VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examination and Syllabus
M.Tech ENERGY SYSTEM ENGINEERING (ESE)

Eligibility: Bachelor's degree in Engineering or Technology in
(a)Electrical and Electronics Engineering (b) Mechanical Engineering (c) Chemical Engineering
(d) AMIE in appropriate branch (f) GATE: EE, ME,CH

(Effective from Academic year 2016-17)

BOARD OF STUDIES IN ELECTRICAL AND ELECTRONICS ENGINEERING

January 2017

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)

I SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EEE11	Applied Mathematics	04	--	03	20	80	100	4
2	16ESE12	Energy Resources and the Environmental Impacts	04	--	03	20	80	100	4
3	16ESE13	Energy Production, Conversion and Conservation	04	--	03	20	80	100	4
4	16ESE14	Energy Conversion Technologies	04	--	03	20	80	100	4
5	16ESE15X	Elective -1	03	--	03	20	80	100	3
6	16ESEL16	Energy Laboratory- I	-	3	03	20	80	100	2
7	16ESE17	Seminar	-	3	-	100	-	100	1
TOTAL			**19**	**06**	**18**	**220**	**480**	**700**	**22**

Number of credits completed at the end of I semester: 22

Elective -1

Subject Code under 16ESE15X	Title
16ESE151	Solar Energy Technologies
16ESE152	Photovoltaics
16ESE153	Introduction to Nuclear Power
16ESE154	Energy Pricing – Economics and Principles

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)

II SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16ESE21	Power System Operation	04	--	03	20	80	100	4
2	16ESE22	Integration of Distributed Generation	04	--	03	20	80	100	4
3	16ESE23	Industrial Energy and Management	04	--	03	20	80	100	4
4	16ESE24	Power System Planning	04	--	03	20	80	100	4
5	16ESE25X	Elective - 2	03	--	03	20	80	100	3
6	16ESEL26	Energy Laboratory - II	-	3	03	20	80	100	2
7	16ESE27	Seminar	-	3	-	100	-	100	1
TOTAL			**19**	**06**	**18**	**220**	**480**	**700**	**22**

Number of credits completed at the end of II semester: 22+ 22 = 44

Elective -1

Subject Code under 16ESE25X	Title
16ESE251	Wind Energy Systems
16ESE252	Power System Harmonics
16ESE253	Carbon Capture and Storage
16ESE254	Piezoelectric Energy

Note: Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech ENERGY SYSTEM ENGINEERING (ESE)

CHOICE BASED CREDIT SYSTEM (CBCS)

III SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16ESE31	Seminar / Presentation on Internship (After 8 weeks from the date of commencement)	--	--	--	25	--	25	20
2	16ESE32	Report on Internship	--	--	--	25	--	25	
3	16ESE33	Evaluation and Viva-Voce of Internship	--	--	--	--	50	50	
4	16ESE34	Evaluation of Project phase -1	--	--	--	50	--	50	1
TOTAL			**--**	**--**	**--**	**100**	**50**	**150**	**21**

Number of credits completed at the end of III semester: 22+ 22 + 21 = 65

Note:

Internship of 16 weeks shall be carried out during III semester.

Major part of the Project work shall also be carried out during the III semester in consultation with the Guide/s.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)

IV SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16ESE41	Energy Audit	04	--	03	20	80	100	4
2	16ESE42X	Elective - 3	03	--	03	20	80	100	3
3	16ESE43	Evaluation of Project phase -2	--	--	--	50	-	50	3
4	16ESE44	Evaluation of Project and Viva-Voce	--	--	--	--	100 + 100	200	10
		TOTAL	**07**	**--**	**06**	**90**	**360**	**450**	**20**

Number of credits completed at the end of IV semester: 22+ 22 + 21 + 20 = 85

Elective -1

Subject Code under 16ESE42X	Title
16ESE421	Solar Hydrogen Energy Systems
16ESE422	Energy Management Strategies for EV/PHEV
16ESE423	Energy Storage in Power Grids
16ESE424	High-Power Battery Technologies

Note: 1. Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

2. Project Phase-2: 16-week duration during 4th semester**.** Evaluation shall be done by the committee comprising of HoD as Chairman, Guide and Senior faculty of the department.

3. **Project Evaluation**: Evaluation shall be taken up at the end of 4th semester. Project work evaluation and Viva-Voce examination shall conducted

4**. Project evaluation:**

a. Internal Examiner shall carry out the evaluation for 100 marks.
b. External Examiner shall carry out the evaluation for 100 marks.
c .The average of marks allotted by the internal and external examiner shall be the final marks of the project evaluation.
d. Viva-Voce examination of Project work shall be conducted jointly by Internal and External examiner for 100 marks.

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
APPLIED MATHAMATICS (Core Course)			
Course Code	16EEE11	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- The objectives of this course is to acquaint the students with principles of advanced mathematics through linear algebra, transform methods for differential equations, calculus of variations and linear and non-linear programming, that serve as an essential tool for applications of electrical engineering sciences. ■

Module-1		Teaching Hours
Numerical Methods: Solution of algebraic and transcendental equations- iterative methods based on second degree equation – Muller method(no derivation), Chebyshev method. Fixed point iteration method (first order), acceleration of convergence- Δ^2 - Aitken's method. System of non-linear equations – Newton-Raphson method. Complex roots by Bairstow's method.■		**10**
Revised Bloom's Taxonomy Level	L_2 – Understanding, L_3 – Applying	
Module-2		
Numerical Solution of Partial Differential Equations: Classification of second order equations, parabolic equations-solution of one dimensional heat equation, explicit method, Crank-Nicolson method. Hyperbolic equations- solution of one dimensional wave equation and two-dimensional Laplace equation by explicit method. ■		**10**
Revised Bloom's Taxonomy Level	L_3 – Applying	
Module-3		
Linear Algebra: Vector spaces, linear dependent, independence, basis and dimension, elementary properties, examples. **Linear Transformations**: Definition, properties, range and null space, rank and nullity, algebra of linear transformations-invertible, singular and non-singular transformations, representation of transformations by matrices.■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding	
Module-4		
System of linear algebraic equations and Eigen value problems: Iterative methods - Gauss-Seidal method, SOR method, Eigen value problems – Gerschgorian circle theorem, Eigen values and Eigen vectors of real symmetric matrices -Jacobi method. **Interpolation:** Hermite interpolation, spline interpolation, numerical solution of differential equations – Numerov method. ■		**10**
Revised Bloom's Taxonomy Level	L_3 – Applying	
Module-5		
Optimization: Linear programming- formulation of the problem, general linear programming problem, simplex method, artificial variable technique, Big M-method. **Graph Theory:** Basic terminologies, types of graphs, sub graphs, graphs isomorphism, connected graphs-walks, paths, circuits, connected and disconnected graphs, operations on graphs, Eulerian paths and circuits, Hamiltonian paths and circuits, applications to electrical circuits. ■		**10**
Revised Bloom's Taxonomy Level	L_3 – Applying, L_4 – Analysing.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16EEE11 APPLIED MATHAMATICS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Course outcomes:

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

1. Employ numerical techniques in order to achieve more accurate values in the computation of roots of algebraic and non-linear equations.
2. Utilize analytical and numerical schemes to solve partial differential equations applicable to engineering problems.
3. Understand vector spaces, basis, linear transformations and the process of obtaining matrix of linear transformations arising in magnification and rotation of images.
4. Apply standard iterative methods to compute Eigen values and solve ordinary differential equations.
5. Employ linear and non-linear programming techniques in simulation of network systems and optimization of electrical circuits. ■

Graduate Attributes (As per NBA):

Critical Thinking, Problem Solving, Research Skill,Usage of Modern Tools.

Question paper pattern:

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 16 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Text/Reference Books

1	Linear Algebra and its Applications	David C.Lay et al	Pearson	5th Edition,2015
2	Numerical methods in Engineering and Science (with C, C++ & MATLAB)	B.S.Grewal	Khanna Publishers	2014
3	Graph Theory with Applications to Engineering and Computer Science	Narsingh Deo	PHI	2012
4	Numerical Methods for Scientific and Engineering Computation	M. K. Jain et al	New Age International	9th Edition, 2014
5	Higher Engineering Mathematics	B.S. Grewal	Khanna Publishers	43rd Edition,2015
6	Linear Algebra	K.Hoffman et al	PHI	2011
7	**Web links:**1. *http://nptel.ac.in/courses.php?disciplineId=111* 2. *http://www.class-central.com/Course/math(MOOCs)* 3.*www.wolfram.com*			

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

ENERGY RESOURCES AND THE ENVIRONMENTAL IMPACTS (Core Course)

Subject Code	16ESE12	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To provides as an overview on energy management including introduction to energy, to energy-related engineering principles, regulations, to energy conservation, and to sustainability/green engineering.
- To provide a knowledge about different energy resources.
- To explain the analysis of the energy management issues such as energy demand and distribution, conservation, sustainability, environmental and economic considerations. ■

Module-1	Teaching Hours
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE) 16ESE12 ENERGY RESOURCES AND THE ENVIRONMENTAL IMPACTS (Core Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)	
Module-5	**Teaching Hours**
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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.

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Modern Tool Usage, Environment and sustainability, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Energy Resources Availability, Management, and Environmental Impacts.	Kenneth J. Skipka, Louis Theodore	CRC Press	2014

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
ENERGY PRODUCTION, CONVERSION AND CONSERVATION (Core Course)			
Subject Code	16ESE13	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To explain different types of systems, property and variables, energy and types of energy.
- To explain different forms of external and internal energy and their calculations.
- To explain about energy balance and energy production by different means.
- To explain different methods of energy conversion, storage and conservation.

Module-1		**Teaching Hours**
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

<table>
<tr><td colspan="5">M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE13 ENERGY PRODUCTION, CONVERSION AND CONSERVATION (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)</td></tr>
<tr><td colspan="4">Module-5</td><td>Teaching Hours</td></tr>
<tr><td colspan="4">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. ■</td><td rowspan="2">10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td colspan="3">L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">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. ■</td></tr>
<tr><td colspan="5">Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Environment and sustainability.</td></tr>
<tr><td colspan="5">Question paper pattern:
The question paper will have ten questions.
Each full question is for 16 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. ■</td></tr>
<tr><td colspan="5">Text Book</td></tr>
<tr><td>1</td><td>Energy Production, Conversion, Storage, Conservation, and Coupling.</td><td>Yasar Demirel</td><td>Springer,</td><td>2012</td></tr>
<tr><td colspan="5"></td></tr>
</table>

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
ENERGY CONVERSION TECHNOLOGIES (Core Course)			
Subject Code	16ESE14	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- 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
- To explain schemes and operational principles of single-phase and three-phase AC rectifiers.
- To explain schemes and operational principles of single-phase and three-phase AC regulators, operational characteristics of convertors with and without galvanic isolation.
- To 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.
- To discusses 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. ■

Module-1		**Teaching Hours**
1Energy 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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

<table>
<tr><td colspan="2">M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE14 ENERGY CONVERSION TECHNOLOGIES (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)</td></tr>
<tr><td>Module-5</td><td>Teaching Hours</td></tr>
<tr><td>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. ■</td><td>10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.</td><td></td></tr>
</table>

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

SOLAR ENERGY TECHNOLOGIES (Elective Course)

Subject Code	16ESE151	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To discuss 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.
- To discuss photovoltaic cell their characteristics and their operation, performance parameters and design of photovoltaic systems.
- To discuss different types of solar water heating, soar collectors, solar water heater components, estimation of cost of solar water heating system, etc.
- To discuss applications of solar energy in solar ventilation air preheating space heating and cooling and their design considerations. ■

Module-1	Teaching Hours
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-2	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-3	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE151 SOLAR ENERGY TECHNOLOGIES (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-5		
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Environment and sustainability, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Solar Energy Technologies and the Project Delivery Process for Buildings	Andy Walker	Wiley	2013

<table>
<tr><td colspan="4">M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I</td></tr>
<tr><td colspan="4">PHOTOVOLTAICS (Elective Course)</td></tr>
<tr><td>Subject Code</td><td>16ESE152</td><td>IA Marks</td><td>20</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>03</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>40</td><td>Exam Marks</td><td>80</td></tr>
<tr><td colspan="4">Credits - 03</td></tr>
</table>

Course objectives:

- To discuss solar insolation on horizontal and tilted surfaces and their calculations.
- To 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.
- To discuss solar modules, laminates and solar generators, and detailed discussion on solar cell and solar module wiring options, particularly in scenarios involving partially shaded solar generators configuration.
- To discuss in detail the layout and configuration of PV installations, their design and operating principles.
- To discuss grid-connected PV systems, and the problems that can arise when such installations are connected to the public grid. ■

<table>
<tr><td colspan="2">Module-1</td><td>Teaching Hours</td></tr>
<tr><td colspan="2">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. ■</td><td>08</td></tr>
<tr><td>Revised Bloom’s Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td><td></td></tr>
<tr><td colspan="3">Module-2</td></tr>
<tr><td colspan="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. ■</td><td>08</td></tr>
<tr><td>Revised Bloom’s Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td><td></td></tr>
<tr><td colspan="3">Module-3</td></tr>
<tr><td colspan="2">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.■</td><td>08</td></tr>
<tr><td>Revised Bloom’s Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td><td></td></tr>
<tr><td colspan="3">Module-4</td></tr>
<tr><td colspan="2">PV Energy Systems: Stand-alone PV Systems, Grid-Connected Systems -Grid-Connected Operation,Design Engineering and Operating Principles of PV System Inverters. ■</td><td>08</td></tr>
<tr><td>Revised Bloom’s Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.</td><td></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="2">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</td><td>08</td></tr>
<tr><td colspan="3"></td></tr>
</table>

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE152 PHOTOVOLTAICS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
PV Energy Systems (continued): Control Characteristics, Overall Inverter Efficiency, Dynamic MPP Tracking Test - Simple Dynamic MPP Tracking Test Using Quasi-square Test Patterns. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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.

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Photovoltaics System Design and Practice	Heinrich Ha¨berlin	Wiley	2012

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
INTRODUCTION TO NUCLEAR POWER (Elective Course)			
Subject Code	16ESE153	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- 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.

Module-1		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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). ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE153 INTRODUCTION TO NUCLEAR POWER (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

ENERGY PRICING – ECONOMICS AND PRINCIPLES (Elective Course)

Subject Code	16ESE154	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To differentiate between cost and price and to explain different types of costs.
- To discuss 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.
- To discuss two different value influenced pricing, one the value approach of pricing – demand and the other pricing – planning for demand.
- To 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.
- To 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.

Module-1	**Teaching Hours**
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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.	**08**

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE154 ENERGY PRICING – ECONOMICS AND PRINCIPLES (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-3 (continued)		**Teaching Hours**
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. ■		
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Environment and sustainability, Modern Tool Usage, Engineers and society.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

ENERGY LABORATORY-I

Subject Code	16ESEL16	IA Marks	20
Number of Practical Hours/Week	03	Exam Hours	03
Total Number of Practical Hours	40	Exam Marks	80

Credits - 02

Course objectives:

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

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 concentrators.
10	Study of sun tracking system by mechanical movements.
11	Testing and performance analysis of solar PV operated pump.

Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.

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.■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Conduct investigations of complex Problems, Individual and Team work, Communication.

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
SEMINAR			
Course Code	16ESE17	IA Marks	100
No. of Lecture Hours/Week	--	Exam Hours	--
Number of contact Hours/week	03	Number of Tutorial Hours/week	--
Total No. of contact Hours	--	Exam Marks	--
Credits - 01			

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, 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 Internal Assessment 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 Chairman. ■

Marks distribution for internal assessment of the course 16ESE17 seminar:
Seminar Report: 30 marks
Presentation skill:50 marks
Question and Answer:20 marks

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Modern Tool Usage, Engineers and society, Environment and sustainability, Ethics, Individual and Team work, Communication.

*** END ***

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)

II SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16ESE21	Power System Operation	04	--	03	20	80	100	4
2	16ESE22	Integration of Distributed Generation	04	--	03	20	80	100	4
3	16ESE23	Industrial Energy and Management	04	--	03	20	80	100	4
4	16ESE24	Power System Planning	04	--	03	20	80	100	4
5	16ESE25X	Elective - 2	03	--	03	20	80	100	3
6	16ESEL26	Energy Laboratory - II	-	3	03	20	80	100	2
7	16ESE27	Seminar	-	3	-	100	-	100	1
TOTAL			**19**	**06**	**18**	**220**	**480**	**700**	**22**

Number of credits completed at the end of II semester: 22+ 22 = 44

Elective -1

Subject Code under 16ESE25X	Title
16ESE251	Wind Energy Systems
16ESE252	Power System Harmonics
16ESE253	Carbon Capture and Storage
16ESE254	Piezoelectric Energy

Note: Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
POWER SYSTEM OPERATION (Core Course)			
Course Code	16ESE21	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To explain operator needs, processes for power system monitoring and function of operator in the power system scenario analysis.
- To explain the operator needs and processes on security and stability of power system and optimization of power system operation.
- To provide complete description of the control centers energy management systems and distribution management systems.
- To explain evolving state of art solutions in power system operation. ■

Module-1		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE21 POWER SYSTEM OPERATION (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Practical Power System Operation	Ebrahim Vaahedi	Wiley	2014

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
INTEGRATION OF DISTRIBUTED GENERATION (Core Course)			
Course Code	16ESE22	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To explain power generation by alternate energy source like wind power and solar power.
- To explain selection of size of units and location for wind and solar systems.
- Discuss the effects of integration of distributed generation on the performance the system.
- To provide practical and useful information about grid integration of distributed generation.■

Module-1		Teaching Hours
Distributed Generation: Introduction, Sources of Energy - Wind Power, Solar Power, Combined Heat-and-Power, Hydropower, Tidal Power, Wave Power, Geothermal Power, Thermal Power Plants.■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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.■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-5		
Power Quality Disturbances (continued): Low-Frequency Harmonics, High-Frequency Distortion, Voltage Dips, Increasing the Hosting Capacity. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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.

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE22 INTEGRATION OF DISTRIBUTED GENERATION (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Course outcomes (continued):

- 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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Engineers and society, Environment and sustainability, Ethics, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

INDUSTRIAL ENERGY AND MANAGEMENT (Core Course)

Course Code	16ESE23	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To explain technical aspects of industrial energy and environmental performance management, starting with a definition of industrial energy systems.
- To 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.
- To explain the environmental impacts of the considered industrial energy system. ■

Module-1		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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.■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-4		
Refrigeration System: Description of System, Performance Definitions, Performance Analysis, Performance Improvement Opportunities, Performance Monitoring, Example: Improvement of Chilled Water System Operation. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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). ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE23 INDUSTRIAL ENERGY AND MANAGEMENT (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Engineers and society, Environment and sustainability, Ethics, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Applied Industrial Energy and Environmental Management	Zoran K. Morvay et al	Wiley	2088

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

POWER SYSTEM PLANNING (Core Course)

Course Code	16ESE24	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To define the power system and its components, discuss the planning process of power systems and different aspects related to this process.
- To discuss regulatory and market constraints in light of the new trends of privatization and market deregulation affecting the future evolution of power systems directly and indirectly.
- To discuss the planning criteria which constitute of the general framework and guidelines that govern the planning of power systems.
- To discuss load research, the activity responsible for data collection and compilation without which no proper planning can be done.
- To explain the tools and methodologies for forecasting future energy and electrical loads.
- To discuss energy efficiency methods and techniques to decreases demand of consumers and demand side management in order to reduce future demand.
- To discuss about generation of electricity from renewable energy sources and the expansion planning studies.
- To discuss Integrated Resource Planning (IRP) taking into account all generation options, supply and demand, the system interconnections with other systems and financing of power projects for system expansion and enhanced interconnection.
- To explain tariff calculation models, impact of tariff on society and planning tools used in all phases of planning process. ■

Module-1	**Teaching Hours**
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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.	**10**

M.TECH ENERGY SYSTEM ENGINEERING (ESE) **16ESE24 POWER SYSTEM PLANNING (Core Course) (continued)** **CHOICE BASED CREDIT SYSTEM (CBCS)**		
Module-3 (continued)		**Teaching Hours**
System Expansion Studies: Introduction, Generation Expansion, Transmission and Distribution Expansion, Cost Considerations and Expansion Obligations, Regulatory Incentives, Case Study. ■		
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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). ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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. ■

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Engineers and society, Environment and sustainability, Ethics, Communication.

Question paper pattern:
- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Power System Planning Technologies and Applications: Concepts, Solutions, and Management	Fawwaz Elkarmi	Engineering Science Reference (an imprint of IGI	2012

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
WIND ENERGY SYSTEMS (Elective Course)			
Course Code	16ESE251	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To give an overview of wind turbine technology, wind energy system classifications, costs, and grid codes for wind power integration.
- To introduces the fundamentals and control principles of wind energy systems, including wind turbine components, aerodynamics, stall and pitch controls, and maximum power point tracking schemes.
- To explain about commonly used wind generators and the dynamic and steady-state modeling of generators to facilitate the analysis of wind energy systems.
- To discuss various power converters and PWM schemes used in wind energy systems.
- To present a general overview of configurations and characteristics of major practical Wind energy conversion systems. ■

Module		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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.■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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.■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE251 WIND ENERGY SYSTEMS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
POWER SYSTEM HARMONICS (Elective Course)			
Course Code	16ESE252	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To define harmonics, derive expressions for electrical parameters under non-sinusoidal situations and describe different types of sources of harmonics.
- To describe the industry standards of harmonic distortion levels and to explain effects of harmonics in different situations.
- To explain the important aspects and industry recommendations to take into account when deciding to undertake the task of characterizing harmonic levels at a given facility.
- To explain the operation of filters for mitigation of harmonics, design of different filters and other methods of harmonic elimination.
- To explain important aspects of power losses in electrical equipment due to harmonic waveform distortion.
- To provide the concept of smart grid, the harmonics present and their characteristics in the smart grid. ■

Module-1		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**

M.TECH ENERGY SYSTEM ENGINEERING (ESE) 16ESE252 POWER SYSTEM HARMONICS (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-4 (continued)		**Teaching Hours**
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. ■		
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Conduct investigations of complex Problems, Engineers and society, Environment and sustainability.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

CARBON CAPTURE AND STORAGE (Elective Course)

Course Code	16ESE253	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To provide an overview of carbon capture and carbon storage and explain the fundamentals of power generation.
- To explain carbon capture from power generation, industrial processes, using solvent absorption and other technologies including membranes, adsorbents, chemical looping, cryogenics and gas hydrate technology.
- To explain different geological storage methods including storage in coal seams, depleted gas reservoirs and saline formations.
- To explain Carbon dioxide compression and pipeline transport. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE253 CARBON CAPTURE AND STORAGE (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	

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. ■

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Ethics, Communication.

Question paper pattern:
- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Carbon Capture and Storage	Stephen A. Rackley	Elsevier	2010

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
PIEZOELECTRIC ENERGY (Elective Course)			
Course Code	16ESE254	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To give an introduction to vibration-based energy harvesting using piezoelectric transduction and to discuss Analytical distributed-parameter modeling of the transverse and longitudinal vibrations for cantilevered beams and bars under base excitation.
- To 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 and to provide an experimental validations.
- To give detailed mathematical analyses of the single-mode electromechanical equations and experimental validations.
- To presents approximate analytical solutions using an electromechanical version of the assumed-modes method for relatively complicated structural configurations which do not allow analytical solutions.
- To introduces distributed-parameter electromechanical models for piezoelectric energy harvesting under various forms of dynamic loading.
- To explain modeling and exploiting mechanical nonlinearities in piezoelectric energy harvesting.
- To explain how to harvest piezoelectric energy from aeroelastic vibrations of structures with piezoceramic layers under airflow excitation. ■

Module-1	**Teaching Hours**
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. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.	
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,	**08**

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE254 PIEZOELECTRIC ENERGY (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-3(continued)		Teaching Hours
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. ■		
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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.

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE254 PIEZOELECTRIC ENERGY (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Course outcomes(continued):

- 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. ■

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Engineers and society, Environment and sustainability, Ethics, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Piezoelectric Energy Harvesting	Alper Erturk	Wiley	2011

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

POWER SYSTEM LABORATORY-II

Course Code	16ESEL26	IA Marks	20
Number of Practical Hours/Week	03	Exam Hours	03
Total Number of Practical Hours	40	Exam Marks	80
Credits - 02			

Course objectives:

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

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.

Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.

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.■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Modern Tool Usage, Ethics, Individual and Team work, Communication.

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
SEMINAR			
Course Code	16ESE27	IA Marks	100
No. of Lecture Hours/Week	--	Exam Hours	--
Number of contact Hours/week	03	Number of Tutorial Hours/week	--
Total No. of contact Hours	--	Exam Marks	--
Credits - 01			

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, 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 Internal Assessment 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 Chairman. ■

Marks distribution for internal assessment of the course 16ESE27 seminar:
Seminar Report: 30 marks
Presentation skill:50 marks
Question and Answer:20 marks

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Modern Tool Usage, Engineers and society, Environment and sustainability, Ethics, Individual and Team work, Communication.

*** END ***

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)

III SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16ESE31	Seminar / Presentation on Internship (After 8 weeks from the date of commencement)	--	--	--	25	--	25	20
2	16ESE32	Report on Internship	--	--	--	25	--	25	
3	16ESE33	Evaluation and Viva-Voce of Internship	--	--	--	--	50	50	
4	16ESE34	Evaluation of Project phase -1	--	--	--	50	--	50	1
TOTAL			**--**	**--**	**--**	**100**	**50**	**150**	**21**

Number of credits completed at the end of III semester: 22+ 22 + 21 = 65

Note:
Internship of 16 weeks shall be carried out during III semester.
Major part of the Project work shall also be carried out during the III semester in consultation with the Guide/s.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech ENERGY SYSTEM ENGINEERING (ESE)

CHOICE BASED CREDIT SYSTEM (CBCS)

IV SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16ESE41	Energy Audit	04	--	03	20	80	100	4
2	16ESE42X	Elective - 3	03	--	03	20	80	100	3
3	16ESE43	Evaluation of Project phase -2	--	--	--	50	-	50	3
4	16ESE44	Evaluation of Project and Viva-Voce	--	--	--	--	100 + 100	200	10
TOTAL			**07**	**--**	**06**	**90**	**360**	**450**	**20**

Number of credits completed at the end of IV semester: 22+ 22 + 21 + 20 = 85

Elective -1

Subject Code under 16ESE42X	Title
16ESE421	Solar Hydrogen Energy Systems
16ESE422	Energy Management Strategies for EV/PHEV
16ESE423	Energy Storage in Power Grids
16ESE424	High-Power Battery Technologies

Note: 1. Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

2. Project Phase-2: 16-week duration during 4th semester**.** Evaluation shall be done by the committee comprising of HoD as Chairman, Guide and Senior faculty of the department.

3. **Project Evaluation**: Evaluation shall be taken up at the end of 4th semester. Project work evaluation and Viva-Voce examination shall conducted

4**. Project evaluation:**

a. Internal Examiner shall carry out the evaluation for 100 marks.
b. External Examiner shall carry out the evaluation for 100 marks.
c .The average of marks allotted by the internal and external examiner shall be the final marks of the project evaluation.
d. Viva-Voce examination of Project work shall be conducted jointly by Internal and External examiner for 100 marks.

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
ENERGY AUDIT (Core Course)			
Course Code	16ESE41	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To explain the importance of energy audit , its types and energy audit methodology.
- To explain the parameters required for energy audit and the working of the instruments used in the measurement of the parameters.
- To explain the energy audit of different systems and equipment and buildings
- To explain electrical load management techniques, harmonics and their effects, electricity tariffs and power factor improvement. ■

Module-1		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE41 ENERGY AUDIT (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Conduct investigations of complex Problems, Environment and sustainability, Ethics, Individual and Team work, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Handbook on Energy Audit	Sonal Desai	Mc Graw Hill	2015

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
SOLAR HYDROGEN ENERGY SYSTEMS (Elective Course)			
Course Code	16ESE421	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To introduces the macro-economical, technical and historical aspects of the new hydrogen-based energy system and to 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.
- To explain in detail the behavior and the modeling of electrolysers and fuel cells and describe the fundamentals of photovoltaic and wind energies.
- To explain other potential renewable energy sources for hydrogen production.
- To explain the process of the storage of hydrogen and the chemical storage in standard batteries and other more advanced alternatives
- To explain in detail the complete implementation of the hydrogen system and simulation of the system behaviour with the help of mathematical models and some of the most interesting real-life applications. ■

Module-1		**Teaching Hours**
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.■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE) 16ESE421 SOLAR HYDROGEN ENERGY SYSTEMS (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Environment and sustainability, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
ENERGY MANAGEMENT STRATEGIES FOR EV/PHEV (Elective Course)			
Course Code	16ESE422	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To explain the practical issues for commercialization of current and future EVs/PHEVs.
- To explain advanced power electronics and motor drives solutions for both current as well as future EV/PHEV drive trains.
- To discuss EV/PHEV power system architectures, battery technologies on-board energy management issues.
- To discuss advanced power electronic converter topologies for current and future battery charging infrastructures.
- To 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. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE422 ENERGY MANAGEMENT STRATEGIES FOR EV/PHEV (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Engineers and society, Environment and sustainability, Ethics, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
ENERGY STORAGE IN POWER GRIDS (Elective Course)			
Course Code	16ESE423	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To demonstrate the importance of electrical energy storage within the context of sustainable development in intelligent electrical networks or "smart grids".
- To show the various services that electrical energy storage can provide.
- To introduce the methodological tools based on causal formalisms, artificial intelligence and explicit optimization techniques used to construct an energy storage management system.
- To illustrate methodological approaches via numerous examples concerning the integration of renewable energies into electrical networks. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE423 ENERGY STORAGE IN POWER GRIDS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Engineers and society, Environment and sustainability, Ethics, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

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

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - IV

HIGH-POWER BATTERY TECHNOLOGIES (Elective Course)

Course Code	16ESE424	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To explain the current status of various primary and secondary (rechargeable) batteries and fuel cells for various applications, their performance capabilities and limitations.
- To explain the performance requirements for next-generation high-power rechargeable batteries suited for applications requiring high-energy and -power densities, their design configurations for some specific applications with a particular emphasis on safety, reliability, longevity, and portability.
- To explain fuel cells that are best suited for applications where electrical power requirements vary between several kilowatts (kW) to a few megawatts (MW).
- To explain high-power batteries currently used by EVs and HEVs and their performance review and rechargeable battery design configurations capable of providing significant improvements in depth of discharge, state of charge, and service life.
- To explain low-power battery configurations that are best suited for compact commercial, industrial, and medical applications.
- To describe rechargeable batteries for military and battlefield applications where sustainable performance, reliability, safety, and portability are principal operating requirements. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH ENERGY SYSTEM ENGINEERING (ESE)
16ESE424 HIGH-POWER BATTERY TECHNOLOGIES (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 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. ■

Text Book

1	Next-Generation Batteries and Fuel Cells for Commercial, Military, and Space Applications	A.R. JHA	CRC Press	2012

*** END ***