Course Curriculum for M. Tech.

In

Renewable Energy and Energy Management

Electrical Engineering

(For students admitted in 2020-21 onwards)

National Institute of Technology Arunachal Pradesh

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1.0 Semester wise Credit point distribution

Sl. No.	Year	Credit Point	
		ODD	EVEN
1	First	21	20
2	Second	12	12
Total Credit Point		**33**	**32**
		65	

2.0 Subject Category wise Credit point Distribution

Course Category	Sem-I	Sem-II	Sem-III	Sem-IV	Total Credit Point
Core (Basic Science)	**3**	**--**	**--**	**--**	**3**
Core (Engineering Science)	**--**	**--**	**--**	**--**	**0**
Core (Professional)	**15**	**16**	**3**		**34**
Core (Humanities)	**--**	**3**	**--**	**--**	**3**
Elective (Professional)	**--**	**--**	**--**	**--**	**0**
Open Elective	**--**	**--**	**--**	**--**	**0**
Elective (online course)	**--**	**--**	**--**	**--**	**0**
Lab (Basic Science)	**--**	**--**	**--**	**--**	**0**
Lab (Engineering Science)	**--**	**--**	**--**	**--**	**0**
Lab (Humanities)	**--**	**--**	**--**	**--**	**0**
Lab (Professional)	**3**	**1**	**4**	**--**	**8**
Internship	**--**	**--**	**--**	**--**	**0**
Academic Project	**--**	**--**	**5**	**12**	**17**
Audit (NSS/NCC)	**--**	**--**	**--**	**--**	**0**
Grand Viva	**--**	**--**	**--**	**--**	**0**
Total Credit Point	**21**	**20**	**12**	**12**	**65**

❖ INSTITUTE VISION

To transform into an acclaimed institution of higher learning with creation of an impact on the north eastern region in terms of innovation and entrepreneurship

❖ INSTITUTE MISSION

- ❖ *To generate new knowledge through state-of-the-art academic program and research in multidisciplinary field*
- ❖ *To identify regional, Indian and global need to serve the society better.*
- ❖ *To create an ambience to flourish new ideas, research and academic excellence to produce new leaders and innovators*
- ❖ *To collaborate with other academic, research institutes and industries for wholistic growth of the students*
- ❖ *Utilization of available big resources to encourage entrepreneurship through formation of startups.*

❖ Vision of the Department

Mould generations of Electrical Engineers on global standards with multidisciplinary perspective to meet evolving societal needs for the north eastern region.

❖ Mission of the Department

M1: *Empower students with knowledge in electrical and allied engineering facilitated in innovative class rooms and state-of-the art laboratories.*

M2: *Inculcate technical competence and promote research through industry interactions, field exposures and global collaborations.*

M3: *Promote professional ethics and selfless service.*

❖ Programme Outcome

PO1: Engineering Knowledge
PO2: Problem Analysis
PO3: Design/Development of Solutions
PO4: Conduct Investigations of complex problems
PO5: Modern tools usage
PO6: Engineer and Society
PO7: Environment and Sustainability
PO8: Ethics
PO9: Individual & Team work
PO10: Communication
PO11: Project management & Finance
PO12: Lifelong learning

❖ Programme Specific Outcome

PSO1: Future Technology.
PSO2: Research and Innovation.

COURSE STRUCTURE

M. Tech. 1st Year, Semester I

Sl. No	Course Code	Course Title	L	T	P	C
1.	EE-501	Principles of Energy Conversion Systems	3	0	0	3
2.	EE-502	Solar Energy Conversions and Photovoltaics	3	0	0	3
3.	EE-503	Wind Energy Conversion Systems	3	0	0	3
4.	EE-504	Hydro Power Generation Systems	3	0	0	3
5.	EE-505	Energy Economics and Planning	3	0	0	3
6.	EE-506	Solar Power Laboratory	0	0	2	1
7.	EE-507	Wind Power Laboratory	0	0	2	1
8.	EE-508	Hydro Power Laboratory	0	0	2	1
9.	MA-501	Advanced Numerical Methods	3	0	0	3
Total Credits			18	0	6	21

M. Tech. 1st Year, Semester II

Sl. No	Course Code	Course Title	L	T	P	C
1.	EE-521	Advanced Power Electronics and Drives	3	0	0	3
2.	EE-522	Smart and Micro Grid	3	0	0	3
3.	EE-523	Power Quality Issues and Remedies	3	0	0	3
4.	EE-524	ELECTIVE-I	3	0	0	3
5.	EE-525	ELECTIVE-II	3	1	0	4
6.	EE-526	Advance Power Electronics and Drives Laboratory	0	0	2	1
7.	MH- 901	Industrial Management	3	0	0	3
Total Credits			18	1	2	20

M. Tech. 2nd Year, Semester III

Sl. No	Course Code	Course Title	L	T	P	C
1.	EE-601	ELECTIVE-III	3	0	0	3
2.	EE-602	UG Teaching Assistance	0	0	2	1
3.	EE-603	Seminar	0	0	6	3
4.	EE-691	Dissertation I	0	0	10	5
Total Credits			3	0	18	12

M. Tech. 2nd Year, Semester IV

Sl. No	Course Code	Course Title	L	T	P	C
1.	EE-692	Dissertation II	0	0	24	12
Total Credits			0	0	24	12

Elective-I

A. Fundamentals of Thermal and Electrical Engineering
B. Bio-fuels and Decentralized Energy Systems
C. HVAC Transmission System

Elective- II

A. Building Energy and Green Building
B. HVDC Transmission System
C. Waste to Energy

Elective-III

A. Grid integration of Renewable Energy
B. Optimization Techniques for Energy Management and Planning
C. Power Generation Economics

EE 501: Principles of Energy Conversion Systems

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed for:

1. familiarization of students with theories of energy conversion techniques.
2. utilization process of various energy resources.

Course Content:

Introduction, characterization of coal and conventional routes for energy production from coal.
Cleaner routes for energy production form coal.
Characterization of crude oil and conventional routes for crude oil utilization.
Cleaner routes for energy production form petroleum crude.
Cleaner energy production from gaseous fuels.
Solar and wind energy production.
Production of hydro and geothermal energy.
Energy production from biomass and wastes and energy conservation.

Course Outcome:

At the end of this course, students will demonstrate the ability to:
CO1: impart knowledge in the domain of energy conservation
CO2: bring out Energy Conservation Potential and Business opportunities across different user segments under innovative business models
CO3: inculcate knowledge and skills about assessing the energy efficiency of an entity/ establishment

Text Books:

1. G. B. Miller, "Coal Energy Systems", Elsevier Academic Press, Paris 2005
2. J. Twidel and W. Tony, "Renewable Energy Resources", Second Edition, Taylor and Francis 2006.

Reference Books:

1. F. Kreith, D. Y.Goswami, "Energy Management and Conservation", CRC Press 2008
2. S. Sukhatme, J. Nayak, "Solar Energy: Principles of thermal Collection and Storage", 3rd Ed., Tata McGrow-Hill Pulishing Company Ltd. 2008
3. P. Mondal and A. Dalai, "Sustainable utilization of natural resources", CRC Press 2017

EE 502: Solar Energy Conversion and Photovoltaics

L	T	P	Credit
3	0	0	3

Course Objectives:

The course objectives aim to sensitize students on:

1. development capability in the students to design solar thermal and solar photovoltaic power generating units in various modes for example: standalone, grid connected, hybridization,
2. financial and related environmental implications of the two systems,
3. case studies and actual application of available software for design of solar power systems are also covered

Course Content:

Global solar PV deployment status, Solar policy in India – rooftop and ground mounted, Current Central and State schemes and targets. Review of solar radiation components, radiation on tilted surface.

PV module technology: c-Si, Thin-film technology, response to weather parameters, commercial module ratings, standards, module reliability.

Inverter technology: Inverter technologies, types of inverters, inverter selection, voltage levels, performance, power quality.

Balance of system/plant: Module mounting structure, tracking system, Cabling and electrical design, single line diagrams, metering

Safety systems: Hotspot, Blocking and bypass diodes, surge protection, PID and its protection, Lighting protection, anti-islanding.

Battery technologies: Introduction to battery, battery technologies, standalone system and utility scale storage

Types of PV systems: Design considerations for standalone and grid connected plants, rooftop and ground mounted, floating solar plant, BIPV.

Rooftop PV plant: design consideration, types of mounting structures, standards Ground mounted PV plant: Array design and PV panel mounting, electrical layout, standards.

Performance parameter: Losses in solar PV power plant, Yield, Capacity Utilization Factor and Performance Ratio Design exercises using PVsyst for ground mounted and rooftop plants with shadow analysis.

Preliminary site survey and feasibility study, statutory clearances and permits, Different modes of project development, PPA and evacuation planning, DPR Project schedule, procurement schedule, civil and electrical works, installation of module and inverter Grid-synchronization and power evacuation, Testing and acceptance Concept of Mega Solar Parks.

Monitoring of PV plant, Best practices in operation, cleaning and maintenance.

Performance analysis and estimation of energy payback period for SPV power plant – rooftop, ground-mounted, stand alone and small-scale and large-scale power plant scenarios, assessment of carbon footprints and carbon credit calculation, estimating CO2 mitigation potential.

Course Outcome:

After completing this course, a student will be able to:

CO1: develop understanding on the PV plant design and select suitable technologies.

CO2: design and simulate a PV power plant using software tool.

CO3: plan project implementation, operation and maintenance.

CO4: carry out techno-economic-environmental performance evaluation of a solar PV power plant.

Text Books:

1. A. Luque and S. Hegedus, "Handbook of photovoltaic science and engineering", John Wiley and Sons, 2010.
2. C. S. Solanki, "Solar Photovoltaics – Fundamentals, Technologies and Applications", PHI Learning, 2011.

Reference Books:

1. V.V.N. Kishore, "Renewable Energy Engineering and Technology – A Knowledge Compendium", TERI Press, 2008.
2. R. A. Messenger and A. Abtahi, "Photovoltaic system engineering", 3rd ed. CRC Press, 2010.
3. Grid connected PV systems design and installation, GSES India Sustainable Energy, 2013.

EE 503: Wind Energy Conversion Systems

L	T	P	Credit
3	0	0	3

Course Objectives:

The course objectives aim to sensitize students:

1. to develop capability in the students to design wind power generation systems and make students aware with the challenges of the field,
2. to give students in depth understanding of wind generators, their integration to electric grid, related technical and economic challenges.

Course Content:

Introduction: Review of wind resource assessment, basic laws and concepts of aerodynamics (2-D, 3-D aerodynamics). Description and performance of the horizontal–axis wind machines, description and performance of the vertical–axis wind machines. Site Selection – Wind climatology, terrain features, surface roughness etc. Micro siting of wind turbines, site Identification, wind mast installation. Annual Energy Output estimation Uncertainties in estimation. Probabilities of Estimation. Betz criterion, Analysis of wind regimes – statistical analysis of wind regimes, Dynamics of data acquisition. Time distribution, Frequency distribution. Statistical Modelling.

Wind Power Project Planning and Structuring:

Bank ability of Projects: Promoters, Financing, Balance Sheet, Non-Recourse or Project Finance, Leasing, Taxation Issues.

Electricity off Take Arrangements and Structures:

PPA with utility, Captive, Group Captive, Open Access and Merchant Sale Project Contracts:

Wind Turbine Supply Contracts, Works Contracts, EandC Contract, OandM Contract

Risk Mitigation Indemnities and Liabilities Power Curve Measurement, Project Management: Project Implementation Activities, Pert/ CPM/ MS Projects, Quality Assurance in Project Implementation. Evaluation and analysis, Implementation and monitoring, Performance indices.

Wind Turbine Generators: Induction, Synchronous machine, constant V and F and variable V and F generations, Reactive power compensation.

Site Selection, Concept of wind form and project cycle, Cost economics and viability of wind farm.

Course Outcome:

After completing this course, a student will be able to:

CO1: adequately trained to research WECS.

CO2: skilled both theoretically and practically to use this subject for the application in wind power generation systems.

Text Books:

1. G. L. Johnson, "Wind Energy Systems", (Electronic Edition), Prentice Hall Inc, 2006
2. S. Mathew, "Wind Energy: Fundamentals, Resource Analysis and Economics", Springer, 2006

Reference Books:

1. T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, "Wind Energy Handbook", John Wiley, 2001
2. A. R. Jha, "Wind Turbine Technology", CRC Press, Taylor and Francis, 2011
3. P. Jain, "Wind Energy Engineering", McGraw-Hill 2011
4. P. K. Nag, "Power Plant Engineering", 3rd Edition, Tata McGraw Hill, 2008.

EE 504: Hydro Power Generation Systems

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed to meet the objectives of:

1. making students aware about the uses of small and micro hydro plants,
2. identification of hydro as a competitive conventional source of energy.

Course Content:

Introduction to Hydropower, Hydrology – descriptive hydrology, hydrograph, mass curve, storage, dams. Classification of Hydropower Plants, Small Hydropower, Systems: Overview of micro, mini and small hydro systems Status of Hydropower Worldwide

Advantages and Disadvantages of Hydropower, Selection of site for hydroelectric plant, Hydrological cycle, Essential elements of a hydroelectric power plant.

Classification of Fluids, Characteristic of Water, units of Pressure, Pascal's law, applications of Pascal's law, Hydraulic press, Pressure measurement Types of fluid flow, stream line and turbulent flow Velocity Equation, Bernoulli's Equation, Power Equation, Continuity Equation, Cavitations, venturi meter, orifice meter, Pitot tube.

Components of hydropower plants Hydraulic Turbines: Types and Operational Aspects Classification of Hydraulic Turbines, Theory of Hydro turbines; Francis, Pelton, Kaplan and Propeller Turbine; differences between impulse and reaction turbines; Operational Aspects of Turbines Efficiency and selection of turbines, Types of generators - synchronous and induction, transformers, protection and control, transmission and distribution system. Dam and Spillway, Surge Chambers, Penstock, Tailrace.

Site selection, environmental aspect, run-of-the-river and storage schemes; diversion structures, power channels, desilting arrangements, forebay tank and balancing reservoir, penstock and power house; transmission and distribution system.

Course Outcome:

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

CO1: adequately trained to research micro hydel systems.

CO2: skilled both theoretically and practically to use this subject for the application in hydro power generation systems.

Text Books:

1. T. Jiandong, "Mini hydropower", John Wiley, 1997
2. H. Wagner and J. Mathur, "Introduction to Hydro energy Systems : Basics, Technology and Operation", Springer, 2011.

Reference Books:

1. P. K. Nag, "Power Plant Engineering", 3rd Edition, Tata McGraw Hill, 2008.
2. R. K. Bansal, "A textbook of fluid mechanics and hydraulic machines", Laxmi publications, 2005, New Delhi
3. Z. Hussian, M. Z. Abdullah, "Basic Fluid Mechanics and Hydraulic Machines", Wiley 2012.

EE 505: Energy Economics and Planning

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed to:

1. introduce students with study related to cost effectiveness and economic policies of renewable energy projects.
2. teach calculations of life cycle of multiple renewable energy technologies.
3. it will cover a variety of theoretical and empirical topics related to energy demand, energy supply, energy prices, environmental consequences of energy consumption and production, and various public policies affecting energy demand, supply, prices, and environmental effects

Course Content:

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.

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.

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, power exchange.

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.

Course Outcome:

By the end of this course, the student will be able to:

CO1: evaluate the cost effectiveness of individual renewable energy projects using the methods learned and draw inferences for the investment decisions.

CO2: compare the life cycle cost of multiple renewable energy technologies using the methods learned and make a quantitative decision between alternate options.

CO3: utilize spreadsheet functions to perform economic calculations.

CO4: compare the differences in economic analysis between the private and public sectors.

CO5: recognize the limits of mathematical models for factors hard to quantify.

CO6: understand of structure of energy markets and methods used for pricing electricity and other forms of energy.

Text Books:

1. S. C. Bhattacharyya, “Concepts, Issues, Markets and Governance”, Springer 2011.
2. T. C. Kandpal and H. P. Garg, “Financial Evaluation of Renewable Energy Technologies”, Macmillan India.

Reference Books:

1. C. S. Park, G. Kim, and S. Choi, “Engineering Economics”, Pearson Prentice Hall, New Jersey.
2. G. L. Thuesen and W. J. Fabrycky, “Engineering economy”, Prentice Hall of India.

EE 506: Solar Power Laboratory

L	T	P	Credit
0	0	2	1

Course Objectives:

The course objectives aim to sensitize students on:

1. development capability in the students to design solar thermal and solar photovoltaic power generating units in various modes for example: standalone, grid connected, hybridization,
2. financial and related environmental implications of the two systems,
3. case studies and actual application of available software for design of solar power systems are also covered

List of Practical:

1. Determining the intensity of solar radiation.
2. Arrangement of Photovoltaic cells.
3. Setting up of the Photovoltaic panel with the help of the given settings to get the maximum exposure of the sunlight.
4. Measurement of V/I Characteristics of the mono-crystalline cells
5. Measurement of V/I Characteristics of Polycrystalline cells
6. Connecting of Photovoltaic cells in series and measuring their V/I Characteristics.
7. Connecting of Photovoltaic cells in Parallel and measuring their V/I Characteristics.
8. Connecting of Monocrystalline and polycrystalline cells in series and parallel and measuring their characteristics
9. Connecting a battery to the inverter and measuring the output using a meter
10. Connecting a battery to the inverter and observing the waveform using a oscilloscope
11. Doing exp no 8 and 9 with different loads.
12. Connecting a solar panel with inverter and measuring the output using meter.
13. Connecting a solar panel with inverter and observing the output using Oscilloscope.

Course Outcome:

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

CO1: adequately trained to research Solar Photovoltaics Systems.

CO2: skilled both theoretically and practically to use this subject for the application in solar power generation systems.

EE 507: Wind Power Laboratory

L	T	P	Credit
0	0	2	1

Course Objectives:

The course objectives aim to sensitize students:

1. to develop capability in the students to design wind power generation systems and make students aware with the challenges of the field,
2. to give students in depth understanding of wind generators, their integration to electric grid, related technical and economic challenges.

List of Practical:

1. Study of the aero generator operation in function of the wind speed variation.
2. Generator angle of incidence variation.
3. Operation differences using the three available blades configurations (aero generator with 6, 3 or 2 blades).
4. Operation differences depending on the angle of the blades.
5. Load variation influence on the aero generator.
6. Study of the voltage, power and current.
7. Study of V, I, W in function of different loads.
8. Efficiency experimental determination (depending on: number of blades, angle of the blades, generator´s angle; among others).
9. Wind energy measurement.
10. Familiarization with the regulator parameters.
11. Study of the power generated by the aero generator depending on the wind speed.
12. Study of the power generated by the aero generator depending on the air incident angle.
13. Connection of loads to direct voltage.
14. Study of the grid utility inverter.

Course Outcome:

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

CO1: adequately trained to research WECS.

CO2: skilled both theoretically and practically to use this subject for the application in wind power generation systems.

EE 508: Hydro Power Laboratory

L	T	P	Credit
0	0	2	1

Course Objectives:

The course is designed to meet the objectives of:

1. making students aware about the uses of small and micro hydro plants,
2. identification of hydro as a competitive conventional source of energy.

List of Practical:

1. Perform a detailed study on the pumped storage hydro power plant.
2. Operate the given hydropower plant and find out the terminal voltage and frequency.
3. Synchronization of the given power plant with grid system using dark lamp method.
4. Synchronization of the given power plant with grid system using bright lamp method.
5. Synchronization of the given power plant with grid system using three lamp method.
6. Operation of three phase induction machine as micro hydro power plant.

Course Outcome:

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

CO1: adequately trained to research micro hydel systems.

CO2: skilled both theoretically and practically to use this subject for the application in hydro power generation systems.

MA 501: Advanced Numerical Methods

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed to meet the objectives of:

1. introducing the basic concepts of round off error, truncation error, numerical stability and
2. condition, taylor polynomial approximations; to derive and apply some fundamental algorithms for solving scientific and engineering problems: roots of nonlinear equations, systems of linear equations, polynomial and spline interpolation, numerical differentiation and integration, numerical solution of ordinary differential equations.
3. application of computer oriented numerical methods which has become an integral part of the life of all the modern engineers and scientists. the advent of powerful small computers and workstation tremendously increased the speed, power and flexibility of numerical computing.
4. injecting future scope and the research directions in the field of numerical methods.

Course Content:

Algebraic and Transcendental Equations: Definition and sources of errors, solutions of nonlinear equations, Bisection method, Newton's method, fixed point iterations, Regula-Falsi method, convergence analysis, Newton's method for two variables.

Solution of the system of Linear equations: Gauss elimination method, Gauss Jordan method, Matrix Inversion, Operations Count, LU Factorization method, Gauss-Jacobi and Gauss-Seidel method, Successive Over Relaxation method

Initial value problems: Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, Predictor-Corrector method, multistep methods and its stability analysis.

Finite difference schemes for partial differential equations:Discretization, Explicit and Implicit schemes, Consistency, Stability and Convergence, Stability analysis by matrix and Von Neumann methods, Lax's equivalence theorem, Finite difference schemes for initial and boundary value problems - FTCS, backward Euler and Crank-Nicolson schemes, ADI methods for Parabolic and Hyperbolic PDEs, Central difference schemes Elliptic PDEs.

Course Outcome:

Upon Completion of the subject:

CO1: students will be skilled to do Numerical Analysis, which is the study of algorithms for solving problems of continuous mathematics.

CO2: students will know numerical methods, algorithms and their implementation in C++for solving scientific problems.

CO3: students will be substantially prepared to take up prospective research assignments.

Text Books:

1. G. D. Smith, “Numerical Solutions to Partial Differential Equations”, Oxford University Press, 3rd edition, 1986.
2. K. W. Morton and D. F. Mayers, “Numerical Solution of Partial Differential Equations”, Cambridge University Press, 2nd edition, 2005.

Reference Books:

1. S. Saha Roy, “Numerical Analysis with Algorithm and Programming”, CRC Press, 1 st edition, 2016.
2. D. Kincaid and W. Cheney, ‘Numerical Analysis: Mathematics of Scientific Computing”, 3rd edition., AMS, 2002.
3. K. E. Atkinson, “An Introduction to Numerical Analysis”, Wiley, 1989.
4. S. D. Conte and C. de Boor, “Elementary Numerical Analysis - An Algorithmic Approach”, McGraw-Hill, 1981.

5. John H. Mathews, “Numerical Methods for Mathematics Sciences and Engineering”, Prentice Hall of India, New Delhi 2nd edition 2003.
6. M.K.Jain, S.R.K. Iyengar and R.K. Jain, “Numerical method for Scientific and Engineering Computation”, New Age International Pvt. Ltd. 3rd edition, 1993.
7. J. C. Strikwerda, “Finite Difference Schemes and Partial Differential Equations’, SIAM, 2004.
8. L. Lapidus and G. F. Pinder, ‘Numerical Solution of Partial Differential Equations in Science and Engineering”, John Wiley, 1982.

EE 521: Advanced Power Electronics and Drives

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed for students:

1. to gather knowledge on power electronics equipment used for non-conventional energy systems.
2. to work on electrical machine drives in various non-conventional energy generation techniques.

Course Content:

Introduction: Power Electronics, requirements and application areas, Brief idea of Power Electronics application in areas like Power System, Motion Control, Heating, Automotive, Electric Welding, Renewable energy sources etc., Concept of power processing.

Signal-Processing: Concept of Signal Processing and its requirements in PES Analog signal processing circuits like precision rectifier, Log and Antilog Amplifier, Voltage multiplier, Divider, peak detector etc., Switched Capacitor circuits concept and realization of simple circuits, Analog computation, solution of simultaneous equations and differential equations through analog circuits, ADC and DAC, V/F, F/V Converters, PLL, Timing Circuit, Multi-vibrators, Timer.

Designing of GATE driver circuits for power semi-converter switches:- Need and purpose of designing GATE driver circuits, GATE driver circuits for MOSFET, IGBT, BJT and other power semi-converter devices.

PWM control, SVM and closed loop control of power converters: Need of fixed and variable pulse width PWM, Sine PWM, Current Hysteresis controlled PWM, Selective Harmonic Elimination based PWM, Space Vector PWM, Bus Clamping PWM and its effect on minimizing line current ripple, torque pulsation, switching energy loss etc.

Digital control in converters: Averaged switch modeling and simulation, Techniques of Design-Oriented Analysis, with Application to Switching Converters, Dynamic modeling and simulation of converters operating in discontinuous conduction mode, Current Programmed Control, Introduction to Digital Control of Switching Converters, Low-Harmonic Single-Phase Rectifiers and Inverters.

Modelling and analysis: Modelling of DC machine, Modelling of Induction Machine, Modelling of Synchronous machine and modelling of different special machines.

Advanced controllers for drives:- Generalized theory and Kron’s primitive machine model, Modeling of dc machines Modeling of induction machine Modeling of synchronous machine Reference frame theory and per unit system, Control of Induction Motor Drive Scalar control of induction motor Principle of vector control and field orientation Sensorless control and flux observers Direct torque and flux control of induction motor Mutilevel converter-fed induction motor drive Utility friendly induction motor drive, Control of Synchronous Motor Self-controlled synchronous motor Vector control of synchronous motor, Cycloconverter-fed synchronous motor drive Control of synchronous reluctance motor, Control of Special Electric Machines Permanent magnet synchronous motor Brushless dc motor Switched reluctance motor Stepper motors and control.

DC to DC converter, Power System Applications Introduction: Power system problems Concept and working of HVDC Transmission, Development of HVDC Technology, Power Conversion, 3-Phase Converter, 3-Phase Full Bridge Converter, 12-Pulse Converter, Control of HVDC Converter and System, Converter Control for an HVDC System, Commutation Failure, HVDC Control and Design, HVDC Control Functions, Reactive Power and Voltage Stability, FACTS Concept and General System Considerations, Power factor correction, Static VAR Compensation, Static Shunt Compensators, Static Series Compensators, Active power filter, Interconnection of renewable energy sources and Energy storage system to the utility grid.

Power Supply and energy storage: Concept, working and types of SMPS and UPS Battery principle, Battery types, construction, applications, Charging methods and charging circuits for battery, Power Supply applications in various electronics systems.

Consumer Electronics Applications: High Frequency Fluorescent lighting, LED lighting, fan regulator, Space Heating , Air Conditioning, Induction Cooking, Automation in industry and motor drives applications like flow control, robot control, Electric Train, battery operated vehicles, conveyer belt, elevator, hoist etc.

Course Outcome:

At the end of this module, students are expected to be able to:

CO1: design of power electronics converters for various renewable energy systems.

CO2: design and develop consumer products for the betterment of human kind.

Text Books:

1. Mc Pherson George, "Introduction to Electric Machines and transformers", John Wiley and Sons, 1980
2. Nasser Syed, "Electric Machine and Transformer", New York, Macmillan, 1984.

Reference Books:

1. P.C. Sen., "Thyristor DC Drives", New York Wiley, 1991.
2. Fitzgerald, C. Kingsley and S. D. Umans, "Electric Machinery",(5th Ed.,),McGraw-Hill 1992.
3. A. E. Clayton, "Performance and Design of Direct Current Machines",3rd Ed. Pitman 1961.
4. R. S. Ramshaw, "Power Electronics Semiconductor Switches", Champman and Hall, 1993.
5. N. Mohan, T. M. Undeland and W. P. Robbins, "Power Electronics, Converter, Application and Design", Third Edition, John Willey and Sons, 2004.
6. M. H. Rashid, "Power Electronics, circuits, Devices and Applications", Pearson, 2002, India.
7. K. Billings, "Switch Mode Power Supply Handbook", McGraw-Hill, 1999, Boston.
8. I. Pressman, "Switch Mode Power Supply Design", McGraw-Hill, 1999, New York.
9. N. G. Hingorani and L. Gyugyi, "Understanding FACTS", IEEE Press, Delhi, 2001.
12. B. K. Bose, "Power Electronics and Variable Frequency Drive", Standard Publishers Distributors.

Syllabus for M. Tech in Renewable Energy and Energy Management

EE 522: Smart and Micro Grid

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed for students:

1. to introduce the concept of smart grid,
2. to discuss the future trends of power system industry.

Course Content:

Introduction Indian smart grid policy. Basic concept and definition of smart grid. Smart grid architecture. Smart grid technologies. Properties of smart grid: flexibility, reliability, demand response and other performance parameters. DC smart micro grids.

Communication technologies Generic model of communication network needed for Smart-grid, two way and real-time communication in power network, Introduction to different communication technologies available in the market (Latest standards. Emphasis on importance of inoperability and standardization of communication protocols), Matrix of different technologies against the smart-grid communication needs in a given utility environment, AMI, AMR and MDA: How it works and how it will help to; reduce peaks manage networks more efficiently and contribute towards smarter grids, Communication Standards IEC6150, Wide Area Situation awareness (WASA), Network stability

Smart meters Introduction, technology, data management, energy monitoring, smart energy meter, Phasor Measurement Unit (PMU), smart metering infrastructure, data acquisition Flexible AC transmission system (FACTS) Congestion management and loadability enhancement, reactive power compensation, concept of series compensation, shunt compensation, FACTS: working principle, classification, series controllers, shunt controllers, series-series controllers, series-parallel controllers.

IoT for power systems Internet of things for electricity infrastructure and energy management. SCADA, Demand response, AMI, IoT aided smart grid, Big data for power system and introduction to data analytics.

Application of smart grid Challenges being faced during implementation of smart grid. virtual power plants, Smart Utilities (case studies), Smart Grid Maturity Model (SGMM).

Course Outcome:

On successful completion of this course, students should be able to:

CO1: apply advanced knowledge of electrical power system operations and control to analyse the challenges and opportunities due to increased penetration of renewable energy sources.

CO2: understand and conceptualize the design of smart grid by selecting appropriate communication technologies, implementing smart meter and FACTS.

CO3: describe the principles and requirements of the next generation future power network (or smart grid), using the latest trends in IoT for power systems.

Text Books:

1. M.S.Hossain, N.A.Madlool, N.A.Rahim, J.Selvaraj, A.K.Pandey, Abdul Faheem Khan, "Role of smart grid in renewable energy: An overview", Elsevier Journal of Renewable and Sustainable Energy Reviews, Volume 60, July 2016, pp. 1168-1184.
2. P. Siano, "Demand response and smart grids—a survey", Elsevier Journal of Renewable and Sustainable Energy Reviews, Volume 30, 2014, pp. 461-478.

Reference Books:

1. Xi Fang, Satyajayant Misra, Guoliang Xue, Dejun Yang, "Smart Grid — The New and Improved Power Grid: A Survey", IEEE Communications Surveys and Tutorials, Volume: 14, Issue: 4, Fourth Quarter 2012
2. Murat Kuzlu, Manisa Pipattanasomporn, Saifur Rahman, "Communication network requirements for major smart grid applications in HAN, NAN and WAN", Elsevier Journal of Computer Networks, Volume 67, 4 July 2014, pp. 74-88

3. Yasir Saleem, Noel Crespi, Mubashir Husain Rehmani, Rebecca Copeland, "Internet of Things aided Smart Grid: Technologies, Architectures, Applications, Prototypes, and Future Research Directions", IEEE transaction on Networking and Internet Architecture, 2017

EE 523: Power Quality Issues and Remedies

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed to:

1. introduce overview of power system operation and control,
2. acquire knowledge of modelling power frequency dynamics to design power frequency controllers,
3. model reactive power-voltage interaction and the control actions to be implemented for maintaining voltage profile against varying system load.

Course Content:

Introduction of the Power Quality problem, Terms used in Power Quality: Voltage Sag, Swell, Surges, Harmonics, over voltages, spikes, voltage fluctuations, Transients, Interruption, Long Interruptions, Short interruptions. Sources for Electric Power Quality problem in power system: poor load power factor, Nonlinear and unbalanced loads

Single phase circuit: Power definition and components, Power terms, Sinusoidal Voltage Source Supplying Non-linear Load Current, Non-sinusoidal Voltage Source Supplying Non-linear Loads, Three phase circuit: Power definition and components, Three-phase Sinusoidal Balanced System, Instantaneous Active and Reactive Powers for Three-phase Circuits,

Harmonic , Introduction, Voltage versus Current distortion, Harmonics versus Transients, Power system quantities under non sinusoidal conditions,- Powers, harmonics phase sequences, Triplen harmonics, THD,TDD, Harmonic sources –from commercial loads and industrial loads. Principles for controlling harmonics. Where to control harmonics? Devices for controlling harmonics-Zigzag transformers, passive filters, active filters, a case study.

Fundamental theory for load compensation and its analysis, Introduction, Power Factor and its Correction, An Approximation Expression for the Voltage Regulation, and Control theories for load compensations.

Course Outcome:

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

CO1: become Operation Engineers in field of Process Control.

CO2: work in designing and operation of control systems employed in various industries.

CO3: to take up prospective research assignments.

Text Books:

1. David D. Shipp and William S. Vilcheck, “Power Quality and Line Considerations for Variable Speed AC Drives”, IEEE Transactions on Industry Applications, Vol. 32, March- April – 1996
2. Arindam Ghosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002.

Reference Books:

1. Roger.C.Dugan, Mark.F.McGranagham, Surya Santoso, H.Wayne Beaty, “Electrical Power Systems Quality”, McGraw Hill, 2003.
2. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition).
3. Jos Arrillaga, Neville R. Watson, “Power System Harmonics”- John Wiley and Sons, 2003.

EE 526: Advanced Power Electronics and Drives Laboratory

L	T	P	Credit
0	0	2	1

Course Objectives:

The course is designed for students:

1. to gather knowledge on power electronics equipment used for non-conventional energy systems.
2. to work on electrical machine drives in various non-conventional energy generation techniques.

List of Practical:

1. Determination of complete torque speed characteristics of three phase induction machine in braking, motoring and generation regions and its calibration.
2. Understanding the effect of rotor resistance on the load characteristics of a wound–rotor induction motor.
3. Determination of equivalent circuit parameters, prediction of performance. Verification from actual load test. (b) Separation of losses of Induction motors and estimation of efficiency.
4. Speed control of Induction motor–Conventional, electronic. Solid state speed control using (i) V constant, (ii) V/f constant, (iii) slip–energy injection.
5. Load characteristic of Induction generator working in (i) Grid connected mode (ii) Self Determination of equivalent circuit parameters of a single-phase Induction motor. Prediction of torque–speed characteristic. Verification from load test.
6. Determination of torque step rate characteristic of a stepper motor. Determination of operating range.
7. Load characteristic of universal motor, operating and AC supply Comparison of performance.
8. Experimental determination of performance characteristics of two-phase servomotor.
9. Load characteristic of hysteresis motor and shaded pole motor.
10. Characteristic of permanent magnet motor.
11. Characteristic of switched reluctance motor.

Course Outcome:

At the end of this module, students are expected to be able to:

CO1: design of power electronics converters for various renewable energy systems.

CO2: design and develop consumer products for the betterment of human kind.

MH 901: Industrial Management

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed to meet the objectives of:

1. Imparting theoretical lectures with case discussion.
2. Providing teaching with inclusive learning.
3. Making students aware about the importance of this subject in their future career.

Course Content:

Concept of Management: Various approaches to management , management as an art, a Science and a profession, Managerial Skills, Process Management, Planning Mission, Goals, Strategy, Program and Procedure; Decision making process, decision making under risk and uncertainty, Models of decision making.

Principles of Organization: Organizational Structure, Span of control, Staffing function with emphasis on performance appraisal, training and development.

Direction and Coordination: Motivation and Leadership, Control function- Process and Techniques

Production Management: Types of Production, Locational Decision, Plant Layout and Design, Production.

Planning Scheduling and Control: Work Study, Method Study and Wage, Payment Schemes and Bonus, Productivity concept and measurement.

Material management: Inventory Planning, Procurement functions, Procedures and Control, Storing planning procedure and control, Issue and Pricing, Inventory Control Techniques, Value Analysis and Engineering.

Course Outcome:

At the end of this module, students are expected to be able to:

CO1: student shall be able to describe basic concepts and theories within the area of industrial management.

CO2: the student shall be able to use these concepts and theories in limited analysis of an organization.

CO3: with the backup knowledge their performance will be definitely much better in their workplace.

Text Books:

1. Khanna, O.P.,Industrial Engineering and Management, New Delhi, Dhanpat Rai Publishers, 2018
2. 2. Raju, N.V.S., Industrial Engineering & Management, First Edition , New Delhi , Cengage Learning India , 2013.

Reference Books:

1. Badiru, A, Hand Book of Industrial and System Engineers, Second Edition, Boca Raton CRC press, 2020
2. Blanchand, B & Fabrycky,J. W, System Engineering Analysis , Fourth Edition , Englewood Cliffs, NJ, Prentice Hall,2005

EE 524A: Fundamentals of Thermal and Electrical Engineering

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed to make students:

1. understanding the basics of characteristics and behavior of laws of thermodynamics.
2. solving the problems related to thermodynamic applications.
3. understanding the use of steam tables and apply them to real problems.
4. understanding the basics of DC and AC sources along with their applications on electrical circuits.
5. solving the problems related to applications of network theorems and solving complex DC circuits.
6. solving the problems related to R-L-C circuits connected to single phase and three phase AC.
7. solving the problems related to magnetic circuits.

Course Content:

System, surroundings and properties. Energy and Processes. Work and heat. Zeroth law of thermodynamics. First law of thermodynamics. Constant pressure process. Adiabatic and Polytropic Process. Steady state flow process. Limitations.

Kelvin-Plank statement and Clausius statement. Reversibility, irreversibility and carnot cycle. Entropy. Temperature entropy diagram. Second law of thermodynamics

Reheat, regeneration and binary vapour cycle. Gas power cycle. Refrigeration cycle. Thermodynamics of ideal gas mixture

Resistance (R), Inductance (L) and Capacitance (C). Ohm's law. DC and AC sources – voltage and current, ideal and practical, dependent and independent

KCL and KVL, loop or mesh analysis, nodal analysis, star□delta transformation, Thevenin's and Norton's theorem, superposition theorem, maximum power transfer theorem.

Representation of sinusoidal quantities, steady state analysis of R-L-C series and parallel circuits, resonance in electrical circuits, energy and power, complex power – apparent, active and reactive power, three phase ac circuits – phase and line voltages and currents

Magnetic flux and mmf, analogy between electrical and magnetic circuits, magnetic materials, eddy current and hysteresis losses.

Course Outcome:

At the end of this module, students are expected to be able to:

CO1: understanding the basics of characteristics and behavior of laws of thermodynamics.
CO2: solving the problems related to thermodynamic applications.
CO3: understanding the use of steam tables and apply them to real problems.
CO4: understanding the basics of DC and AC sources along with their applications on electrical circuits.
CO5: solving the problems related to applications of network theorems and solving complex DC circuits.
CO6: solving the problems related to R-L-C circuits connected to single phase and three phase AC.
CO7: solving the problems related to magnetic circuits.

Text Books:

1. R. E. Sonntag, C. Borgnakke, G. J. Van Wylen, "Fundamentals of Thermodynamics", Sixth Edition, (Wiley-India, 2007).
2. P. K. Nag, "Engineering Thermodynamics", Third Edition (Tata McGraw-Hill, 2005)

Reference Books:

1. Y. A. Cengel and M. A. Boles, "Thermodynamics: An Engineering Approach", Sixth Edition (Tata McGraw-Hill, 2008)
2. S. R. Turns, "An Introduction to Combustion: Concepts and Applications", Second Edition (McGraw

Hill, 2000)
3. B. L. Theraja, A. K. Theraja, "A text book of Electrical Technology", S. Chand Publication, 2012
4. D. P. Kothari, I. J. Nagrath, "Fundamentals of electrical engineering", Tata Mc Graw-Hill Publication, 2016

EE 524B: Bio-fuels and Decentralized Energy Systems

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed to:

1. make students familiar with concepts of decentralization of energy resources.
2. work of renewables and bio-fuels in rural India.

Course Content:

Advance material and energy balance. Traditional and modern energy use; Methods of accounting the role of traditional energy in the overall energy system. Energy consumption patterns in rural areas.

Need and development of rural energy data bases (REDB); Case studies of REDB Energy access in rural India, access to clean energy: power and cook stove; rural industries and social development Use of efficient/appropriate/renewable energy technologies for rural areas. Technologies/products for cooking, water heating, drying, irrigation pumping, small/micro enterprises, lighting, motive power etc. Syngas and poly-generation, chemical conversion of syngas to methanol and ethanol and some advanced fuels like bio butanol, bio propanol. Bio CNG: biogas to green vehicle fuel; anaerobic digestion; Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.

Bioethanol: First- and second-generation ethanol; production technologies World scenario; challenges and some solutions. Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by products, Environmental impacts of biodiesel, biodiesel from algae, biodiesel engines.

Pyrolysis oil: fast pyrolysis technologies; composition and issues of biooil; Bio-oil up gradation technologies Case study: International success stories and failures.

Course Outcome:

On successful completion of this course the students will be able to:

CO1: create rural energy database.

CO2: interpreted big data.

CO3: design biofuel plant.

CO4: critically analyze biofuel cases.

Text Books:

1. Donald Klass, “Biomass for Renewable Energy, Fuels, and Chemicals”, Entech International Inc., USA.
2. T. Astra, “Biofuels engineering process technology’, TERI Publications.

Reference Books:

1. Caye Dapcho, John Nghiem, “Biofuels”, Tata McGraw Hill.
2. Wim Soetaert, Erik Vandamme, “An Assessment of the Biofuels Industry in India”, John Wiley and Sons.

EE 524C: HVAC Transmission Systems

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed for students:

1. to gather knowledge on HVAC transmission systems and its advantages.
2. to work on new transmission techniques

Course Content:

FACTS Concepts: Transmission line inter connections, Power flow in an AC system, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

Voltage Source Converters: Single phase three phase full wave bridge converters, transformer connections for 12, 24 and 48 pulse operation. Three level voltage source converters, pulse width modulation converter, basic concept of current source Converters, comparison of current source converters with voltage Source converters.

Static Shunt Compensation: Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, Methods of controllable var generation, variable impedance type static var generators, switching converter type var generators, hybrid var generators.

SVC and STATCOM: The regulation and slope transfer function and dynamic performance, transient Stability enhancement and power oscillation damping, operating point control and summary of compensator control.

Static Series Compensation: Concept of series capacitive Compensation, improvement of transient stability, power oscillation damping, Functional requirements, GTO Thyristor controlled series capacitor (GSC), Thyristor switched series capacitor (TSSC) and Thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

Course Outcome:

At end of this course, students will demonstrate the ability to:

CO1: understand load ability of the transmission line.

CO2: emphasize the importance of the voltage and reactive power control in electrical systems

CO3: state different compensation techniques through facts devices

CO4: analyse the real and reactive power flow and control in transmission lines

Text Books:

1. M. Mathur, R. Rajiv, K.Varma, “Thyristor–Based Facts Controllers for Electrical Transmission Systems”, Wiley Publishers.
2. A.T. John, “Flexible AC Transmission System”, IEEE Press.

Reference Books:

1. N. G. Hingorani, L. Gyugyl, “Understanding FACTS Concepts and Technology of Flexible AC Transmission System”, Wiley Publishers.
2. A. R. Bergen, “Power Systems Analysis”, Pearson Publications.
3. K. R. Padiyar, “FACTs Controller in Power Transmission and Distribution”, New Age International.

EE 525A: Building Energy and Green Building

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed to:

1. building integrated renewable energy generation.
2. performance testing of buildings.

Course Content:

Review of topics on thermal comfort Classification of climate zones Review of traditional architecture.

Unsteady heat flows through walls, roof, windows etc. Direct heat gains through windows Convective gains/losses, air exchange rates Gains from people, appliances etc. Air conditioning load calculations.

Passive cooling/heating concepts Building form and orientation Internal and external shading devices Ventilation, passive concepts for composite climates, evaporative and nocturnal cooling Earth–air tunnel, sky-thermal system Solar chimney-based hybrid system

Introduction and use of different building simulation software for modelling of non-air-conditioned spaces such as TRNSYS, ECOTECT etc.

Introduction and use of different building simulation software for modelling of air-conditioned spaces such as VISDOE, EPLUS etc Rating systems in different countries. Green building rating systems such as LEED and GRIHA. BEE and ECBC.

Course Outcome:

Upon completion of the course, students will be:

CO1: having an understanding of core building science fundamentals.

CO2: able to perform some building sustainability concepts

CO3: able to understand energy efficiency in relation to cost performance, ROI, etc.

CO4: able to understand and perform some building performance testing (ex. energy audit, Rating) and be exposed to different agencies involved in the testing.

CO5: able to understand and perform some weatherization fundamentals.

Text Books:

1. G. Minke, "Building with Earth: design and technology of a sustainable architecture", SpringerLink
2. B. Givoni, "Climate and Architecture". Elsevier Publishing Company Ltd.

Reference Books:

1. B. Givoni, "Climatic Considerations in Buildings and Urban Design", John Wiley and Sons, Canada
2. N. K. Bansal, Gerd Hauser, Gernot Minke, "Passive building design: a handbook of natural climatic control", Elsevier Science
3. B.V. Krishnan, A., Baker, N., Yannas, S., Szokolay, S., "Climate Responsive Architecture- A Design Handbook for Energy Efficient Buildings", Tata McGraw-Hill, New Delhi
4. B. Givoni, "Passive and Low Energy Cooling of Buildings", John Wiley andSons Inc., New York
5. M. Santamouris, "Passive Cooling of Buildings", James and James (Science Publishers) Ltd., London

EE 525B: HVDC Transmission Systems

L	T	P	Credit
3	0	0	3

Course Objectives:

The course is designed for students:

1. to gather knowledge on HVDC transmission systems and its advantages.
2. to work on new transmission techniques

Course Content:

Evolution of HVDC Transmission, Comparison of HVAC and HVDC systems, Type of HVDC Transmission systems, Components of HVDC transmission systems.

Analysis of simple rectifier circuits, Required features of rectification circuits for HVDC transmission, Analysis of HVDC converter, Different modes of converter operation, Output voltage waveforms and DC voltage in rectification, Output voltage waveforms and DC in inverter operation, Thyristor voltages, Equivalent electrical circuit.

HVDC system control features, Control Modes, Control Schemes, Control comparisons. Converter mal-operations, Commutation failure, Starting and shutting down the converter bridge.

Converter protection. Smoothing reactor and DC Lines, Reactive power requirements. Harmonic analysis, Filter design, Component Models for the Analysis of AC DC Systems. Power flow analysis of AC-DC systems, Transient stability analysis, Dynamic stability analysis, Multi- terminal HVDC system, Advances in HVDC transmission, HVDC system application in wind power generation.

Protection against over current and over voltage in converter station, Generation of Harmonics, adverse effects of harmonics, Calculation of voltage and Current harmonics, Effect of Pulse number on harmonics

Course Outcome:

At the end of this module, students are expected to be able to:

CO1: design of power electronics converters for various HVDC transmission systems.

CO2: design and develop consumer products for the betterment of human kind.

Text Books:

1. K. R. Padiyar, “HVDC Power Transmission Systems”, Willey Eastern Limited, Second edition.
2. J. Arrillaga, “High Voltage Direct Current Transmission”, Peter Peregrinus Ltd, UK.

Reference Books:

1. E. W. Kimbark, “Direct Current Transmission”, Wiley-Interscience, New York.
2. S. N. Singh, “Electric Power Generation, Transmission and Distribution, PHI, New Delhi 2nd edition, 2008.
3. Mc Pherson George, “Introduction to Electric Machines and transformers”, John Wiley and Sons, 1980.
4. Nasser Syed, “Electric Machine and Transformer”, New York, Macmillan, 1984.
5. P. C. Sen, “Thyristor DC Drives”, New York Wiley, 1991.
6. Fitzgerald, C. Kingsley and D. S. Umans, “Electric Machinery”, (5th Ed.,),McGraw-Hill 1992.

EE 525C: Waste to Energy

L	T	P	Credit
3	0	0	3

Course Objectives:

On successful completion of this course the students will be able to:

1. apply the knowledge about the operations of Waste to Energy Plants.
2. analyse the various aspects of Waste to Energy Management Systems.
3. carry out Techno-economic feasibility for Waste to Energy Plants.
4. apply the knowledge in planning and operations of Waste to Energy plants.

Course Content:

The Principles of Waste Management and Waste Utilization. Waste Management Hierarchy and 3R Principle of Reduce, Reuse and Recycle. Waste as a Resource and Alternate Energy source.

Waste production in different sectors such as domestic, industrial, agriculture, postconsumer, waste etc. Classification of waste – agro based, forest residues, domestic waste, industrial waste (hazardous and non-hazardous). Characterization of waste for energy utilization. Waste Selection criteria. Biochemical Conversion – Energy production from organic waste through anaerobic digestion and fermentation. Thermo-chemical Conversion – Combustion, Incineration and heat recovery, Pyrolysis, Gasification; Plasma Arc Technology and other newer technologies. Landfill gas, collection and recovery. Refuse Derived Fuel (RDF) – fluff, briquettes, pellets. Alternate Fuel Resource (AFR) – production and use in Cement plants, Thermal power plants and Industrial boilers. Conversion of wastes to fuel resources for other useful energy applications. Energy from Plastic Wastes – Non-recyclable plastic wastes for energy recovery. Energy Recovery from wastes and optimization of its use, benchmarking and standardization. Energy Analysis

Waste activities – collection, segregation, transportation and storage requirements. Location and Siting of 'Waste to Energy' plants. Industry Specific Applications – In-house use – sugar, distillery, pharmaceuticals, Pulp and paper, refinery and petrochemical industry and any other industry. Centralized and Decentralized Energy production, distribution and use. Comparison of Centralized and decentralized systems and its operations. Environmental standards for Waste to Energy Plant operations and gas clean-up. Savings on non-renewable fuel resources. Carbon Credits: Carbon foot calculations and carbon credits transfer mechanisms.

Course Outcome:

On successful completion of this course the students will be able to:

CO1: apply the knowledge about the operations of Waste to Energy Plants.

CO2: analyse the various aspects of Waste to Energy Management Systems.

CO3: carry out Techno-economic feasibility for Waste to Energy Plants.

CO4: apply the knowledge in planning and operations of Waste to Energy plants.

Text Books:

1. Industrial and Urban Waste Management in India, TERI Press.
2. B. Lal and M. Patwardhan, "Wealth from Waste: Trends and Technologies", TERI Press.

Reference Books:

1. S. N. Mukhopadhyay, "Fundamentals of waste and Environmental Engineering", TERI Press.
2. Gazette Notification on Waste Management Rules 2016.
3. CPCB Guidelines for Co-processing in Cement/Power/Steel Industry Waste-to-Energy in Austria – White Book – Figures, Data Facts, 2nd edition, May 2010
4. Report of the task Force on Waste to Energy, Niti Ayog (Formerly Planning Commission) 2014.
5. Municipal Solid Waste Management Manual, CPHEEO, 2016

EE 601A: Grid Integration of Renewable Energy

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed to:

1. introduce the concept of advances in grid integration techniques of renewable energy.
2. teach next generation future power network practices.

Course Content:

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.

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 equipments in grid integration, converter, inverter, chopper, ac regulator and cyclo-converters for AC/DC conversion.

THD, voltage sag, voltage swell, frequency change and its effects, network voltage management, frequency management, system protection, grid codes.

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).

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.

Based on synchronous/induction generator for peak demand reduction, grid connected PV system.

Course Outcome:

On successful completion of this course, students should be able to:

CO1: 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.

CO2: assess renewable energy applications and projects in the context of integration into both the physical and economic electricity markets.

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.

Text Books:

1. A. Felix and M. Godoy, “Integration of Alternative sources of Energy”, IEEE Press – Wiley-Interscience publication, 2006.
2. Majid Jamil, M. Rizwan, D.P.Kothari, “Grid integration of solar photovoltaic systems”, CRC Press (Taylor & Francis group), 2017.

Reference Books:

1. Marco H. Balderas, “Renewable Energy Grid Integration”, Nova Science Publishers, New York, 2009.
2. B. Fox, D. Flynn L. Bryans, N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, “Wind Power Integration connection and system operational aspects”, IET Power and Energy Series 50 (IET digital library), 2007.
3. Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheblé, “Power Generation, Operation, and Control”, John Wiley & Sons, New York, 2013 (3rd edition).

EE 601B: Optimization Techniques for Energy Management and Planning

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed to:

1. introduce optimization techniques involved in engineering problems.
2. use of algorithms in management and planning of renewable energies.

Course Content:

The nature of random variables: populations and samples, parameters and statistics. Probability concepts; properties of random variables, probability distribution function.

Drivers of energy demand, Sectoral energy demand: - domestic, commercial, industrial, agricultural. Projections for future demands.

Problem formulation: decision variables, objective function, maxima, minima, constraints. Analysis techniques: simulation, optimization, stochastic optimization.

Assumptions, problems formulation and solutions, graphical methods, simplex algorithm, duality concept, sensitivity analysis. Power system planning using optimization techniques, case study.

Introduction, multi stage decision problems, recursive equations, principle of optimality, discrete dynamic programming. Optimal energy resource, technology mix in micro and macro level energy planning exercises. Power generation expansion planning, case study.

Introduction, non-inferior solutions, trade off analysis, weighted and constraints method.

Course Outcome:

After completing this course, students would be able to:

CO1: define and use optimization terminology and concepts.

CO2: apply optimization methods for energy system planning, including developing a model, defining an optimization problem, applying optimization methods, exploring the solution, and interpreting results.

CO3: explain methods for power system planning and operation: Least-cost planning, integrated planning of resources.

Text Books:

1. H. A. Taha, “Operations Research—An Introduction”, Prentice Hall of India. New Delhi.
2. N. D. Vohra, “Quantitative Techniques in Management”, 3e. Tata McGraw-Hill Education.

Reference Books:

1. R. L. Rardin, “Optimization in operations research”, Upper Saddle River, NJ: Prentice Hall.
2. J. S. Dhillon and D. P. Kothari, “Power system optimization”, Preintce Hall of India Private Limited.
3. B. M. Ayyub and R. H. McCuen, “Probability, Statistics and Reliability for Engineers and Scientists”, CRC Press, Boca Raton.
4. N. T. Kottegoda and R. Rosso, “Applied Statistics for Civil and Environmental Engineers”, McGraw-Hill, International Edition.

EE 601C: Power Generation Economics

L	T	P	Credit
3	0	0	3

Course Objectives:

The course has been designed to:

1. introduce students with study related to cost effectiveness and economic policies of renewable energy projects.
2. teach calculations of life cycle of multiple renewable energy technologies.
3. it will cover a variety of theoretical and empirical topics related to energy demand, energy supply, energy prices, environmental consequences of energy consumption and production, and various public policies affecting energy demand, supply, prices, and environmental effects

Course Content:

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

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.

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, power exchange.

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.

Course Outcome:

By the end of this course, the student will be able to:

CO1: evaluate the cost effectiveness of individual renewable energy projects using the methods learned and draw inferences for the investment decisions.

CO2: compare the life cycle cost of multiple renewable energy technologies using the methods learned and make a quantitative decision between alternate options.

CO3: utilize spreadsheet functions to perform economic calculations.

CO4: compare the differences in economic analysis between the private and public sectors. Recognize the limits of mathematical models for factors hard to quantify.

CO5: understand of structure of energy markets and methods used for pricing electricity and other forms of energy.

Text Books:

1. S. C. Bhattacharyya, “Concepts, Issues, Markets and Governance”, Springer.
2. T. C. Kandpal and H. P. Garg, “Financial Evaluation of Renewable Energy Technologies”, Macmillan India.

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1. C. S. Park, G. Kim, and S. Choi, “Engineering Economics”, Pearson Prentice Hall, New Jersey.
2. G. J. Thuesen, W. J. Fabrycky, “Engineering economy”, Prentice Hall of India.