HONOURS DEGREE SPECILIZATION COURSES
(3. ENERGY AND GRID TECHNOLOGY)

EEH-413: ENERGY CONSERVATION AND MANAGEMENT

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	HDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar & field work etc.

Pre requisites: Power Generation, SCADA System, Smart Grid, Electrical Power System

COURSE OBJECTIVES & COURSE DESCRIPTION: Energy Management has been identified as a key instrument to reduce greenhouse gas emissions, besides increasing the cost competitiveness of the entity/ facility while enhancing the energy security of the nation. Policy makers and technology providers have been working towards the cause of energy efficiency and its overall management. This course is designed to educate students on the various dimensions of energy management across the entire value chain.

COURSE OUTCOMES: After successfully completing the course, students should be able to

CO1	Analyse energy systems from a supply and demand perspective
CO2	Impart knowledge in the domain of energy conservation.
CO3	Bring out Energy Conservation Potential and Business opportunities across different user segments.
CO4	Develop innovative energy efficiency solutions and demand management strategies

UNIT-I: Introduction to Energy Conservation:

Overview **-** Global & Indian Energy Scenario Energy Sources, Supply & Demand Overview of Electrical and Thermal Energy Imperative for Energy Conservation, Policy & Regulations for Energy Conservation.

UNIT-II: Energy Conservation Requirements:

Global EE Programmes India **-** Energy Conservation Policies, Energy Conservation Opportunities – Electrical Buildings & Lighting Systems Motors, Pumps, Transformers Power Transmission & Distribution System

UNIT III:Energy Conservation Opportunities:

Thermal Boilers, Furnaces & Waste Heat Recovery Systems Cogeneration Systems HVAC, Cooling Towers & DG Systems, Energy Data Analysis IT Tools and Applications Smart Energy Systems.

UNIT-IV:Case Studies:

Industrial Use Cases, Business Approaches Market Opportunities Overview on EE Financing ESCO Business Models Case studies

TEXTBOOKS:

[T1] LC Witte, PS Schmidt and DR Brown: Industrial Energy Management and Utilization (Hemisphere Publishing Corporation, Washington, 1998)

REFERENCE BOOKS:

[R1] WC Turner and Steve Doty: Energy Management Handbook, Seventh Edition, (Fairmont Press Inc., 2007)
[R2] Sumper Andreas and Baggini Angelo: Electrical Energy Efficiency: Technologies and Applications (John Wiley 2012)
[R3] Frank Kreith: Handbook on Energy Efficiency and Renewable Energy (CRC Press, 2007)
[R4] George Polimeros: Energy Cogeneration Handbook (Industrial Press, Inc., New York, 1981)

Websites:

[W1] National Productivity Council (http://www.npcindia.gov.in)
[W2] Bureau of Energy Efficiency (https://www.beeindia.gov.in)
[W3] Petroleum Conservation Research Association (http://www.pcra.org)

EEH-513: ENERGY ECONOMICS AND AUDITING

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	HDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar etc.

Pre requisites: Fundamentals of Power systems

COURSE OBJECTIVES & COURSE DESCRIPTION: This course aims to provide students an understanding of the economic fundamentals and principles of decision making involved in energy projects. The course also sensitize the students on the mechanism of energy audit and the technologies/ tools typically employed to undertake an audit exercise, supported by case study.

COURSE OUTCOMES: After successfully completing the course, students should be able to:

CO1	Understand the basics of engineering economics
CO2	Understand the structure of energy markets and methods used for pricing electricity and other forms of energy.
CO3	Evaluate the cost effectiveness of individual renewable energy projects.
CO4	Gain knowledge on tools and techniques employed in energy auditing
CO5	Comprehend an energy audit report, including economic parameters

UNIT-I: Basics of engineering economics: Role of engineering economics in the decision-making process, Economic decisions versus design decisions, discount rate and economic equivalence, worth analysis, rate-of-return analysis, depreciation, and taxation, developing project cash flows, social cost benefit analysis, origins of renewable energy project risks, sensitivity and, break-even analysis, expected value decisions.

UNIT-II: Energy Modelling: Review of Energy Prices and Markets, 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

UNIT-III: Techno-economic evaluation of Renewable Energy Technologies: Technology dissemination models, 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.

UNIT-IV: Energy Audit Basics: Definition and Objectives, types, Energy Profiling, Energy Flow diagram, Types of Energy Audit, Duties of Energy Auditor & Manager.

UNIT-V: Energy Audit Procedure: Energy Audit Procedure Tools/Techniques/Equipment, Energy Audit Report, Financing EEC Activities. Case study on energy audit in Power Distribution Utilities.

TEXTBOOKS:

[T1] G. J. Thuesen and W. J. Fabrycky, "Engineering economy". Prentice Hall of India.
[T2] T.C. Kandpal and H.P. Garg, "Financial Evaluation of Renewable Energy Technologies", Macmillan India.
[T3] LC Witte, PS Schmidt and DR Brown," Industrial Energy Management and Utilization", Hemisphere Publishing Corporation, Washington, 1998.

REFERENCE BOOKS:

[R1] C. Dahl, "International Energy Markets: Understanding Pricing, Policies, & Profits". PennWell Books.
[R2] S. Kaplan, "Energy economics: quantitative methods for energy and environmental decisions". McGraw-Hill College.
[R3] YP Abbi and Shashank Jain, "Handbook on Energy Audit and Environment Management", TERI Press, 2006.
[R4] WC Turner, "Energy Management Handbook", Seventh Edition, Fairmont Press Inc., 2007.

WEB RESOURCE:

[W1] https://onlinecourses.swayam2.ac.in/nou23_es05/preview
[W2] Bureau of Energy Efficiency (https://www.beeindia.gov.in/)
[W3] National Productivity Council (http://www.npcindia.gov.in/)

ALTERNATIVE NPTEL/SWAYAM COURSE:

S. No.	NPTEL/SWAYAM Course Name	Instructor	Host Institute
1.	Basic Principles of Energy Management & Energy Audit	Dr. R. N. Patel & Mr. Akhilesh Kumar Tiwari	Chhattisgarh Swami Vivekanand Technical University

EEH-613: RENEWABLE ENERGY RESOURCE CHARACTERISTICS

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	HDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar etc.

Pre requisites: Energy Conservation and Management

COURSE OBJECTIVES & COURSE DESCRIPTION: This subject introduces the different renewable energy sources to the students. Students get knowledge of Electric Power generation by wind, solar, small hydro, Biomass, Fuel Cell and MHD. The course is designed to familiarize and train the student with the tools and techniques used to assess the various renewable energy resources and its potential at any location across the globe, so that a student is able analyse a case quantitatively at the end of the term.

COURSE OUTCOMES: After successfully completing the course, students should be able to:

CO1	Summarize, classify and compare types of renewable energy sources, outline as per Global and Indian context.
CO2	Utilize solar energy for various applications, estimate solar radiation geometry
CO3	Select a site for wind energy source
CO4	Understand the characteristic of biomass energy.
CO5	Demonstrate, Classify and utilize small hydro, geothermal and ocean energy.

UNIT-I: INTRODUCTION TO ENERGY SOURCES
World Energy Futures, Conventional Energy Sources, Renewable Energy Sources, Prospects of Renewable Energy Sources. Environmental aspects of Electrical Energy Generation..

UNIT-II: : SOLAR ENERGY RESOURCES
Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extra-terrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution Sun-earth movement in different seasons, solar geometry, solar radiation on tilted surface, local apparent time, irradiance, insolation Attenuation of solar radiation by the atmosphere, albedo, beam and diffuse components of hourly and daily radiation, GHI and DNI, clearness index, Radiation augmentation Different climatic zones and their impact on site selection
Measurement of solar radiation: Instruments: sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), Hands-on measurement of beam, diffuse and total radiation.
Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components

UNIT-III: WIND ENERGY
Introduction to wind energy Conversion, the nature of the wind, Power in the wind. Wind Energy Conversion: Wind data and energy estimation, Site Selection Considerations, Worldwide development.
Introduction to Atmospheric Boundary Layer Theory, Wind gradient and geographical importance, Wind energy database-Wind atlas.
Wind Systems in India as Case, Potential sites, diurnal and seasonal variations, Instruments used and measurement process wind data.

UNIT-IV: BIOMASS
Basics: Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis.
Biomass resource assessment: Estimation of woody biomass, non woody biomass and wastes, ASTM standards.
Bulk chemical properties: Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids.
Chemical composition of biomass: Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD.
Structural properties: Physical structure, particle size and size distribution, permeability. Physical properties: Bulk density, angle of repose, thermal analysis (thermogravimetric, differential thermal and differential scanning calorimetry).Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.

UNIT-V: SMALL HYDRO RESOURCES, GEOTHERMAL AND OCEAN RESOURCES
Small Hydro: Indian resource potential and exploitation, power potential estimation, hydrographs. Methods for determining head and flow, head and flow measurements, site evaluation, cartography, geotechnical studies.

Geothermal and Ocean Energy: Heat mining, potential sites, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks, estimation of wave power, tidal power sites, scatter diagram of wave heights, OTEC resource map.

TEXTBOOKS:

[T1] B.H. Khan, "Non Conventional Energy Resources", McGraw Hill Education India Private Limited ·.
[T2] VVN Kishore, "Renewable Energy Engineering and Technology – A Knowledge Compendium, TERI Press, 2008.

REFERENCE BOOKS:

[R1] Donald Klass, "Biomass for Renewable Energy, Fuels, and Chemicals", Entech International Inc., USA.
[R2] JA Duffie and WA Beckman, "Solar Engineering of Thermal Processes", Third Edition, John Wiley & Sons.
[R3] S Sukhatme and J Nayak, "Solar Energy: Principles of Thermal Collection and Storage", Third Edition, Tata McGraw Hill, 2008.

WEB RESOURCE:

[W1] https://archive.nptel.ac.in/courses/
[W2] https://mnre.gov.in/
/ ,

EEL-623: GRID TECHNOLOGY LAB

L	T	P	Credit	Assessment:	Type of Course
0	0	2	1	Mid Sem.60%+ End Sem.40% =100%	HDC-L

A Grid Technology Lab focuses on the practical implementation and experimentation with grid computing and energy management systems. In this lab, students gain hands-on experience in understanding and configuring distributed computing systems, including smart grids and renewable energy integration into power networks. The lab provides a platform for exploring technologies such as demand response, energy storage, and monitoring and control of electrical grids. By simulating various grid scenarios, students can analyze the performance, efficiency, and scalability of grid systems, as well as investigate solutions to enhance grid stability, reliability, and sustainability.

EEH-713: GRID INTEGRATION OF RENEWABLE ENERGY

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	HDC	42

Pedagogy: Classroom instruction will consist of interactive lectures, class discussions, PowerPoint presentations, and video illustrations.

Pre requisites: Basic understanding of Power System and Power Electronics Engineering.

COURSE OBJECTIVES & COURSE DESCRIPTION:
The characteristics and behaviour of power systems changes when the share of variable energy increase in the total mix. With the increase in penetration from renewable energy sources, the dynamics of the existing electricity infrastructure must be understood. This course provides a platform for strong understanding related to the phenomenon of integrating renewable energy sources. The course is focussed on causes, effects and recovery measures when power from renewable energy sources are injected to the grid.

COURSE OUTCOMES: After successfully completing the course, students should be able to:

CO1	Acquire a strong understanding of power systems, their operation and control focussed on the issues related to the integration of distributed renewable generation into the network.
CO2	Apply advanced knowledge of electrical power system operations and control to analyse the challenges and opportunities for distributed renewable generation in both large interconnected grid and microgrid settings.
CO3	Describe the principles and requirements of the next generation future power network, incorporating distributed generation and storage and demand management
CO4	Understand the principles, power and limitations of complex power networks incorporating distributed generation and storage

UNIT-I: Introduction of various techniques of utilizing power from renewable energy sources, concept of nano/micro/mini grid. Need of integrating large renewable energy sources, issues related to integration of large renewable energy sources, rooftop plants. Concept of VPP.

UNIT-II: Power system equipment for grid integration Synchronous generator: synchronization/integration to existing grid, load sharing during parallel operation, stability (swing equation and solution) Induction Generator: working principle, classification, stability due to variable speed and counter measures Power Electronics: need of power electronic equipment in grid integration, converter, inverter, chopper, ac regulator and cyclo-converters for AC/DC conversion

UNIT-III: Power quality and management Importance of power quality and corresponding standards, THD, voltage sag, voltage swell, frequency change and its effects, network voltage management, frequency management, system protection, grid codes

UNIT-IV: Grid stabilization Scheduling and dispatch, Forecasting, reactive power and voltage control, frequency control, operating reserve, storage systems, electric vehicles Ancillary services in Indian Electricity Market (regulatory aspect),CERC and CEA orders (technical and safety standards)

UNIT-V: Integration of alternate sources of energy Introduction, principles of power injection: converting technologies, power flow; instantaneous active and reactive power control approach; integrating multiple renewable energy sources; DC link integration; AC link integration; HFAC link integration; islanding and interconnection, Case studies based on synchronous/induction generator for peak demand reduction, grid connected PV system.

TEXTBOOKS/REFERENCE BOOKS:

1. Integration of Alternative sources of Energy, IEEE Press –Wiley-Interscience publication, 2006.
2. Grid integration of solar photovoltaic systems, M. Jamil, M. Rizwan, D.P. Kothari, CRC Press(Taylor & Francis group), 2017
3. Renewable Energy Grid Integration, Marco H. Balderas, Nova Science Publishers, New York, 2009.
4. Wind Power Integration connection and system operational aspects, B. Fox, D. Flynn L. Bryans, N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, IET Power and Energy Series 50 (IET digital library), 2007
5. Power Generation, Operation, and Control, Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheblé, John Wiley & Sons, New York, 2013 (3rd edition)
6. Power Electronics: Circuits, Devices, and Applications. M. H. Rashid, Pearson Education India, 2013
7. Advanced power system analysis and dynamics, L.P. Singh, New age international publishers,2017

EEP-713: PROJECT

L	T	P	Credit	Assessment:	Type of Course
0	0	4	2	Mid Sem.60%+ End Sem.40% =100%	PROJ

The objective of the project for Honours degree specialization is to develop and enhance students' analytical and problem tackling skills. Also it is expected that the students must learn to use the latest equipment and software so that the Industry gets trained Engineers. The project may be analytical, computational and experimental or combination of them based on energy management and grid technogies. During the project period, every student has to present the progress of their works before the duly constituted committee of Faculty Members of the department. The assessment by the committee members are a part of Mid Term Evaluation. A report of the project in the form of hard copy must be submitted in the office before the final evaluation by the External Examiners.

EEH-813: DISTRIBUTED GENERATION AND MICRO GRID TECHNOLOGIES

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	HDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar etc.

Pre requisites:

COURSE OBJECTIVES & COURSE DESCRIPTION: This subject introduces the concept of distributed generation to the students. It also familiarizes the students with the concept of microgrid and its configuration. Through this course the students will develop the skill to find optimal size, placement and control aspects of DGs.

COURSE OUTCOMES: After successfully completing the course, students should be able to:

CO1	Find the type, size and optimal placement DG and storage systems.
CO2	Analyze the impact of DGs grid integration and its control aspects
CO3	Describe the operational impacts and performance analysis of DGs connected to integrated power systems
CO4	Analyze the Micro Grid taking into consideration the operational and control issues of the DGs.
CO5	Understand the necessity of Micro Grid protection

UNIT-I: Distribution Generation (DG) and Storage Technologies
Introduction, Definition and Benefits of DG, Distributed generation (DG) overview and technology trend, Renewable and Non-renewable DG Technologies. Comparison amongst different DG technologies, Brief overview of various Distribution Generations.
Concept of distributed generations (DG) or distributed energy resources (DERs) topologies, Renewable DG Technologies: PV, Wind, Fuel Cell, micro hydro. Hybrid system. Classification and comparison of Energy Storage Systems (ESS), Battery, Super Capacitor, Flywheel, SMES, etc. Optimal placement of DG sources in distribution systems.

UNIT-II: : Operational benefits of Grid connected Renewable DG systems
Benefits of Renewable DG integration on :Reliability of Distribution System (Methods of improving reliability, reliability indices), Power loss reduction (optimal sizing of DG), Voltage profile improvement, Economic benefits, Emission reduction

UNIT-III: Technical impacts of DGs on Grid
Grid interconnection issues for grid connected operation of various types of DG systems.nImpact of DGs upon transient and dynamic stability, grid power quality, and protective relaying of existing distribution systems.

UNIT-IV: Introduction and Operation Control and Modeling of Micro Grid
Concept and definition of Micro Grid, Types of Micro Grid (AC, DC and Hybrid AC-DC), review of sources of Micro Grid, typical structure and configuration of a microgrid, Autonomous and non-autonomous grids, Sizing of Micro Grid, Micro grid with multiple DGs – Power Electronics interfaces in DC and AC microgrids, communication infrastructure, Micro Grid implementation in Indian and international scenario.

UNIT-V: Controls & Protection of Micro Grid
Control techniques for voltage, frequency, active and reactive power control of AC Micro Grid system, transients in Micro Grid, Protection of Micro Grid. DC Microgrid: Unipolar and Bipolar LVDC.

TEXTBOOKS:

[T1] H. Lee Willis, Walter G. Scott," Distributed Power Generation – Planning and Evaluation", Marcel Decker Press.
[T2] Robert Lasseter, Paolo Piagi, "Micro Grid: A Conceptual Solution", PESC, 2004.

REFERENCE BOOKS:

[R1] M.Godoy Simoes, Felix A.Farret, "Renewable Energy Systems – Design and Analysis with Induction Generators", CRC Press.
[R2] S. Chowdhury, S.P. Chowdhury and P. Crossley, "Microgrids and Active Distribution Networks', The Institution of Engineering and Technology, London, U.K.

WEB RESOURCE:

[W1] https://archive.nptel.ac.in/courses/
[W2] https://mnre.gov.in/

MINOR DEGREE SPECIALIZATION COURSES (ELECTRIC VEHICLE AND AUTOMATION)

EED-411: POWER ELECTRONICS FOR ELECTRIC VEHICLE

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
2.5	0.5	0	3	Mid Sem.40%+ End Sem.60% =100%	OEC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies.

Pre requisites:

COURSE OBJECTIVES & COURSE DESCRIPTION: The course objectives for an undergraduate (UG) Power Electronics & Electric Vehicle (EV) course typically aim to provide students with a fundamental understanding of power electronics and its use in Electric Vehicle applications . These objectives include the following topics to be taught : Introduction of Power Electronics, Semiconductor devices, Power semiconductor switching, Converter topologies for EV application, control techniques etc.

COURSE OUTCOMES: After successfully completing the course, students should be able to

CO1	Explain basics of Power electronics, device operation and its control.
CO2	Analyze the operation of uncontrolled and fully control rectifiers along with expressions of fourier series for EV applications.
CO3	Apply the circuit topology to get the operation of DC-AC converters and AC-AC converters for EV application.
CO4	Understand the process of operation of DC-DC converters along with its control for EV application.
CO5	Discuss various control techniques and few advance topics with understanding of related simulation software for EV application.

UNIT-I:

Introduction, Devices: Diodes-silicon, fast recovery, Schottky diode, SCR,TRIAC, SCS, GTO, PUT, SUS, CUJT, LASCR, Mosfet, IGBT with their V-I characteristics. SCR: Operating principle, Gate Characteristics, Two transistor model, over-current and over voltage protection, snubber circuits, methods of turning on (triggering) and turning off (commutation). Fundamentals of SiC, GaN devices.

UNIT-II:

Fundamentals of AC- DC converters. AC- DC converters topologies for Electric Vehicle, Application, Design and Control. Performance parameters of AC-DC converters for Electric Vehicle

UNIT III:

Fundamentals of DC-AC Converters, types. DC-AC converters topologies for Electric Vehicle application: design and control. Performance parameters of DC-AC converters for Electric Vehicle.

UNIT-IV

Fundamentals of DC- DC converters, Bidirectional DC-DC converter. DC-DC converters topologies, Bidirectional DC-DC converter topologies for Electric Vehicle application: design and control. Performance parameters of DC-DC converters for Electric Vehicle.

UNIT-V:

Advance applications of Power Electronics in EV charging station, onboard chargers/ off board chargers, Solar PV technology, Simulation software: PSIM, Real time HIL.

TEXTBOOKS:

[T1] M. H. Rashid, "Introduction to Power Electronics- Circuits, devices and application", Pearson Education India, New Delhi.

[T2] A Haque, M A Khan, K V S Bharath, "Design and Control of Grid connected PV System" CRC Press, USA.

REFERENCE BOOKS:

[R1] P. C. Sen, "Power Electronics" Tata McGraw Hill Book Co., New Delhi.

[R2] G. K. Dubey, S.R. Doradla, A.Joshi and R.M.K. Sinha, "Thyristorised Power Controllers" ,Wiley Eastern Ltd., New Delhi.

WEB RESOURCE:

[W1] www.nptel.ac.in

EED-511: ELECTRIC VEHICLE CONTROL SYSTEMS

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
2.5	0.5	0	3	Mid Sem.40%+ End Sem.60% =100%	MDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar etc.

Prerequisites:

To understand this course, the student must have idea of:

Sl. No.	Subject	Description	Level of Study
01	Mathematics	Linear Differential Equations, Laplace Transform	Class XII, 2nd Sem
02	Physics	Rotational Motion	Class XI
03	Circuit Theory	Network Theory	3rd Sem

COURSE OBJECTIVES & COURSE DESCRIPTION:

- Understand the principles of control systems and their applications in electric vehicles.
- Develop mathematical models of EV components and analyze their dynamic behavior.
- Design and simulate control strategies for key EV functionalities.
- Apply advanced control techniques to improve EV performance and energy management..

COURSE OUTCOMES: After successfully completing the course, students should be able to

CO1	Simplify and analyze complex control system block diagrams using algebra and signal flow graphs.
CO2	Analyze the dynamic behavior of EV systems and their components.
CO3	Perform time domain analysis of first and second-order systems.
CO4	Implement energy management strategies using modern control techniques.
CO5	Implement and evaluate advanced control strategies for EV subsystems.

UNIT-I: Introduction: Concept of feedback and Automatic control, Effects of feedback, Objectives of control system. Types of control systems. Merits and demerits of open and closed loop control systems, Transfer function concept.
Mathematical modeling of dynamic systems: Translational systems, Rotational systems, Mechanical coupling, Liquid level systems, Electrical analogy of Spring– Mass-Dashpot system. Mathematical modelling of electrical systems. Analogous systems, Force-current analogy, Force –voltage analogy. Mathematical modelling of electromechanical systems. Mathematical modeling of mechanical, electrical, thermal, hydraulic and pneumatic systems.

UNIT-II: Block diagram representation of control systems. Block diagram algebra. Block diagram reduction rules. Overall transfer function of complex block diagrams. Signal flow graph. Mason's gain formula.
Control system components: Potentiometer, Synchros, Resolvers, Position encoders. DC and AC tacho-generators. Actuators. Block diagram level description of feedback control systems for position control, speed control of DC motors, temperature control, liquid level control, Servomechanisms and regulators.

UNIT-III: Time domain analysis: Time domain analysis of a first and standard second order closed loop system. Time Response Specifications, Dependence of time domain performance parameters on natural frequency and damping ratio. Step and Impulse response of first and second order systems.
Error Analysis: Steady state errors in control systems due to step, ramp and parabolic inputs. Concepts of system types and error constants.

UNIT-IV: Stability Analysis in Time Domain: Stability concept, Necessary conditions for stability. Routh-Hurwitz's stability criterion, Root locus techniques, construction of Root Loci for simple systems. analysis of control system by root loci. Sensitivity of the roots of the characteristic equation. Relative stability analysis. Effects of gain on the movement of Pole and Zeros.

UNIT-V: **Frequency domain analysis of linear system**: Relationship between time and frequency response, Procedure to plot Polar plot, Bode plots, Determination of margin of stability in Bode plot, Concept of resonance frequency of peak magnification. Nyquist criteria, measure of relative stability, phase and gain margin.

TEXTBOOKS:

1) I. J. Nagrath and M. Gopal, "Control Systems Engineering" New Age International Ltd , New Delhi, 7th Edition
2) Norman S. Nise, "Control System Engineering", 7th Edition, Wiley
3) Kou, B.C., "Automatic Control System", Prentice Hall of India Pvt. Ltd., New Delhi.
4) Ogata, K., "Modern Control Engineering", Prentice Hall of India Pvt. Ltd., New Delhi.
5) Wei Liu, "Hybrid Electric Vehicle System Modeling and Control", Wiley.
6) Krishnan, R. "Electric Motor Drives: Modeling, Analysis, and Control." Prentice Hall.
7) Xi Zhang & Chris Mi, "Vehicle Power Management: Modeling, Control and Optimization." Springer.
8) Wei Liu, "Introduction to Hybrid Vehicle System Modeling and Control", Wiley.

WEB RESOURCE :

1. https://www.controleng.com
2. https://www.mathworks.com
3. https://nptel.ac.in/courses/108/102/108102043/

EED-611: ELECTRIC VEHICLE ENERGY SYSTEM

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
2.5	0.5	0	3	Mid Sem.40%+ End Sem.60% =100%	MDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar & field work etc.

Pre requisites: Basic Electrical Engineering, Power Electronics for EVs

COURSE OBJECTIVES&COURSE DESCRIPTION: This course aims to provide students with an in-depth understanding of energy systems used in Electric Vehicles (EVs).The students will be to understand different energy sources, storage technologies, and energy management strategies.

COURSE OUTCOMES: After successfully completing the course, students should be able to

CO1	Understand the fundamentals of energy systems and their components in Electric
CO2	Analyze battery technologies for Electric vehicles..
CO3	Apply the concepts of battery management system in Electric vehicles.
CO4	Explore alternative energy storage technologies for Electric vehicles.
CO5	Apply energy management strategies in Electric vehicles.

UNIT-I: Introduction to Electric Vehicle Energy Systems
Overview of Electric Vehicles (EVs), Basic structure of EV energy systems, Comparison of internal combustion engine (ICE) vehicles vs. electric vehicles, Energy flow and efficiency considerations in EVs, EV classification and their electrification levels, Power and energy requirements of various types of EVs such as 2/3/4 wheelers, trucks and buses etc., Environmental impact and benefits of EVs, Future of EVs.

UNIT II: Battery Technologies
Types of Battery, Introduction to Electrochemical Battery, Electrochemical Reactions, Battery Parameters: Cell and Battery voltage, Battery Capacity, Discharge Rate, Charging Rate, State of Charge (SOC), State of Discharge (SOD), State of Health (SOH), Depth of Discharge (DOD), Thermodynamic Voltage, Specific Energy, Specific Power, Energy Efficiency, Battery Technologies: Lead-Acid Battery, Nickel Based Battery, Lithium Battery (Li-ion Li-Polymer), Role in Electric Drive Train, Selection of battery for EVs & HEVs

UNIT III: Battery Management Systems (BMS)
Introduction to BMS, Objectives of BMS, Discharging control, Charging control, State-of-Charge Determination, State-of-Health Determination, Cell Balancing, Energy & Power estimation; Battery thermal management system, BMS topologies: Distributed Topology, Modular Topology and Centralized Topology, Firmware development, Certification, Aging. Battery Standards & Tests.

UNIT IV: Alternative Energy Storage
Fuel Cell: Overview of Key Fuel Cell Technologies – Various Types of Fuel Cells, Materials for Electrodes, Electrolytes and Other Components, Working Mechanisms, Hydrogen Generation and Storage: Limitations, Recent Progress in Fuel Cells, Safety Issues and Cost Expectation and Life Cycle Analysis of Fuel Cells; Supercapacitors, Flywheel

UNIT V: Energy Management Systems
Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicle, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy strategies.
EV charging standards, Vehicle to Grid (V2G), Grid to Vehicle (V2G), Vehicle to Home (V2H) technologies.

TEXT BOOK:

[T1] James Larminie, John Lowry, "Electric Vehicle Technology Explained", John Wiley & Sons Ltd, 2003.

REFERENCE BOOKS:

[R1] Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
[R2] Iqbal Husain, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003
[R3] S. Onori, L. Serrao and G. Rizzoni, "Hybrid Electric Vehicles: Energy Management Strategies", Springer, 2015.
[R4] Ibrahim Dinçer, Halil S. Hamut and Nader Javani, "Thermal Management of Electric Vehicle Battery Systems", John Wiley & Sons Ltd., 2016.

EEL-624: ELECTRIC VEHICLE LAB

L	T	P	Credit	Assessment:	Type of Course
0	0	2	1	Mid Sem.60%+ End Sem.40% =100%	MDC-L

This laboratory course is designed to equip the students with experiments related to the application of power electronics in electric vehicles and electric vehicle drives. It also enabled the students to use the AI and optimization tools of EVs. It consists of 8-10 experiments which includes single phase rectifier fed DC shunt and DC series motor, operation of Universal motor , V/f control of a3-phaseinduction motor, inverter fed BLDC motor, DC-DC and DC-AC converter for ElectricVehicle etc.

EED-711: ELECTRIC VEHICLE DRIVES

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
2.5	0.5	0	3	Mid Sem.40%+ End Sem.60% =100%	MDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies, Group discussion, Seminar & field work etc.

Pre requisites: Electric machines

COURSE OBJECTIVES&COURSE DESCRIPTION: This course aims to provide the students with a comprehensive understanding of Electric Vehicle drives and its control involved in starting, speed regulation, braking, and reversal. It also aims to provide the students with an understanding of the application of power electronic converters for controlling the electric vehicle drives

COURSE OUTCOMES: After the completion of the course;

CO1	Student will be able to demonstrate the knowledge of particular type of AC/DC drives.
CO2	Student will use the knowledge for the analysis the DC drive system.
CO3	Student will be able to analyze the AC drive systems.
CO4	Students will be able to effectively apply the knowledge of drives for closed-loop systems.
CO5	Student will be able to analyze applications of solar powered drives and traction drives.

UNIT-I: Introduction, concept of electric drives, EV drives -classification and components, characteristic, starting, speed control and braking of electric motors (dc and ac), Electro-mechanical transients during starting and braking, time energy calculation, load equalization.

UNIT-II: Converters for feeding electric vehicle motors – line commutated converters, choppers, inverters, cycloconverters, ac voltage controllers.

UNIT III: Induction motor drive systems for EVs, scalar control, vector control, sensor less control.

UNIT-IV: Permanent magnet motor drive system for EVs, Energy conservation in Electric drives. Switched Reluctance Motor Drive Systems for EVs.

UNIT-V: Solar and battery powered drives Solar powered EVs, Traction drives, mainline and suburban train configurations, Application of polyphase ac motors in traction drives

TEXTBOOKS:

[T1] G K Dubey, Power Semiconductor Controlled Drives, Prentice Hall Englewood Cliffs, New Jersey.

REFERENCE BOOKS:

[R1] S. K. Pillai, A First Course in Electric Drives, New Age Publications, New Delhi.
[R2] P C Sen, Principles of Electric Machines and Power Electronics, John Wiley.
[R3] M. H. Rashid, “Introduction to Power Electronics”, Pearson Education India, New Delhi.
[R4] G. K. Dubey, Fundamentals of Electric Drives, Narosa Publications, New Delhi.

WEB RESOURCE :

[W1] https://archive.nptel.ac.in/courses/108/104/108104140/

ALTERNATIVE NPTEL/SWAYAM COURSE:

S. No.	NPTEL Course Name	Instructor	Host Institute
1.	Industrial Drives	Dr. K .R. Rajagopal	IIT Delhi
2.	Advanced Electric Drives	Dr. S.P. Das	IIT Kanpur
3.	Fundamentals of Electric Drives	Prof. Shyama Prasad Das	IIT Kanpur
4.	Industrial Drives - Power Electronics	Prof. K. Gopakumar	IISc Bangalore

EEP-721: PROJECT

L	T	P	Credit	Assessment:	Type of Course
0	0	4	2	Mid Sem.60%+ End Sem.40% =100%	PROJ

The objective of the project is to develop and enhance students' analytical and problem tackling skills in the area of Electric Vehicle. Also it is expected that the students must learn to use the latest equipment and software so that the Industry gets trained Engineers. The project may be analytical, computational and experimental or combination of them based on electric vehicles. It should consist of objectives of study, scope of work, critical literature review, methodology and results. During the project period, every student has to present the progress of their works before the duly constituted committee of Faculty Members of the department. The assessment by the committee members are a part of Mid Term Evaluation. A report of the project in the form of hard copy must be submitted in the office before the final evaluation by the External Examiners.

EED-811: AI AND ML APPLICATION IN ELECTRIC VEHICLE

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	MDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies.

Prerequisites:

COURSE OBJECTIVES&COURSE DESCRIPTION: The objective of the course "AI and ML Application in Electric Vehicle is to understand the principles of artificial intelligence (AI) and machine learning (ML) ,Explore the applications of AI/ML in electric vehicles (EVs), Learn to design and develop AI/ML models for optimizing EV systems, Analyze real-world case studies of AI/ML in EV technology.

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COURSE OUTCOMES: After successfully completing the course, students should be able to

CO1	Explain basics of electric vehicle and Fundamentals of AI & ML.
CO2	Analyze the fundamentals of battery management system, power train optimization
CO3	Apply the knowledge autonomous drive system & Smart Charging Infrastructure
CO4	Understand the fundamentals of Data analytics in EVs and Cyber security in AI enabled EVs.
CO5	Discuss the case studies and industry trends along with hands on capstones

UNIT-I:

Overview of EV architecture and components, Challenges in EV technology, Role of AI and ML in EV development, Basics of AI and ML: Definitions, Types (Supervised, Unsupervised, Reinforcement Learning, Overview of Deep Learning and Neural Networks, Tools and platforms for AI/ML (Python, Tensor Flow, PyTorch, etc.

UNIT-II:

Battery state estimation using ML (SOC,SOH,SOP), Predictive maintenance using AI, Thermal management in batteries with AI-based optimization, ML-based motor control and optimization, AI for energy management systems, Predictive analytics for drive train efficiency

UNITIII:

AI algorithms for autonomous navigation (path planning, object detection), Sensor fusion and perception in autonomous EVs, Deep learning for computer vision applications in EVs, AI-based smart charging optimization, Load forecasting and demand-side management, Integration of EVs with renewable energy grids

UNIT-IV

Big data analytics for EV performance, AI for fleet management in electric vehicles, Predictive analytics for driver behavior and efficiency, Threat modeling in connected EVs, AI for detecting and preventing cyber threats in EV systems, Secure communication protocols

UNIT-V:

Real-world applications of AI/ML in EV startups and companies, Tesla, Rivian, and other pioneers in AI/ML-driven EV technology, Challenges and ethical considerations, Develop an AI model for EV battery state prediction, Build a simple reinforcement learning model for energy optimization, Real-time analysis of EV fleet data using ML

TEXTBOOKS:

[T1] AI for Power Electronics, Haque, Azra, Saad, IEEE Wiley Press 2025
[T2] Deep Learning for Autonomous Vehicles by Seth Russell, Springer 2019
[T2] Machin eLearning for Predictive Models by John D. Kelleher, MIT Press,2015

WEBRESOURCE:

[W1] www.nptel.ac.in

EED-812: ELECTRIC VEHICLE ADVANCE TECHNOLOGIES AND ECONOMICS

L	T	P	Credit	Assessment:	Type of course	Total No. of Teaching Hours
3	0	0	3	Mid Sem.40%+ End Sem.60% =100%	MDC	42

Pedagogy: Classrooms lecture, Tutorial, Case studies.

Prerequisites:

COURSE OBJECTIVES&COURSE DESCRIPTION: The course objectives for a course on "Electric Vehicle Advance Technologies & Economics" aims to provide students with a strong foundation in the principles, technologies, and practical applications of electric vehicle (EV) system and related Economics. This includes the basic to advance knowledge of EV charging infrastructure requirements and design.

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COURSE OUTCOMES: After successfully completing the course, students should be able to

CO1	Explain basics of electric vehicle and its architecture.
CO2	Analyze the fundamentals of battery, BMS ,power electronics and drive technology for EVs
CO3	Apply the knowledge to plan and design the EV charging infrastructure
CO4	Understand the requirement of power electronics, control with standards for EV charging station along with Energy management system.
CO5	Discuss economical aspects of electric vehicle charging management system

UNIT-I:

History and evolution of Electric vehicles. Overview of Electric Vehicles and their types. Environmental and economic considerations. Electric Vehicle Architecture and components. Government policies and Industry specifications.

UNIT-II:

Fundamentals of Battery parameters. Battery technology and management system. Supercapacitors-Technology and management, Electric Motors and drive trains for EVs. Motor Control techniques. Power Electronics for electric vehicle drives.

UNITIII:

Electric Vehicle charging infrastructure: Types of EV chargers (Level 1, Level 2, DC Fast Chargers), Charging standards (ChadeMo, CCS, Tesla supercharges) , Charging infrastructure deployment and challenges, Smart Charging and Vehicle to Grid, Grid to vehicle charging concepts.

UNIT-IV

Power Electronics and control systems for charging of EVs (Battery, Battery with Supercapacitors etc). Charging cables and connectors, Safety standards and protocols. Charging station design and installation -A case study. Electric Vehicle Energy Management: Energy consumption, modelling and estimation, Battery state of charge and state of health monitoring, thermal management in EVs, Reliability analysis of EV converters (with Advance techniques – Image Processing, AI etc).

UNIT-V:

Economic analysis of EV charging station and its operation: Load Scheduling, Load prediction, Cost analysis, Case Study

TEXTBOOKS:

[T1] Advanced Electric Drive Vehicles Editor: Ali Emadi, CRC Press

[T2] Smart Charging Solutions for Hybrid and Electric Vehicles, Sulabh Sachan, P. Sanjeevi Kumar, Sanchari Deb, Wiley Press.

WEBRESOURCE:

[W1] www.nptel.ac.in