Department of Electrical Engineering

Interdisciplinary Minor

Title: Electric Mobility

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	IDP-01	*<tbd>*	Fundamentals of E-Mobility	3	-	-	1	**3**	30	20	50	--	--
IV	IDP -02	*<tbd>*	Battery Management System	3	-	2	1	**4**	30	20	50	50	50
V	IDP -03	*<tbd>*	EV Charger	3	-	2	1	**4**	30	20	50	50	50
VI	IDP -04	*<tbd>*	Vehicle Test Bed	3	-	2	1	**4**	30	20	50	50	50
VII	IDP -05	*<tbd>*	Electric Motor Drives and Testing for E-Mobility	3	-	-	1	**3**	30	20	50	--	--
			Total	**15**	**-**	**06**	**05**	**18**					

Interdisciplinary Minor

Title: Renewable Energy Systems

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	IDP-01	*<tbd>*	Renewable Energy Technology	3	-	-	1	**3**	30	20	50	--	--
IV	IDP -02	*<tbd>*	Energy Storage Systems	3	-	2	1	**4**	30	20	50	50	50
V	IDP -03	*<tbd>*	Solar and Wind Energy	3	-	2	1	**4**	30	20	50	50	50
VI	IDP -04	*<tbd>*	Grid Interface of Renewable Energy Sources	3	-	2	1	**4**	30	20	50	50	50
VII	IDP -05	*<tbd>*	Energy Economics and Policy	3	-	-	1	**3**	30	20	50	--	--
			Total	**15**	**-**	**06**	**05**	**18**					

Detailed Syllabi

Fundamentals of E-Mobility						
Course Code			**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Explain the fundamentals of measurement, units, standards, and types of errors.
2. Apply safety procedures and first-aid practices in electrical laboratories and industry.
3. Interpret safety regulations and standards such as IS, IEC, IEEE, OSHA, and CEA.
4. Evaluate earthing methods and measure earth resistance as per IS and IEC codes.
5. Identify and operate measuring instruments used for electrical safety.
6. Select and use appropriate Personal Protective Equipment (PPE) in electrical laboratories.

Unit 1: Measurement, Units & Standards **[8 Hrs]**

Definition and importance of measurement; SI units; calibration; accuracy; precision; errors; minimization.
Safety Practices: Electrical hazards – shock, burns, arc flash; LOTO; first aid.
Safety Regulations: IS, IEC, IEEE, ANSI, OSHA; CEA guidelines; safety audits.
Earthing & Standards: Plate, pipe, rod earthing; earth resistance; IS:3043 code.
Measuring Instruments: Earth tester; insulation tester; measurement principles.
PPE: Gloves, helmets, mats, arc suits; selection; IEC standards

Unit 2: Data Acquisition (DAQ) **[8 Hrs]**

Architecture, sensors, signal conditioning, NI DAQ modules
Virtual Instrumentation concepts – virtual panels, GUI-based measurement, measurement automation.
Electronic Loads – programmable DC electronic loads, constant current/voltage/resistance/power modes.
Programmable AC Sources – voltage/frequency programming, THD control, harmonic simulation.
Grid Emulators – utility simulation, fault simulation, EV-grid testing applications.
Battery Emulators – programmable voltage-current profiles, EV charger testing applications.
Regenerative Test Systems – energy regeneration, high-efficiency test benches.
Introduction to LabVIEW – front panel, block diagram, dataflow programming, simple DAQ applications.

Unit 3: Introduction to EVs & HEVs **[8 Hrs]**

A brief history of EV & PHV, Basics of EV&HEV, Architectures of EV&HEV, HEV fundamentals.

Unit 4: Plug-in HEVs **[8 Hrs]**

Introduction to PHEVs, PHEV architectures, Power management of PHEVs, Fuel economy of PHEVs, PHEV design & component sizing, Vehicle-to-grid technology.

Unit 5: Power Electronics in EVs & HEVs: **[8 Hrs]**

Introduction, Principles of power electronics, Rectifiers, Converters, Inverters, Battery chargers used in EVs & HEVs, Emerging power electronic devices.

Self-Study (SS):

1. Evolution of Electric Mobility and global EV adoption trends.
2. Electric Vehicle architectures and subsystems: BEV, HEV, PHEV and FCEV.
3. Battery fundamentals: Cell, Module, Pack, Lithium-ion batteries, SOC and SOH concepts.
4. EV charging infrastructure, charging methods and charging standards.

5. Emerging traction motor technologies for electric vehicles.
6. Advanced E-Mobility technologies: Vehicle-to-Grid (V2G), Battery Swapping, Wireless Charging and Autonomous EVs.
7. EV standards, regulations and functional safety requirements.

Textbooks:

[1]	A.K. Sawhney, Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai & Co., 19th Edition, 2011.
[2]	Alan S. Morris, Measurement and Instrumentation Principles, Elsevier, 3rd Edition, 2011
[3]	John Cadick et al., Electrical Safety Handbook, McGraw-Hill, 4th Edition, 2012.
[4]	S. Rao, Testing, Commissioning, Operation & Maintenance of Electrical Equipment, Khanna Publishers, 8th Edition, 2017.
[5]	B.L. Theraja, A Textbook of Electrical Technology Vol 1, S. Chand, 23rd Edition, 2005.
[6]	Gary W. Johnson & Richard Jennings, LabVIEW Graphical Programming, McGraw-Hill, 4th Edition, 2006
[7]	National Instruments, LabVIEW for Everyone, Prentice Hall, 3rd Edition, 2006.
[8]	Sanjay Gupta & Joseph John, Virtual Instrumentation Using LabVIEW, McGraw-Hill, 2nd Edition, 2017
[9]	Keysight Technologies, Application Handbook for Power Supplies, Electronic Loads, and Emulators, Keysight, 2020.
[10]	Chroma Systems Solutions, Programmable AC Sources, DC Sources, and Electronic Loads – Application Guide, Chroma, 2019.
[11]	Tektronix, Fundamentals of Power Electronics Testing and Measurement, Tektronix Application Note, 2018.
[12]	Chris Mi, M. Abul Masrur, David Wenzhong Gao, “Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives”, 2011, Wiley publication.

Reference Books:

[1]	Allen Fuhs, “Hybrid Vehicles and the future of personal transportation”, 2009 ,CRC Press.
[2]	James Larminie, John Lowry, “Electric Vehicle Technology Explained”, 2003, Wiley publication.

Note:

[1] To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
[2] To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
[3] To measure CO3, questions will be based on applications of core concepts.
[4] To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5] To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

Battery Management System

Course Code			**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Understand Li-ion battery characteristics, charging behavior, and performance limitations.
2. Model cells and battery packs including electrical, thermal and aging aspects.
3. Analyze thermal management challenges and design appropriate cooling strategies.
4. Explain the functions and architecture of BMS including SoC, SoH, balancing, and protection.

5. Describe the battery packaging process including cell grading, welding, integration and testing.	
Unit 1: Introduction to Li-ion Batteries	
Types of cells – cylindrical, prismatic, pouch, Li-ion chemistries – NMC, LFP, NCA, LCO, battery characteristics – OCV, internal resistance, capacity, charging behavior – CC/CV, significance of C-rate, desired EV battery specifications – energy, power, lifecycle, safety.	**[8 Hrs]**
Unit 2: Battery Pack Modelling	
Cell electrical models – Rint model, Thevenin model, HPPC Test – purpose and procedure, extraction of resistance and capacity, SOC, temperature and aging impact, battery pack modelling – series/parallel configuration, cell balancing requirements, thermal impact on battery performance and safety.	**[8 Hrs]**
Unit 3: Thermal Management of Batteries	
Heat generation mechanisms in Li-ion cells, cooling approaches – air cooling, liquid cooling, PCM-based cooling, refrigerant cooling, thermal runaway – causes, detection and mitigation strategies, thermal interface materials, effects of temperature on safety, cycle life and performance	**[8 Hrs]**
Unit 4: Battery Management System (BMS)	
Functions of BMS – monitoring, estimation, protection and communication, SoC estimation – Coulomb counting, voltage-based estimation and EKF methods, SoH and RUL basics, balancing – passive and active methods, communication protocols – CAN, LIN, SPI, I2C, safety protection features – overcurrent, overcharge, overdischarge and thermal protections	**[8 Hrs]**
Unit 5: Battery Packaging Process	
Cell grading – voltage, IR and capacity tests, sorting procedures, spot welding – nickel strip selection and weld quality, module assembly – busbars, insulation, mechanical fixtures, BMS integration and wiring harness, battery pack validation – capacity testing, thermal testing, vibration testing and safety certification tests.	**[8 Hrs]**
Self-Study (SS):	
1. Advanced battery chemistries for electric mobility: NMC, NCA, LFP, LTO and Sodium-ion batteries. 2. Advanced SoC and SoH estimation methods including EKF, UKF and AI-based approaches. 3. Battery safety standards and regulations: IEC 62660, ISO 12405, AIS-156 and UN 38.3. 4. Thermal runaway mechanisms, battery fire case studies and mitigation techniques. 5. Battery manufacturing processes, gigafactories and quality control practices. 6. Battery passport, second-life applications, recycling and circular economy concepts. 7. Emerging trends in BMS: Wireless BMS, Digital Twin, Cloud-connected BMS and predictive diagnostics.	

Textbooks:	
[1]	Gregory L. Plett, Battery Management Systems (Volumes 1–3), Artech House, 2015–2021.
[2]	Davide Andrea, Battery Management Systems for Large Lithium-Ion Battery Packs, Artech House, 2010.
Reference Books:	
[1]	Rui Xiong, Lithium-Ion Batteries: Advanced Models, Diagnostics and Control, Elsevier, 2020.
[2]	Isidor Buchmann, Batteries in a Portable World, Cadex Electronics, 4th Edition, 2016.
[3]	Mohammad B. Shadmand& Bikash C. Pal, Battery Systems Engineering, Wiley, 2013
[4]	IEC/ISO Standards: IEC 62660, ISO 12405 – EV Battery Testing Standards

List of Experiments:	
[1]	Experimental extraction of cell parameters and mathematical modelling of a cell.
[2]	Charging characteristics of a single cell for multiple C-ratings.
[3]	Thermal simulation of a cell & EV battery pack using Ansys.
[4]	Thermal shock test for battery pack.
[5]	Evaluation of State of Charge (SoC) balancing techniques.
[6]	Functional testing of BMS.
[7]	Comparative evaluation of coulomb counting and Kalman filter-based SoC estimation.
[8]	Capacity evaluation of a battery pack.
[9]	Hands-on in Battery packaging Process.
[10]	Battery Pack Communication and Diagnostics using CAN Protocol
Note:	
[1] [2] [3] [4] [5]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc. To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc. To measure CO3, questions will be based on applications of core concepts. To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc. To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

EV Charger						
Course Code			**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--
Course Outcomes: Students will be able to:						
1. Understand different types of EV chargers, charging standards and charger architectures. 2. Explain the operation of power converters used in EV chargers including PFC and isolated 3. converter stages. 4. Apply digital control techniques for EV charger implementation using C2000 microcontrollers. 5. Design magnetics, thermal systems and hardware modules for EV chargers. 6. Conduct testing, validation and compliance evaluation of EV chargers.						
Unit 1: Need and Types of Chargers						
Need for EV chargers, AC vs DC charging, EV charger block diagram, IEC categorization of chargers, onboard and off-board chargers, charging standards – CHAdeMO, GBT, CCS, connector types, Indian EV charging infrastructure, Open Charge Point Protocol (OCPP).						**[8 Hrs]**
Unit 2: Power Converters used in Chargers						
Boost PFC rectifier design, PSFB converter operation, bridgeless totem pole topology, isolated DC-DC topologies – flyback, HBLLC, FBLLC, PSFB, DAB, review of SiC and GaN wide bandgap devices, auxiliary power converters – buck, boost, buck-boost, converter efficiency considerations.						**[8 Hrs]**
Unit 3: Digital Control of EV Chargers						

C2000 microcontroller peripherals – EPWM, ADC, SCI and CAN for EV charger control, signal conditioning for voltage/current sensing, ZVS and ZCS switching techniques, CC/CV charging control implementation, digital control of PFC and isolated DC-DC stages.	**[8 Hrs]**
Unit 4: Design and Fabrication of EV Chargers	
Planar magnetics for charger design, thermal management strategies, PCB layout guidelines for high-power chargers, isolation and protection requirements, hardware design steps – power stage, gate drivers, EMI/EMC considerations, fabrication and integration of EV charger modules.	**[8 Hrs]**
Unit 5: Testing of EV Chargers	
Functional testing of EV chargers, efficiency measurement, thermal evaluation, protection validation, compliance testing, communication protocol testing, use of battery emulators and grid emulators for EV charger testing, reliability and safety evaluation.	**[8 Hrs]**

Self-Study (SS):

1. Global and Indian EV charging infrastructure and charging ecosystem.
2. Advanced charging standards and communication protocols: CCS, CHAdeMO, GB/T, NACS, ISO 15118 and OCPP.
3. Wide bandgap semiconductor devices (SiC and GaN) for EV charger applications.
4. Wireless and dynamic EV charging technologies.
5. Vehicle-to-Grid (V2G), bidirectional charging and smart charging systems.
6. Fast charging infrastructure, battery charging challenges and Megawatt Charging Systems (MCS).
7. Cybersecurity, functional safety and emerging trends in EV charging technologies.

Textbooks:

[1]	M. H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, 4th Edition, 2014.
[2]	Sanjaya Maniktala, Switching Power Supplies A to Z, Elsevier, 3rd Edition, 2020.
[3]	Ned Mohan, Power Electronics: Converters, Applications and Design, Wiley, 3rd Edition, 2002.
[4]	Muhammad H. Rashid, Power Electronics Handbook, Academic Press, 4th Edition, 2017

Reference Books:

[1]	Texas Instruments, C2000 Real-Time Control MCU Technical Reference Manuals, TI Publications, Latest Edition.
[2]	Chroma Systems Solutions, EV Charger and Power Conversion Testing – Application Notes, Chroma Technical Publications, Latest Revision.
[3]	Keysight Technologies, Power Converter Testing Handbook, Keysight Power Solutions Series, Latest Edition.
[4]	IEC 61851, Electric Vehicle Conductive Charging System, International Electrotechnical Commission, Latest Standard Revision.
[5]	IEC 62196, Plugs, Socket-Outlets, Vehicle Connectors and Inlets – Conductive Charging of EVs, IEC, Latest Revision.
[6]	IEC 62196, Plugs, Socket-Outlets, Vehicle Connectors and Inlets – Conductive Charging of EVs, IEC, Latest Revision.
[7]	CHAdeMO Association, CHAdeMO Technical Specifications, Latest Edition.
[8]	SAE J1772, Electric Vehicle and Plug-in Hybrid Conductive Charge Coupler, SAE International, Latest Revision.

List of Experiments:

[1]	Design and fabrication of high-frequency ferrite inductors and transformers.
[2]	PCB design of high-frequency, high power-density power electronic converters.
[3]	Design, fabrication, and testing of isolated voltage and current sensing circuits.
[4]	Design and fabrication of PFC rectifier topologies.

[5]	Performance evaluation of different topologies used in PFC rectifiers.
[6]	Firmware development and testing for Constant Current (CC) & Constant Voltage (CV) charging control.
[7]	Design and fabrication of isolated DC–DC converter topologies.
[8]	Performance evaluation of isolated DC–DC converter topologies.
[9]	Study of non-isolated DC–DC converters – Buck & Boost.
[10]	Performance evaluation of an EV charger.
[11]	Evaluation of thermal performance of EV chargers.
[12]	Compliance testing of EV chargers.
[13]	Firmware testing of CAN communication
Note:	
[1] [2] [3] [4] [5]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc. To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc. To measure CO3, questions will be based on applications of core concepts. To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc. To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

Vehicle Test Bed						
Course Code			**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--
Course Outcomes: Students will be able to:						
1. Model and analyze electric vehicle components and subsystems using appropriate EV modelling tools. 2. Develop and simulate electric two-wheeler and three-wheeler models and interpret performance results for rage prediction. 3. Evaluate factors influencing EV range and efficiency under real-world and standard drive cycles. 4. Explain construction, working, and measurement principles of 2W/3W vehicle chassis dynamometers and testbeds. 5. Conduct EV range testing on chassis dynamometers including setup, instrumentation, data acquisition, and safety procedures. 6. Analyze test data, interpret results, perform cycle emulation (MIDC), and identify strategies 7. Analyze EV range improvement and compliance testing.						
Unit 1: EV Modelling and Analysis						
EV modelling approaches including component-level modelling of battery, motor, controller, drivetrain, and vehicle dynamics; methods for developing mathematical and simulation models; introduction to modelling environments for EV performance studies; modelling assumptions, limitations, and validation techniques.						**[8 Hrs]**
Unit 2: Simulation of Electric Two-Wheeler and Three-Wheeler EVs						
Development of EV models for two-wheelers and three-wheelers; creation of drivetrain and vehicle load models; simulation of acceleration, gradeability, energy consumption, and range; interpretation of simulation results; sensitivity studies for motor power, battery capacity, vehicle weight, and control strategies						**[8 Hrs]**
Unit 3: Electric Vehicle Range and Influencing Factors						

Definition of EV range; range estimation methods; key factors affecting EV range including battery characteristics, driving patterns, road gradients, aerodynamics, rolling resistance, temperature effects, accessory loads, and driver behaviour; theoretical and practical considerations for accurate range prediction	**[7 Hrs]**
Unit 4: Vehicle Testbed and Chassis Dynamometer for 2W/3W	
Overview of EV testbeds; construction, types, and operating principles of chassis dynamometers for two-wheelers and three-wheelers; load simulation methods including inertia simulation, road-load coefficient methods, and power-absorption systems; sensors, instrumentation, and measurement systems; safety protocols and calibration procedures; introduction to test cycles used for EV range evaluation	**[8 Hrs]**
Unit 5: Conducting Range Tests on Testbed and Drive Cycle Emulation	
Setup and configuration of chassis dynamometer for range testing; data acquisition systems, communication protocols, and measurement accuracy; steps for conducting range tests; interpreting logged data and generating performance reports; identifying inefficiencies using test data; strategies for improving EV range; drive cycle emulation using testbeds including MIDC, IDC, and custom cycles; homologation requirements and compliance testing.	**[9 Hrs]**

Self-Study (SS):

1. Global drive cycles and vehicle homologation standards: WLTP, NEDC, FTP-75, US06, WMTC and MIDC.
2. EV homologation, certification procedures and regulatory standards including AIS-038, AIS-156 and CMVR.
3. Connected vehicle technologies, telematics systems and remote diagnostics.
4. Advanced EV simulation tools and platforms for vehicle performance analysis.
5. Hardware-in-the-Loop (HIL) testing and Digital Twin technologies for EV validation.
6. Autonomous vehicle and ADAS testing methodologies.
7. Emerging trends in vehicle testing, virtual validation, AI-enabled testing and software-defined vehicles.

Textbooks:

[1]	Mehrdad Ehsani, Yimin Gao, Sebastien Gay, Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, 2nd Edition, CRC Press, 2018
[2]	Sheldon S. Williamson, Electric Vehicle Machines and Drives: Design, Analysis and Application, 1st Edition, Wiley, 2015.
[3]	Iqbal Husain, Electric and Hybrid Vehicles: Design Fundamentals, 3rd Edition, CRC Press, 2021.

Reference Books:

[1]	James Larminie, John Lowry, Electric Vehicle Technology Explained, 2nd Edition, Wiley, 2012.
[2]	Wolfgang Steiger et al., Testing and Validation of Electric Vehicle Systems, 1st Edition, SAE International, 2019.
[3]	Amitava Chattopadhyay, Automotive Testbeds and Dynamometers, 1st Edition, McGraw-Hill, 2017.
[4]	AIS 040, AIS 039, BIS Standards, MIDC – Government of India EV Range & Drive Cycle Evaluation Standards, latest revisions.

List of Experiments:

[1]	Modelling of electric vehicles and assessing their range using different drive cycles.
[2]	Study of different standards relevant to vehicle testing.
[3]	Study of two-wheeler chassis dyno testing for Modified Indian Drive Cycle (MIDC).
[4]	Study of three-wheeler chassis dyno testing for Modified Indian Drive Cycle (MIDC).
[5]	Subsystem modelling: battery, motor, controller, drivetrain.

[6]	Sensitivity analysis of EV range: effect of load, gradient, and temperature.
[7]	Familiarization with vehicle testbed instrumentation and safety procedures.
[8]	Drive cycle emulation and creation of custom drive cycles.
[9]	Data acquisition: CAN logging, DAQ systems, filtering, and signal processing.
[10]	Energy consumption analysis and Wh/km computation from testbed data.
[11]	Hardware-in-the-Loop (HIL) based drive cycle testing.
[12]	Comparative analysis of simulated vs. testbed EV range results.
Note:	
[1] [2] [3] [4] [5]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc. To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc. To measure CO3, questions will be based on applications of core concepts. To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc. To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

Electric Motor Drives and Testing for E-Mobility						
Course Code			**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--
Course Outcomes: Students will be able to:						
1. Understand different types of EV motor drives, their operating principles and selection criteria for EV applications. 2. Apply FEM–based analysis for estimating motor magnetic performance, torque characteristics, losses, and thermal behavior. 3. Explain the operation of powertrain inverters including semiconductor devices, gate drivers, snubbers, and modulation strategies 4. Implement digital control techniques for EV motor drives using C2000 microcontrollers and associated peripherals. 5. Design and analyze control algorithms such as scalar control, field–oriented control, and torque control for EV motors 6. Conduct testing, validation, and performance evaluation of EV motors and drive systems using laboratory test setups.						
Unit 1: Types of EV Motor Drives						
Principles, construction and characteristics of DC motors, induction motors, BLDC motors, PMSM, and switched reluctance motors; torque-speed characteristics; efficiency and performance comparison; drive selection criteria for two-wheelers, three-wheelers and four-wheelers; regenerative braking behaviour; vehicle load dynamics and drive sizing considerations.						**[8 Hrs]**
Unit 2: FEM Analysis of EV Motors						
Fundamentals of FEM modelling; motor geometry creation; mesh generation; magnetic field analysis; flux distribution; torque computation; torque ripple analysis; magnetic saturation study; estimation of copper and core losses; thermal analysis; weight estimation of copper and core materials; FEM-based performance prediction and optimization of EV motors.						**[8 Hrs]**
Unit 3: EV Traction Inverters and Digital Control Hardware						
Introduction to EV traction inverters; semiconductor devices including IGBTs, MOSFETs and SiC devices; inverter topologies; switching and conduction loss analysis; gate driver design; snubber circuits; DC-link design considerations; introduction to						**[8 Hrs]**

SPWM and SVPWM techniques; overview of digital control architectures using C2000 microcontrollers; ADC interfacing; encoder and current sensing; communication interfaces; real-time control implementation and safety interlocks.	
Unit 4: Control Algorithms for EV Motor Drives	
Introduction to motor control algorithms; scalar control and V/f control; field-oriented control (FOC) principles for PMSM and induction motors; current, speed and torque control loops; PI controller tuning; rotor position estimation; sensorless control concepts; transient and steady-state performance analysis; simulation-based validation of control algorithms.	**[8 Hrs]**
Unit 5: Motor and Drive Testing for EV Applications	
Overview of EV motor testing facilities; dynamometer-based testing; measurement of torque, speed, power and efficiency; inverter testing under varying load conditions; thermal performance evaluation; vibration and noise assessment; regenerative braking studies; drive-cycle-based testing; Hardware-in-the-Loop (HIL) concepts; interpretation of motor-drive test data; validation and compliance testing according to relevant IEC and NEMA standards.	**[8 Hrs]**

Self-Study (SS):

1. Emerging EV motor technologies including axial flux, switched reluctance, synchronous reluctance and in-wheel motors.
2. Rare-earth-free motor technologies and sustainable motor design approaches.
3. Advanced motor control methods: Model Predictive Control (MPC), Direct Torque Control (DTC) and sensorless control techniques.
4. Application of SiC and GaN devices in EV traction inverters and motor drives.
5. Motor testing standards, efficiency classifications and certification procedures.
6. Digital Twin and Hardware-in-the-Loop (HIL) techniques for motor-drive validation.
7. Future EV propulsion technologies including e-axles, torque vectoring and multi-motor drive systems.

Textbooks:

[1]	Krishnan R., “Electric Motor Drives: Modeling, Analysis and Control”, Pearson.
[2]	Chee-Mun Ong, “Dynamic Simulation of Electric Machinery”, Prentice Hall
[3]	P. C. Sen, “Principles of Electric Machines and Power Electronics”, Wiley.

Reference Books:

[1]	Boldea I. & Nasar S. A., “Electric Drives”, CRC Press.
[2]	Miller T. J. E., “Brushless Permanent-Magnet and Reluctance Motor Drives”, Oxford
[3]	Erickson & Maksimovic, “Fundamentals of Power Electronics”, Springer
[4]	TI Application Notes for C2000 Motor Control.

Note:

[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
[3]	To measure CO3, questions will be based on applications of core concepts.
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

Interdisciplinary Minor

Title: Renewable Energy Systems

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	IDP-01	*<tbd>*	Renewable Energy Technology	3	-	-	1	**3**	30	20	50	--	--
IV	IDP -02	*<tbd>*	Energy Storage Systems	3	-	2	1	**4**	30	20	50	50	50
V	IDP -03	*<tbd>*	Solar and Wind Energy	3	-	2	1	**4**	30	20	50	50	50
VI	IDP -04	*<tbd>*	Grid Interface of Renewable Energy Sources	3	-	2	1	**4**	30	20	50	50	50
VII	IDP -05	*<tbd>*	Energy Economics and Policy	3	-	-	1	**3**	30	20	50	--	--
			Total	**15**	**-**	**06**	**05**	**18**					

Renewable Energy Technology						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Recognize the impacts of current energy generation and need for the renewable energy.
2. Illustrate the equivalent circuit of solar photovoltaic cell and its characteristics.
3. Explain the solar PV system with necessary power electronic converters.
4. Understand the wind energy conversion systems and solve the problems on efficiency.
5. Acquire the basic knowledge of Biomass, Hydrogen energy systems, Fuel cells, Ocean Thermal Energy Conversion (OTEC), Tidal and wave energy.

Unit 1: Introduction **[8 Hrs]**

Energy and sustainable development, Worldwide renewable energy availability, Classification of energy sources, Co2 Emission, Features of Renewable energy, Renewable energy scenario in India, Environmental aspects of electric energy conversion, impacts of renewable energy generation on environment Per Capital Consumption.

Unit 2: Solar Photovoltaics **[8 Hrs]**

Solar Energy: Basic Characteristics of solar radiation, Angle of sunrays on solar collector, Equivalent circuit of PV Cell, Photovoltaic cell characteristics, P-V and I-V curve of cell-Impact of Temperature and Isolation on I-V characteristics, Shading Impacts on I-V Characteristics-Bypass diode -Blocking diode.

Unit 3: Photovoltaic System Design **[8 Hrs]**

Block diagram of solar photovoltaic system, Line commutated converters (inversion mode) - Boost and buck-boost converters, battery and array sizing - PV systems classification- standalone PV systems, PV systems classification- standalone PV systems - Grid tied and grid interactive inverters-grid connection issues.

Unit 4: Wind Energy Conversion Systems **[8 Hrs]**

Functions of BMS – monitoring, estimation, protection and communication, SoC estimation – Coulomb counting, voltage-based estimation and EKF methods, SoH and RUL basics, balancing – passive and active methods, communication protocols – CAN, LIN, SPI, I2C, safety protection features – overcurrent, overcharge, overdischarge and thermal protections.

Unit 5: Green Energy, Fuel Cells, and Alternative Energy Sources **[8 Hrs]**

Green Hydrogen & Fuel Cells: Working principles and classifications of fuel cells (H_2 based), zero-energy buildings concept. Benefits and production technologies of green hydrogen (electrolysis method), hydrogen storage, and application challenges.

Biomass, Tidal & Ocean Systems: Biomass conversion pathways (photosynthesis basics, bio-fuels, fixed-dome digesters, urbanization waste-to-energy conversion, and gasification). Mechanics of tidal and wave energy harvesting, advantages, and limitations. Ocean Thermal Energy Conversion (OTEC): Open and closed-cycle operating principles, international power stations, and technical hurdles.

Self-Study (SS):

1. Comparative feasibility and techno-economic review of solar-wind hybrid microgrid tracking installations for isolated rural community electrification.

	2. Technical review of carbon capture and storage (CCS) technologies compared alongside utility-scale clean hydrogen deployment matrices.
Textbooks:	
[1]	Principles of Energy conversion, A. W. Culp Jr., McGraw Hill, 1996.
[2]	Non-Convention Energy Resources, Shobh Nath Singh, Pearson, 2018.
Reference Books:	
[1]	S. N. Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009.
[2]	Rai. G.D, “Non conventional Energy Sources”, Khanna publishes, 1993.
[3]	Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, PHI Learning Private Limited, 2012.
[4]	John Twideu and Tony Weir, “Renewal Energy Resources” BSP Publications, 2006.
[5]	Gray, L. Johnson, “Wind Energy System”, prentice hall of India, 1995
[6]	B. H. Khan, " Non-conventional Energy sources", , McGraw-Hill, 2nd Edition, 2009.
[7]	Fang Lin Luo Hong Ye, " Renewable Energy systems", Taylor & Francis Group,2013
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Energy Storage Systems						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Classify energy storage technologies.
2. Analyze the performance of various Electrical Energy Storage Systems.
3. Select the appropriate energy storage system for an application.
4. Design the battery pack for an application.
5. Evaluate techno-economic, social and environmental performance with Performance Indicators.

Unit 1: Energy Storage Systems Overview	**[8 Hrs]**
Scope of energy storage, needs and opportunities in energy storage, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Importance of energy storage systems in electric vehicles, Current storage business.	
Unit 2: Mechanical Storage System	**[8 Hrs]**
Heat pumps, hot water storage tank, CAE, Pumped hydro storage, flywheel energy storage, thermal batteries, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems.	
Unit 3: Chemical Storage System	**[8 Hrs]**

Concept of chemical storage of hydrogen etc, application of chemical energy storage system, advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems. Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems.

Unit 4: Electrical and Electrochemical Storage Systems	**[8 Hrs]**

Electrical Storage: Working principle of supercapacitor, types of supercapacitors, cycling and performance characteristics, difference between battery and supercapacitors, hybrid fuel cell-supercapacitor systems, Superconducting magnetic energy storage(SMES), concepts, applications of SME, advantages and limitations of electromagnetic energy storage systems, and future prospects of electrical storage systems.

Electrochemical Storage: Working principle of battery, primary and secondary (flow) batteries, comparison of supercapacitor and battery, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery and Metal hydride battery vs lead-acid battery

Unit 5: Battery Design	**[8 Hrs]**

Battery design for transportation, smart battery, Mechanical Design and Packaging of Battery Packs for Electric Vehicles, Charging and discharging mechanism, monitoring and testing of batteries, Thermal management of battery systems, State of Charge and State of Health Estimation Over the Battery Lifespan, Recycling of Batteries, Current chemistry of batteries.

Self-Study (SS):

1. Comparative techno-economic evaluation of lithium-ion variants (LFP vs. NMC chemistries) regarding degradation metrics and thermal runaway profiles in tropical climates.
2. Operational analysis of second-life battery deployment strategies using retired electric vehicle packs for stationary grid energy storage applications.

Textbooks:

[1]	Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), CRC press (2011)
[2]	Ralph Zito, Energy storage: A new approach, Wiley (2010).
[3]	A. G. Ter-Gazarian, Energy Storage for Power Systems, Institution of Engineering and Technology, 2011.

Reference Books:

[1]	Pistoia, Gianfranco, and Boryann Liaw. Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost. Springer International Publishing AG, 2018.
[2]	Robert A. Huggins, Energy storage, Springer Science and Business Media (2010).

List of Experiments:

[1]	MATLAB/Simulink modeling and comparison of Ragone plots (Power Density vs. Energy Density) for different storage media.
[2]	Performance evaluation and round-trip efficiency calculation of a simulated Pumped Hydro or Flywheel energy storage loop.
[3]	Experimental parameter tracking or software profiling of a Proton Exchange Membrane (PEM) Fuel Cell to plot its polarization voltage-current curves.
[4]	Constant-current charging and discharging profiling of a Supercapacitor to calculate its actual capacitance and Equivalent Series Resistance (ESR).
[5]	Experimental testing of a Lead-Acid or Lithium-ion cell to chart its open-circuit voltage (OCV) vs. depth of discharge curve.

[6]	Comparative performance testing of a cell under varying ambient temperatures to quantify capacity fade.
[7]	Calculation-based design and series-parallel optimization sizing of a battery pack targeted for a specific Electric Vehicle driving cycle.
[8]	Implementing the standard Coulomb Counting algorithm in code (MATLAB/Python) for online State of Charge (SOC) tracking.
[9]	Simulation and thermal profile mapping of a localized battery pack under high-current discharge conditions to evaluate passive vs. active cooling boundaries.
[10]	Experimental verification of passive cell-balancing networks during a battery pack charging sequence.
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Solar and Wind Energy						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--
Course Outcomes: Students will be able to:						
1. Analyze the potential of various renewable energy systems. 2. Analyze solar thermal systems and their engineering applications. 3. Design and evaluate solar photovoltaic systems for various applications. 4. Analyze the performance of wind energy system. 5. Develop and assess hybrid renewable energy systems considering technical, economic, and environmental aspects.						
Unit 1: Fundamentals of Renewable Energy						**[8 Hrs]**
Introduction to renewable energy sources, Energy scenario: Global and Indian perspective, Environmental impacts of conventional energy sources, Renewable energy policies and sustainable development, Energy storage fundamentals.						
Unit 2: Solar Thermal Systems						**[8 Hrs]**
Solar radiation geometry, Measurement of solar radiation, Solar thermal energy conversion, Flat plate and concentrating collectors, Solar water heating systems, Solar dryers, cookers, and thermal applications, Thermal energy storage systems.						
Unit 3: Solar Photovoltaic Systems						**[8 Hrs]**
Principle of photovoltaic conversion, Solar cell materials and characteristics, PV modules, arrays, and efficiency, Maximum power point tracking (MPPT), Standalone and grid-connected PV systems, Batteries and energy storage for PV systems, Applications of solar PV systems.						
Unit 4: Wind Energy Conversion Systems						**[8 Hrs]**

Nature and characteristics of wind, aerodynamics of wind turbines, Types of wind turbines, Components of wind energy conversion systems, Power coefficient and Betz limit, height, air density effects, Wind farm layout and performance analysis, wind speed distribution.		
Unit 5: Hybrid Renewable Energy Systems and Applications		**[8 Hrs]**
Solar-wind hybrid systems, Grid integration of renewable energy, Power electronics for renewable energy systems, Smart grids and distributed generation, Economic and environmental analysis, Operation and maintenance of renewable systems, Case studies of solar and wind power plants.		
Self-Study (SS):		
1. Comparative review of active tracking mechanisms (single-axis vs. dual-axis) regarding cumulative annual energy yield enhancement in solar PV farms. 2. Aerodynamic and structural comparison of onshore versus offshore wind turbine foundations, focusing on mechanical loading conditions.		
Textbooks:		
[1]	G. M. Masters, “Renewable and Efficient Electric Power Systems”, John Wiley and Sons, 2004.	
[2]	S. P. Sukhatme, “Solar Energy: Principles of Thermal Collection and Storage‖”, McGraw Hill, 1984.	
Reference Books:		
[1]	C. S. Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, 3rd ed. New Delhi, India: PHI Learning Pvt. Ltd., 2015.	
[2]	H. Siegfried and R. Waddington, “Grid integration of wind energy conversion systems”, John Wiley and Sons Ltd., 2006.	
[3]	G. N. Tiwari and M. K. Ghosal, “Renewable Energy Applications”, Narosa Publications, 2004.	
[4]	J. A. Duffie and W. A. Beckman, “Solar Engineering of Thermal Processes”, John Wiley & Sons, 1991.	
List of Experiments:		
[1]	Simulation study on Solar PV Energy System.	
[2]	Experiment on “VI-Characteristics and Efficiency of 1kWp Solar PV System”.	
[3]	Simulation study on Wind Energy Generator.	
[4]	Simulation study on Hybrid (Solar-Wind) Power System.	
[5]	Experiment on Performance Assessment of Hybrid (Solar-Wind) Power System.	
[6]	Simulation study on Hydel Power.	
[7]	Experiment on Performance Assessment of 100W Fuel Cell.	
[8]	Simulation study on Controllers for Hybrid Systems.	
[9]	DC-DC boost converter.	
[10]	DC-DC Buck Converter	
Note:		
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Grid Interface of Renewable Energy Sources						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Analyze the role of power electronic converters in renewable energy systems.
2. Model and evaluate photovoltaic and wind energy systems with appropriate control strategies.
3. Design and select power electronic converters for solar and wind applications.
4. Design and implement grid interface schemes for renewable energy systems.
5. Analyze and mitigate power quality issues in grid-connected renewable systems.

Unit 1: Introduction to Renewable Energy Systems and Grid Interface **[8 Hrs]**

World energy scenario and introduction to renewable energy sources including solar, wind, hydro and geothermal systems. Availability, characteristics and power extraction techniques of renewable energy sources. Grid requirements for renewable energy integration and role of power electronic converters in renewable energy systems.

Unit 2: Solar Photovoltaic Systems and Power Electronic Converters **[8 Hrs]**

Solar Power – PV system configurations, Solar cell technologies, Maximum power point tracking. Photovoltaic standalone systems, grid interface, storage, AC-DC loads. Power converters for solar, bidirectional converters.

Unit 3: Grid Connected Inverters and Grid Integration Issues **[8 Hrs]**

Single-phase and three-phase grid-connected inverters with and without transformers, HERIC and H6 topologies, multilevel inverters and inverter control techniques including unipolar and bipolar PWM, PLL and synchronization, power balancing, bypass operation and parallel power processing. Grid integration issues including leakage current, islanding, harmonics, active and reactive power control, voltage unbalance and power quality improvement techniques.

Unit 4: Wind Energy Conversion Systems **[8 Hrs]**

Wind energy conversion systems, wind turbine characteristics and ratings, turbine-generator-inverter configuration, power extraction and MPPT schemes. Induction generators, synchronous generators, doubly-fed induction generators (DFIG), permanent magnet generators and associated converter topologies for wind energy systems.

Unit 5: Energy Storage Systems and Microgrids **[8 Hrs]**

Battery technologies, charging and discharging methods, energy storage requirements and applications in renewable energy systems. Introduction to AC and DC microgrids, architecture, control strategies and applications of microgrid systems.

Self-Study (SS):

1. Comparative analysis of passive versus active islanding detection methodologies (such as slip-mode frequency shift vs. sandia frequency shift) regarding non-detection zones (NDZ).
2. Evaluation of low-voltage ride-through (LVRT) control strategies for DFIG-based wind energy systems during symmetrical and asymmetrical grid faults.

Textbooks:

[1] Sudipta Chakraborty, Marcelo G. Sim303265es, and William E. Kramer. Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control and Integration. Springer Science & Business, 2013.

[2]	Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli, Power Electronics and control for maximum Energy Harvesting in Photovoltaic Systems,CRC Press,2013.
[3]	Chetan Singh Solanki, Solar Photovoltaics: fundamentals, Technologies and Applications, Prentice Hall of India, 2011.
[4]	N. Mohan, T.M. Undeland& W.P. Robbins, Power Electronics: Converter, Applications & Design, John Wiley & Sons, 1989.
Reference Books:	
[1]	Muhammad H. Rashid, Power Electronics: Circuits, Devices, and Applications, Pearson Education India, 2004
[2]	E. Guba, P. Sanchis, A. Ursa, J. Lpez, and L. Marroyo, 302223Ground currents in single-phase transformerless photovoltaic systems,302224 Progress in Photovoltaics: Research and Applications, vol. 15, no. 7, pp. 629302226650, 2007.
[3]	Remus Teodorescu, Marco Liserre, Pedro Rodriguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley and Sons, Ltd., 2011
[4]	Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley-IEEE Press, 2011.ix
List of Experiments:	
[1]	Simulation and performance tracking of a solar PV array tied to a boost converter utilizing an advanced Incremental Conductance MPPT loop.
[2]	Modeling and verification of a Bidirectional DC-DC Converter managing battery charging profiles from a variable PV bus source.
[3]	Simulation study of a single-phase H-bridge grid-connected inverter evaluating the harmonic profile differences between unipolar and bipolar PWM configurations.
[4]	Design and simulation of a Phase-Locked Loop (PLL) block to achieve rapid phase and frequency synchronization with a distorted utility grid.
[5]	Modeling and analysis of a transformerless single-phase HERIC or H6 inverter to quantify common-mode voltage profiles and ground leakage current behavior.
[6]	Implementation of decoupled P-Q (active and reactive power) control loops for a three-phase grid-tied voltage source inverter.
[7]	Simulation analysis of passive and active islanding detection algorithms under balanced matching R-C load conditions.
[8]	Modeling and speed-torque tracking of a Permanent Magnet Synchronous Generator (PMSG) wind conversion assembly under variable wind velocities.
[9]	Simulation-based performance assessment of a Doubly-Fed Induction Generator (DFIG) wind energy system manipulating rotor-side converter injection parameters.
[10]	Power flow simulation and voltage stability tracking of a hybrid AC/DC Microgrid during transitions between grid-interactive and islanded operating states.
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Energy Economics and Policy						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Explain concepts of energy economics, energy resources, and engineering economic analysis.
2. Analyze energy demand–supply patterns, pricing mechanisms, and energy markets.
3. Apply energy modelling and sustainability concepts for energy planning and climate change analysis.
4. Evaluate energy policies, regulatory frameworks, and techno-economic feasibility of renewable energy systems.
5. Assess financial viability, risk analysis, and economic performance of renewable energy projects.

Unit 1: Energy Economics	**[8 Hrs]**

Origin and Definitions of Energy Economics, Link between Economics and Energy, Energy Resources and Energy Commodities; Properties of Energy Resources and Energy Commodities, concept of Energy conservation and Energy efficiency. Basics of engineering economics, Role of engineering economics in the decision-making process, Economic decisions versus design decisions, discount rate and economic equivalence, present-worth analysis, annual equivalent- worth analysis, rate-of-return analysis, depreciation, and taxation, developing project cash flows, social cost benefit analysis, Origins of renewable energy project risks, sensitivity analysis, break-even analysis, expected value decisions.

Unit 2: Demand and Supply of Energy	**[8 Hrs]**

Demand for Energy as a Derived Demand, National Energy consumption, Economic Growth and World Energy Consumption, Demand substitution and energy use Classification of Energy supplies: renewable and non-renewable, Fossil fuels (coal, oil, natural gas), Renewable energy (Hydro, Marine, wind, solar, Geothermal, bio), Nuclear power, Trend and patterns of energy production.

Unit 3: Energy Modelling and Sustainability	**[8 Hrs]**

Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand – supply balancing, energy modelling in the context of climate change, Concept of Sustainable Development and SDGs, Energy Security: India's initiatives, Energy and Climate Change, Energy Efficiency and carbon emissions: Global and National trends.

Unit 4: Energy Prices and Markets and Policies	**[8 Hrs]**

Global and National scenario Trend and Patterns of Energy Consumption and the Energy Crisis (since 1970 the Oil shocks and other events),Basic pricing principles, short run versus long run marginal cost pricing, peak load, seasonal, sectoral pricing of electricity, pricing of natural gas and petroleum products, green power markets Energy Pricing and Taxation: Production Cost versus Return on Investment, Models of Pricing, Market Failures, Peak and Off-peak Pricing, Subsidies, The role of regulatory bodies like MERC, Energy Finance: Banks, International organisations, Green Finance initiatives, Energy Policy The Economics of Climate Change, Climate Change Background, Overview of GHG Emissions, Economic Approach to Control the Greenhouse Effect, Options to Cope with Global Warming, Generic Options, National Policy Options, Emissions Trading System (ETS).

Unit 5: Techno-Economic Evaluation of Renewable Energy Technologies	**[8 Hrs]**

Technology dissemination models, volume and learning effects on costs of renewable energy systems, dynamics of fuel substitution by renewable energy systems and quantification of benefits, fiscal, financial and other incentives for promotion of renewable energy systems and their effect on financial viability, case studies on financial feasibility evaluation of renewable energy devices and systems. Renewable energy economy policy.

Self-Study (SS):

1. Analytical evaluation of Levelized Cost of Energy (LCOE) tracking matrices across solar, wind, and battery storage systems over the past decade.
2. Comparative study of international carbon pricing policies, analyzing Carbon Border Adjustment Mechanisms (CBAM) vs. localized voluntary carbon markets.

Textbooks:

[1]	Bhattacharyya, S C. (2011), Concepts, Issues, Markets and Governance, Springer Kandpal T.C. & Garg, H.P. (2003),Financial Evaluation of Renewable Energy Technologies, Macmillan India Park.
[2]	C. S., Kim, G., & Choi, S. (2007). Engineering Economics. Pearson Prentice Hall, New Jersey.
[3]	Thuesen, G. J., &Fabrycky, W. J., (2002). Engineering economy. Prentice Hall of India.

Reference Books:

[1]	Belli, P., Anderson, J., Barnum, H., Dixon, J., & Tan, J. P. (1998). Handbook on economic analysis ofinvestment operations. The World Bank, Washington,
[2]	Carol A. Dahl, (2015). International Energy Markets: Understanding Pricing, Policies, & Profits.
[3]	PennWell Books. Desai, V. (1997). Guidelines for the economic analysis of projects. Asian Development Bank.
[4]	Gittinger, J. P.(1973), Economic Analysis of Agricultural Project, The Johns Hopkins University Press. Jebaraj, S., & Iniyan, S. (2006). A review of energy models. Renewable and Sustainable Energy Reviews, 10(4),281-311.
[5]	Kaplan, S. (1983). Energy economics: quantitative methods for energy and environmental decisions.McGraw-Hill College.

e-Resource:

[1]	https://s3.ap-south-1.amazonaws.com/aipnpc.org/downloads/T_5052_ENERGY_EFFICIENCY_IN_ELECTRICAL_UTILITIES_BOOK_03.pdf

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