, Rafal Leszczyna, Springer, 2019

PROJECT WORK PHASE – 1			
Course Code	20ESE34	CIE Marks	100
Number of contact Hours/Week	2	SEE Marks	--
Credits	02	Exam Hours	--

Course objectives:

- Support independent learning.
- Guide to select and utilize adequate information from varied resources maintaining ethics.
- Guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- Develop interactive, communication, organisation, time management, and presentation skills.
- Impart flexibility and adaptability.
- Inspire independent and team working.
- Expand intellectual capacity, credibility, judgement, intuition.
- Adhere to punctuality, setting and meeting deadlines.
- Instil responsibilities to oneself and others.
- Train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas. ■

Project Phase-1 Students in consultation with the guide/s shall carry out literature survey/ visit industries to finalize the topic of the Project. Subsequently, the students shall collect the material required for the selected project, prepare synopsis and narrate the methodology to carry out the project work.

Seminar: Each student, under the guidance of a Faculty, is required to

- Present the seminar on the selected project orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit two copies of the typed report with a list of references.

The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident. ■

Course outcomes:

At the end of the course the student will be able to:

- Demonstrate a sound technical knowledge of their selected project topic.
- Undertake problem identification, formulation and solution.
- Design engineering solutions to complex problems utilising a systems approach.
- Communicate with engineers and the community at large in written an oral forms.
- Demonstrate the knowledge, skills and attitudes of a professional engineer. ■

Continuous Internal Evaluation

CIE marks for the project report (50 marks), seminar (30 marks) and question and answer (20 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session by the student) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with the senior most acting as the Chairperson. ■

MINI PROJECT			
Course Code	20ESE35	CIE Marks	40
Number of contact Hours/Week	2	SEE Marks	60
Credits	02	Exam Hours/Batch	03

Course objectives:

- To support independent learning and innovative attitude.
- To guide to select and utilize adequate information from varied resources upholding ethics.
- To guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- To develop interactive, communication, organisation, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgement, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instil responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas. ■

Mini-Project: Each student of the project batch shall involve in carrying out the project work jointly in constant consultation with internal guide, co-guide, and external guide and prepare the project report as per the norms avoiding plagiarism. ■

Course outcomes:

At the end of the course the student will be able to:

- Present the mini-project and be able to defend it.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information so as to apply these skills to the project task.
- Habituated to critical thinking and use problem solving skills.
- Communicate effectively and to present ideas clearly and coherently in both the written and oral forms.
- Work in a team to achieve common goal.
- Learn on their own, reflect on their learning and take appropriate actions to improve it. ■

CIE procedure for Mini - Project:

The CIE marks awarded for Mini - Project, shall be based on the evaluation of Mini - Project Report, Project Presentation skill and Question and Answer session in the ratio 50:25:25.The marks awarded for Mini - Project report shall be the same for all the batch mates.

Semester End Examination

SEE marks for the mini-project shall be awarded based on the evaluation of Mini-Project Report, Presentation skill and Question and Answer session in the ratio 50:25:25 by the examiners appointed by the University. ■

INTERNSHIP			
Course Code	20ESEI36	CIE Marks	40
Number of contact Hours/Week	2	SEE Marks	60
Credits	06	Exam Hours	03

Course objectives:

Internship/Professional practice provide students the opportunity of hands-on experience that include personal training, time and stress management, interactive skills, presentations, budgeting, marketing, liability and risk management, paperwork, equipment ordering, maintenance, responding to emergencies etc. The objective are further,

- To put theory into practice.
- To expand thinking and broaden the knowledge and skills acquired through course work in the field.
- To relate to, interact with, and learn from current professionals in the field.
- To gain a greater understanding of the duties and responsibilities of a professional.
- To understand and adhere to professional standards in the field.
- To gain insight to professional communication including meetings, memos, reading, writing, public speaking, research, client interaction, input of ideas, and confidentiality.
- To identify personal strengths and weaknesses.
- To develop the initiative and motivation to be a self-starter and work independently. ■

Internship/Professional practice: Students under the guidance of internal guide/s and external guide shall take part in all the activities regularly to acquire as much knowledge as possible without causing any inconvenience at the place of internship.

Seminar: Each student, is required to

- Present the seminar on the internship orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit the report duly certified by the external guide.
- The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident. ■

Course outcomes:

At the end of the course the student will be able to:

- Gain practical experience within industry in which the internship is done.
- Acquire knowledge of the industry in which the internship is done.
- Apply knowledge and skills learned to classroom work.
- Develop a greater understanding about career options while more clearly defining personal career goals.
- Experience the activities and functions of professionals.
- Develop and refine oral and written communication skills.
- Identify areas for future knowledge and skill development.
- Expand intellectual capacity, credibility, judgment, intuition.
- Acquire the knowledge of administration, marketing, finance and economics. ■

Continuous Internal Evaluation

CIE marks for the Internship/Professional practice report (20 marks), seminar (10 marks) and question and answer session (10 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session by the student) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with the senior most acting as the Chairperson. ■

Semester End Examination

SEE marks for the internship report (30 marks), seminar (20 marks) and question and answer session (10 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session) by the examiners appointed by the University. ■

PROJECT WORK PHASE -2			
Course Code	20ESE41	CIE Marks	40
Number of contact Hours/Week	4	SEE Marks	60
Credits	20	Exam Hours	03

Course objectives:

- To support independent learning.
- To guide to select and utilize adequate information from varied resources maintaining ethics.
- To guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- To develop interactive, communication, organisation, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgement, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instil responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas. ■

Project Work Phase - II: Each student of the project batch shall involve in carrying out the project work jointly in constant consultation with internal guide, co-guide, and external guide and prepare the project report as per the norms avoiding plagiarism. ■

Course outcomes:

At the end of the course the student will be able to:

- Present the project and be able to defend it.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information so as to apply these skills to the project task.
- Habituated to critical thinking and use problem solving skills
- Communicate effectively and to present ideas clearly and coherently in both the written and oral forms.
- Work in a team to achieve common goal.
- Learn on their own, reflect on their learning and take appropriate actions to improve it. ■

Continuous Internal Evaluation:

Project Report: 20 marks. The basis for awarding the marks shall be the involvement of the student in the project and in the preparation of project report. To be awarded by the internal guide in consultation with external guide if any.

Project Presentation: 10 marks.

The Project Presentation marks of the Project Work Phase -II shall be awarded by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with the senior most acting as the Chairperson.

Question and Answer: 10 marks.

The student shall be evaluated based on the ability in the Question and Answer session for 10 marks.

Semester End Examination

SEE marks for the project report (30 marks), seminar (20 marks) and question and answer session (10 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session) by the examiners appointed by the University. ■