Courses of Study and Scheme of Assessment
ME ENERGYENGINEERING

(2018 REGULATIONS)
(Minimum No. of credits to be earned: 71) *

Course Code	Course Title	Hours/Week			Credits	Maximum Marks			CAT
		Lecture	Tutorial	Practical		CA	FE	Total	
I SEMESTER									
18SE01	Applied Numerical Analysis	2	2	-	3	50	50	100	FC
18SE02	Concepts of Energy Engineering	3	-	-	3	50	50	100	FC
18SE03	Energy Conservation and Management	2	2	-	3	50	50	100	PC
18SE04	Instrumentations for Energy Systems	3	-	-	3	50	50	100	PC
18SE --	Stream Specific Core 1	3	-	-	3	50	50	100	PC
18SE51	Energy Engineering Laboratory	-	-	4	2	100	-	100	PC
	Total 21hrs	**13**	**4**	**4**	**17**	**350**	**250**	**600**	
II SEMESTER									
18SE07	Energy Resources, Economics and Environment	2	2	-	3	50	50	100	PC
18SE08	Computational Fluid Dynamics	3	-	-	3	50	50	100	PC
18SE --	Stream Specific Core 2	3	-	-	3	50	50	100	PC
18SE --	Stream Specific Core 3	3	2	-	4	50	50	100	PC
18SE --	Professional Elective 1	3	-	-	3	50	50	100	PE
15SE --	Professional Elective 2	3	-	-	3	50	50	100	PE
18SE52	Computational Fluid Dynamics Laboratory	0	-	4	2	100	-	100	PC
18SE61	Industry Visit and Technical Seminar	-	-	4	2	100	-	100	EEC
	Total 29hrs	**17**	**4**	**8**	**23**	**500**	**300**	**800**	
III SEMESTER									
18SE --	Professional Elective 3	3	-	-	3	50	50	100	PE
18SE --	Professional Elective 4	3	-	-	3	50	50	100	PE
18SE --	Professional Elective 5	3	-	-	3	50	50	100	PE
18SE --	Professional Elective 6	3	-	-	3	50	50	100	PE
18SE53	Energy Simulation Laboratory	0	-	4	2	100	-	100	PC
18SE71	Project Work I	0	-	6	3	100	-	100	EEC
	Total 22hrs	**12**	**-**	**10**	**17**	**400**	**200**	**600**	
IV SEMESTER									
18SE72	Project Work II	**-**	**-**	**28**	**14**	**50**	**50**	**100**	**EEC**
STREAM SPECIFIC CORE COURSES									
STREAM SPECIFIC CORE 1 (one to be opted)									
18SE05	Industrial Combustion Systems	3	-	-	3	50	50	100	PC
18SE06	Modeling and Control of Power Converters	3	-	-	3	50	50	100	PC
STREAM SPECIFIC CORE 2(one to be opted)									
18SE09	Thermal Systems Design	3	-	-	3	50	50	100	PC
18SE10	Modeling and Analysis of Electrical Machines	3	-	-	3	50	50	100	PC
STREAM SPECIFIC CORE 3(one to be opted)									
18SE11	Design of Renewable Energy Systems	3	2	-	4	50	50	100	PC
18SE12	Power Electronics in Wind and Solar Power Conversion	3	2	-	4	50	50	100	PC
PROFESSIONAL ELECTIVE COURSES									
COMMON FOR MECHANICAL AND ELECTRICAL ENGINEERING STREAMS									
18SE21	Cleaner Production and Clean Development Mechanism	3	-	-	3	50	50	100	PE
18SE22	Green Buildings	3	-	-	3	50	50	100	PE
18SE23	Design of Solar Systems	3	-	-	3	50	50	100	PE
18SE24	Waste Management and Energy Recovery	3	-	-	3	50	50	100	PE
18SE25	Hydrogen Energy and Fuel Cells	3	-	-	3	50	50	100	PE
18SE26	Bio-Energy Conversion Technologies	3	-	-	3	50	50	100	PE
18SE27	Energy Storage Systems	3	-	-	3	50	50	100	PE

MECHANICAL ENGINEERING STREAM									
18SE31	Fundamentals of Turbulence and Boundary Layer Theory	3	-	-	3	50	50	100	PE
18SE32	Energy Conservation in HVACR Systems	3	-	-	3	50	50	100	PE
18SE33	Aerodynamics of Streamlined and Bluff Bodies	3	-	-	3	50	50	100	PE
18SE34	Design of Wind Energy Systems	3	-	-	3	50	50	100	PE
ELECTRICAL ENGINEERING STREAM									
18SE41	Soft Computing Techniques for Renewable Energy Systems	3	-	-	3	50	50	100	PE
18SE42	Advanced Virtual Instrumentation	3	-	-	3	50	50	100	PE
18SE43	Optimization Techniques	3	-	-	3	50	50	100	PE
18SE44	Hybrid Electric Vehicles	3	-	-	3	50	50	100	PE
18SE45	Distributed Generation and Micro grids	3	-	-	3	50	50	100	PE
18SE46	Smart Grid Technologies	3	-	-	3	50	50	100	PE
18SE47	Flexible AC Transmission system	3	-	-	3	50	50	100	PE

***** Indicated is the minimum number of credits to be earned by a student.

CAT – Category; FC– Foundation Course; PC – Professional Core; PE – Professional Elective ;EEC – Employability Enhancement Course.

I SEMESTER

18SE01 APPLIED NUMERICAL ANALYSIS

2 2 0 3

NUMERICAL SOLUTION OF SYSTEM OF EQUATIONS: Solving system of linear equations –Thomas algorithm, Gauss Jacobi and Gauss Seidel method, successive over relaxation method, system of non-linear equations - Newton Raphson method, eigenvalues - power method and inverse power method. Curve fitting - linear regression, multiple linear regression, cubic splines - Bezier curves and B-splines. (12)

NUMERICAL SOLUTION TO ODE: Boundary value problem **-** Shooting method, finite difference method, derivative boundary conditions. Finite Element Method - Rayleigh-Ritz method, Collocation and Galerkin method. (11)

NUMERICAL SOLUTION TO PDE: Finite difference method: Liebmann's method for Laplace and Poisson equation, alternating direct implicit method, irregular and non-rectangular grids, explicit method and Crank-Nicolson method for parabolic equations, explicit method for hyperbolic equations. (11)

MODELLING AND SIMULATION: Simulating deterministic behaviour, area under a curve, generating random numbers, simulating probabilistic behaviour, inventory model: gasoline and consumer demand. (11)

Total L:30+T:30=60

REFERENCES:

1. Curtis F Gerald and Patrick O Wheatley, Applied Numerical Analysis, Pearson Education, New Delhi, 2013.
2. Steven C Chapra and Raymond P Canale, Numerical Methods for Engineers with Software and Programming Applications, Tata McGraw-Hill, New Delhi, 2013.
3. John H Mathews and Kurtis D Fink, Numerical Methods using MATLAB, Prentice Hall, New Delhi, 2010
4. Douglas J Faires and Richard Burden, Numerical Methods, Cengage Learning, New Delhi, 2013.
5. Frank R Giordano, William P Fox and Steven B Horton, A first course in Mathematical Modeling, Cengage Learning , New Delhi, 2014.

18SE02 CONCEPTS OF ENERGY ENGINEERING

3 0 0 3

Course objectives	Course Outcomes		Related Program outcomes
• To impart knowledge on fluid mechanics, heat transfer and electrical systems and facilitate their application • To familiarize energy sources for sustainable energy conversion	CO1	**Apply** fluid mechanics concepts for sizing and selection of fluid machinery	A
	CO2	**Analyze** heat transfer problems and **apply** different techniques for heat transfer enhancement	A,B
	CO3	**Apply** the concepts of electrical systems to select suitable systems for industrial applications	E
	CO4	**Conceptualize** systems to convert energy from the renewable sources	A

FLUID MACHINERY SIZING AND SELECTION: Mass and momentum balance, continuity equation, Euler's and Bernoulli's equation, major and minor losses, Navier - Stokes equation, principles of operation and selection of fluid machinery, hydraulic turbines and pumps. (12)

SIZING OF HEAT TRANSFER EQUIPMENT: Conduction: One dimensional steady state heat conduction, composite walls, critical thickness; Convection: free convection, forced convection; Radiation: Physical mechanism, radiation properties, radiation shape factors; principles of operation and sizing of heat exchangers and cooling tower. (12)

SELECTION OF ELECTRICAL SYSTEMS: Working principle and selection: Transformer, Induction motor and generators; Speed control techniques; DC machines; Power Systems: generation, distribution and transmission, Power converters. (10)

RENEWABLE ENERGY SYSTEMS: Working principle and resource assessments: Solar, Wind, Biomass, Ocean - thermal, tide, wave; OTEC, geo-thermal, energy storage systems. (11)

Total L: 45

REFERENCES:

1. Wylie, E. Benjamin, and Victor Lyle Streeter, "Fluid Mechanics" ,McGraw-Hill International Book Co., 2017.
2. Bergman, Theodore L., and Frank P. Incropera, “Fundamentals of heat and mass transfer”, John Wiley and Sons, 2017.
3. Sukhatme S P, “A Text book on Heat Transfer”, Orient Longman, 2005.
4. El-Wakil, Mohamed Mohamed, “Power plant technology”. Tata McGraw-Hill Education, 2013.
5. Wilde, Theodore, "Electrical Machines, Drives and Power System", 2005.

18SE03 ENERGY CONSERVATION AND MANAGEMENT

2 2 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on energy managementand facilitate application of energy conservation techniques in process industries • To impart knowledge on thermal and electrical utilities for evaluating energy saving potential	**CO1**	**Develop** procedures for conducting energy audit in different utilities in accordance with national and international energy regulations	A
	CO2	**Evaluate** the performance of thermal utilities like furnace, boilers and steam distribution systems to improve efficiency	A, E
	CO3	**Evaluate** the performance of a electrical utilities like pumps, fans blowers to improve efficiency	A, B
	CO4	**Carryout** performance assessment and suggest methods to improve the overall efficiency for different energy intensive industries	A

ENERGY MANAGEMENT: Scope of energy audit, types of energy audit, detailed energy audit methodology, role of energy managers in industries; Energy Management System (EnMS): ISO standards, implementing energy efficiency measures, detailed project report, energy monitoring and targeting, identification of energy conservation measures / technologies, economic and cost benefit analysis, ESCOS. (7)

ENERGY EFFICIENCY IN THERMAL UTILITIES: Steam engineering in thermal and cogeneration plants- steam traps and various energy conservation measures; Boilers- losses and efficiency calculation methods, controls. Furnaces- heat balance in furnaces, furnace efficiency calculations, energy conservation opportunities in furnaces, Insulation and Refractories. (7)

ENERGY EFFICIENCY IN ELECTRICAL UTILITIES: Electrical system, motor, harmonics, diesel generator, centrifugal pumps, fans and blowers, air compressor, lighting system – energy consumption and energy saving potentials, design considerations. (7)

PERFORMANCE ASSESSMENT: Industrial case studies – assessment of energy generation/consumption in thermal station, steel industry, cement industry, textile industry, etc. (9)

Total L:30+T:30=60

REFERENCES:

1. Energy Audit Manual The Practitioner’s Guide, EMC-Kerala and NPC 2017.
2. Bureau of Energy Efficiency - Energy Management Series, 2006.
3. Eastop T.D and Croft D.R, “Energy Efficiency for Engineers and Technologists”, Logman Scientific and Technical, 1990.

4. Reay D.A, “Industrial Energy Conservation”, Pergamon Press, 1979.
5. Openshaw Taylor E, "Utilisation of Electric Energy", Orient Longman Ltd, 2003.
6. Donald R Wulfinghoff, “Energy Efficiency Manual”, Energy Institute Press, 1999.

15SE04 INSTRUMENTATION FOR ENERGY SYSTEMS

3 0 0 3

Course objectives		Course outcomes	Related program outcomes
• To familiarize the working principles of measuring instruments and facilitate performing error analysis • To facilitate selection of appropriate measuring techniques for evaluation of energy conversion systems	**CO1**	**Analyze** the error components in the measuring instruments for given conditions and perform electrical measurements	
	CO2	**Select** appropriate method of measurement of temperature and pressure for a given application and estimate the error	
	CO3	**Select** appropriate method of measurement of flow for a given application and estimate the error	
	CO4	**Select** appropriate method of measurement of air pollution for a given application	

INSTRUMENTATION SYSTEM AND ELECTRICAL ENERGY MEASUREMENT: Measurement terminologies, precision, range, accuracy, span, linearity, sensitivity, resolution, random errors, systematic errors, relative and absolute errors, uncertainty analysis of single and multiple measurements – calibration of instruments – range –resolution – span – linearity, sensitivity- signal conditioning system; Electrical Energy Measurement: Power factor, load factor, harmonic analyzer, lighting and lamination measurement, digital data processing and data acquisition system. (12)

TEMPERATURE AND PRESSURE MEASUREMENT: Working principle of various temperature devices, thermocouples, thermistor, RTD, measurement analysis, infrared camera; Working principle of pressure transducers and laser induced fluorescence (LIF), quantification, basics of algorithm used for quantification**- c**alibration of Pressure measuring equipment, principles and operation of various vacuum pumps and gauges. (12)

FLOW MEASUREMENT: Variable head flow meters- rota meters-working principle of hot wire/film anemometry and particle image velocimetry, quantification, electromagnetic flow meters, ultrasonic flow meters. (11)

AIR POLLUTION AND ENERGY MEASUREMENTS: Particulate sampling techniques, SO_2, Combustion Products, opacity, odour measurements - Measurement of liquid level, Humidity, O_2, CO_2 in flue gases- pH measurement, moisture analyzer. (10)

Total L: 45

REFERENCES:

1. Sawhney A K and Puneet Sawhney, “A Course in Mechanical Measurements and Instrumentation”Dhanpat Raiand Co 2017.
2. Doebelin EO, “Measurement Systems - Application and Design”, McGraw-Hill, 2017.
3. Rangan C S, Sharma G R and Mani V S V, “Instrumentation Devices and Systems”, Tata McGraw-Hill, 2016.
4. Holman JP, “Experimental methods for engineers”, McGraw-Hill, 2011.
5. Bechwith, Marangoni and Lienhard, “Mechanical Measurements” Addison-Wesley, 2009.

18SE51 ENERGY ENGINEERING LABORATORY

0 0 4 2

Course Objectives		Course Outcomes	Related Program outcomes
1. To impart knowledge on working and performance evaluation of various energy systems 2. To facilitate analysis of energy systems using various methods and tools	**CO1**	**Demonstrate an understanding of** the working principles, construction and various operating parameters of energy conversion equipments	A, G
	CO2	**Evaluate** the performance of various energy systems and **infer** on the effect of operational parameters on the performance	B, G

In this course, students will be provided with an orientation programme on the following equipment/software. After this orientation, each student is expected to formulate and complete an activity of interest which has to be derived from the orientation programme under the guidance of a faculty. The details like background, problem definition, state of technology/knowledge in that area by a good literature review (5 latest papers), objectives, methodology, equipment that can be used (from the orientation programme), results from the experiments and their interpretation will respect to the assumption/background and a formal conclusion are expected in the report which is to be submitted at the end of the semester. This work is evaluated for the credit assigned. Expected hours needed for this work is 45 hours.

TOPICS FOR THE ORIENTATION PROGRAMME

1. Performance evaluation of solar thermal system.
2. Performance evaluation study of biomass digester/gasifier.
3. Energy consumption and lumen measurement of lights and ballasts.
4. Power quality measurements of electrical power systems.
5. Performance evaluation of wind energy systems.
6. Aerodynamic performance study of bluff and streamlined bodies.

REFERENCES:

1. Energy engineering lab manual, Department of mechanical engineering, PSG College of Technology.
2. Solar concentrator training system, Experimental manual, Ecosense world, New Delhi.
3. Wind energy training system, Experimental manual, Ecosense World, New Delhi.

II SEMESTER

18SE07 ENERGY RESOURCES, ECONOMICS AND ENVIRONMENT

2 2 0 3

Course objectives		Course outcomes	Related program outcomes
• To familiarize on the trends in economics of energy use in various sectors and facilitate energy modeling to make policy decisions • To impart knowledge on environment impact of energy use for controlling the pollution and formulating the mitigation strategies	**CO1**	**Demonstrate an understanding of** economics of energy utilization in various sectors and perform cost structure and cost benefit analysis	
	CO2	**Perform** forecast analysis and provide data for decisions on energy policy	
	CO3	**Estimate** the energy cost of projects and develop feasibility reports	
	CO4	**Analyze** energy projects and evaluate their impact on environment and suggest control and mitigation methods	

ENERGY RESOURCES: Current trends in energy production and consumption, world energy flows, energy and economic growth, supply and availability; Electric utilities and regulations, cost structure analysis, economics of energy use in agriculture, transport, building, Industry and energy substitution, cost benefit analysis – carbon credit and footprint. (7)

ENERGY MODELING AND FORECASTING: Modeling concepts like simulation, equilibrium, optimization, concept of energy multipliers and implications of energy multipliers for analysis of regional, national energy policy, energy and environmental input – output analysis including I-O model, interfile substitution models, SIMA model, Markal model for energy policy analysis, methodology for energy demand analysis including regression, econometric energy demand modeling, end-use method of energy demand analysis, time series method, techno-economic approach to forecasting, case studies on forecasting energy needs. (7)

ENERGY ECONOMICS: Simple payback period, time value of money, IRR, NPV, life cycle costing, cost of saved energy, and cost of energy generated, examples from energy generation and conservation, energy chain, primary energy analysis, life cycle assessment, net energy analysis, case studies on life cycle costing. (7)

ENVIRONMENTAL IMPACTS OF ENERGY USE: Global warming - sources of emissions, CO_2 emissions, impacts, mitigation and sustainability. environmental standards, legislation and audits, air pollution - SOx, NOx, CO, particulates, solid and water pollution, formation of pollutants, measurement and controls; Effect of operating and design parameters on emission, control methods, exhaust emission test and procedures, case studies on analysis of energy projects for environmental impact assessment and mitigation. (9)

Total L:30+T:30=60

REFERENCES:

1. Energy and the Challenge of Sustainability, World energy assessment, UNDP New York, 2004.
2. AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997.
3. Nebojsa Nakicenovic, Arnulf Grubler and Alan McDonald “Global energy perspectives”, Cambridge University Press, 1999.
4. Fowler, J.M ., “Energy and the environment”, McGraw Hill,1984.
5. Robert Ristirer, and Jack P. Kraushaar., “Energy and the environment”,Willey,2005.

18SE08 COMPUTATIONAL FLUID DYNAMICS

3 0 0 3

Course objectives		Course outcomes	Related program outcomes
• To familiarize on computational approaches towards solving fluid flow problems • To impart knowledge on CFD techniques for solving fluid flow problems	**CO1**	**Apply** the principles to develop governing equations for fluid flow and **solve** them computationally	
	CO2	**Demonstrate an understanding of** the numerical methods and apply them to solve CFD problems	
	CO3	**Select** a suitable technique for solving fluid flow problems to achieve solution accuracy	
	CO4	**Select** appropriate turbulence model for a given fluid flow problem	

CFD AND THERMO-FLUIDS: Review on the physics of thermo-fluids, governing equations -continuity, momentum, and energy conservation - modeling, grid generation, simulation, and high performance computing. (10)

COMPUTATIONAL APPROACH: Finite difference method, forward, backward and central difference schemes, explicit and implicit methods, properties of numerical solution methods, stability analysis, and error estimation, difference between FDM and FVM, approximation of surface integrals, approximation of volume integrals, interpolation practices, implementation of boundary conditions, specification for a CFD simulation, requirements for accurate analysis and validation for multi scale problems. . (12)

CFD TECHNIQUES: Mathematical classification of flow, hyperbolic, parabolic, elliptic and mixed flow types, Lax - Wendroff technique, MacCormack's technique, relaxation technique, artificial viscosity, ADI technique, pressure correction technique, SIMPLE algorithm, upwind schemes, flux vector splitting. (12)

TURBULENCE MODELING AND CFD APPLICATIONS: Turbulence energy equation, one-equation model, two-equation models (k-ω and k- ε models), review on advanced turbulence models, applications to fluid flow and heat transfer problems. (11)

Total L: 45

REFERENCES:

1. Muralidhar K and Sundararajan T, "Computational Fluid Flow and Heat Transfer", Narosa Publications, 2009.
2. Chung T J, "Computational Fluid Dynamics", Cambridge University Press, 2010.
3. Joel H Ferziger and MilovanPeric, "Computational Methods for Fluid Dynamics", Springer Publications, 2002.
4. John D Anderson, "Computational Fluid Dynamics – The Basics with Applications", McGraw Hill, 1995.
5. Versteeg H K and Malalasekara W, "An Introduction to Computational Fluid Dynamics - The Finite Volume Method', Longman, 2007.

18SE52 COMPUTATIONAL FLUID DYNAMICS LABORATORY

0 0 4 2

Course Objectives	Course Outcomes		Related Program outcomes
1. To impart working knowledge on commercial CFD software 2. To impart knowledge on the solution methods for simple real time problems	**CO1**	**Demonstrate an understanding of** the fundamental physics, principles and selection methodology of physical elements in CFD	A, E, G
	CO2	**Perform** solid modeling; **analyze** heat transfer, mass transfer and fluid flow problems using CFD software and **interpret** the results	B, G

In this course, students will be provided with an orientation programme on the following equipment/software. After this orientation, each student is expected to formulate and complete an activity of interest which has to be derived from the orientation programme under the guidance of a faculty. The details like background, problem definition, state of technology/knowledge in that area by a good literature review (5 latest papers), objectives, methodology, equipment that can be used (from the orientation programme), results from the experiments and their interpretation will respect to the assumption/background and a formal conclusion are expected in the report which is to be submitted at the end of the semester. This work is evaluated for the credit assigned. Expected hours needed for this work is 45 hours.

TOPICS FOR THE ORIENTATION PROGRAMME

1. Flow simulation - Internal flow – Laminar region.
2. Flow simulation - External flow – Laminar region.
3. Flow simulation - Internal flow – Turbulence region.
4. Flow simulation - External flow – Turbulence region.
5. Flow simulation - Internal flow with heat transfer.
6. Flow simulation - External flow with heat transfer.

MINI PROJECT: Simulation of fluid flow/ heat transfer based systems.

REFERENCES:

1. CFD lab manual, Department of mechanical engineering, PSG College of Technology.

18SE61 INDUSTRY VISIT AND TECHNICAL SEMINAR

0 0 4 2

Course Objectives	Course Outcomes		Related Program outcomes
1. To provide exposure on the functioning of an energy industry and its practices 2. To provide a platform for improving communication and presentation skills	**CO1**	**Collect, analyze and interpret** energy related information to achieve conservation	A, B
	CO2	**Prepare** technical reports, one based on industrial visit and the other on current topics of relevance and **make presentations.**	G, I

VISIT TO INDUSTRY: Study of energy utilities, heat transfer equipment, energy consumption data and conservation techniques; Report preparation.

ENERGY AUDIT: Perform an energy audit at anyone industry.

TECHNICAL SEMINAR: Technical presentation and report preparation on current topics based on research publications related to Energy Engineering.

Total P: 60

REFERENCES:

1. Energy Audit Manual – The Practioners Guide, Energy Management Centre, Kerala, 2017.
2. Mitchell John H, "Writing for Professional and Technical Journals", John Wiley and Sons Inc., 2001.

III SEMESTER

18SE53 ENERGY SIMULATION LABORATORY

0 0 4 2

In this course, students will be provided with an orientation programme on the following equipment/software. After this orientation, each student is expected to formulate and complete an activity of interest which has to be derived from the orientation programme under the guidance of a faculty. The details like background, problem definition, state of technology/knowledge in that area by a good literature review (5 latest papers), objectives, methodology, equipment that can be used (from the orientation programme), results from the experiments and their interpretation will respect to the assumption/background and a formal conclusion are expected in the report which is to be submitted at the end of the semester. This work is evaluated for the credit assigned. Expected hours needed for this work is 45 hours.

TOPICS FOR THE ORIENTATION PROGRAMME

1. Time series forecasting of solar radiation using numerical tool.
2. Time series forecasting of wind speed using numerical tool.
3. Load resource analysis for the optimization of hybrid solar-wind systems using numerical tool.
4. Scheduled Heat Gain estimation using building energy management software.
5. Windows and day lighting estimation using building energy management software.
6. Air movement and green features simulation using HVAC simulator.

MINI PROJECT: Modeling and simulation of energy systems using application software.

REFERENCES:

1. Energy simulation lab manual, Department of mechanical engineering, PSG College of Technology.

18SE71 PROJECT WORK I

0 0 6 3

CO No.	Description of Course Outcome
CO1	Problem identification, literature survey, Solution generation, Experimentation/ data collection/code development and evaluation results
CO2	Documentation and presentation of the work done in the given structure and format

1. Identification of a real life problem in thrust areas.
2. Developing a mathematical model for solving the above problem.
3. Finalization of system requirements and specification.
4. Proposing different solutions for the problem based on literature survey.
5. Future trends in providing alternate solutions.
6. Consolidated report preparation of the above.

IV SEMESTER

18SE72 PROJECT WORK II

0 0 28 14

CO No.	Description of Course Outcome
CO1	Problem identification, literature survey, Solution generation, Experimentation/ data collection/code development and evaluation results
CO2	Documentation and presentation of the work done in the given structure and format

1. The project work involves the following:

a) Preparing a project - brief proposal including
b) Problem Identification
c) A statement of system / process specifications proposed to be developed (Block Diagram / Concept tree)
d) List of possible solutions including alternatives and constraints
e) Cost benefit analysis
f) Time Line of activities

2. A report highlighting the design finalization [based on functional requirements and standards (if any)]

a) A presentation including the following:
b) Implementation Phase (Hardware / Software / both)
c) Testing & Validation of the developed system
d) Learning in the Project

3. Consolidated report preparation

CORE ELECTIVE 1

18SE05 INDUSTRIAL COMBUSTION SYSTEMS

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on thermodynamic concepts and combustion theory and facilitate their application • To familiarize performance evaluation of furnaces and boilers	**CO1**	**Demonstrate an understanding of** thermodynamics concepts and perform energy balance on combustion systems	
	CO2	**Select and size** equipments such as fans, blowers and chimney based on combustion theory	
	CO3	**Analyze** and assess the performance of combustion system of industrial furnaces	
	CO4	**Analyze** and assess the performance of combustion system of industrial boilers	

COMBUSTION THEORY: Stoichiometry, lean and rich mixture, basic reaction chemistry, chemistry of combustion, energetics, types of flame, pre mixed, diffusion, laminar and turbulent flames, adiabatic flame temperature, burners and types. (12)

COMBUSTION IN FURNACE: Furnace types and classification, aerodynamic and heat transfer in furnaces, the single gas-zone model, the "long" furnace and other multi-zone models, effect of operating variables, reduction of furnace-wall losses, temperature control in industrial furnaces, oxygen enrichment in combustion processes. (11)

COMBUSTION IN INDUSTRIAL BOILERS: Sectional, shell and water-tube boilers, design features of shell boilers, boiler water treatment and conditioning, gas-side corrosion and fouling problems, oil and gas-firing of boilers, coal firing, wastes as boiler fuel, boiler efficiency and part-load operation, condensing boilers.
(11)

FORMATION OF FLUE GAS AND ANALYSIS: Formation of unburnt combustibles, NOx, SOx, particulates; Thermal oxidizer, scrubber, thermo-gravity analyzer, Fourier-transform infrared spectroscopy (FTIR), cyclone separator, precipitator (11)

Total L: 45

REFERENCES:

1. Kenneth Kuan-yunKuo, “Principles of Combustion”, Wiley - Interscience, 2005.
2. Colin R Ferguson and Allan T Kirk Patrick, “Internal Combustion Engines”, John Wiley and Sons. Inc. 2015.
3. Stephen R Turns, “Introduction to Combustion: Concepts and Applications”, McGraw Hill, 2011.
4. Gary L Borman and Kenneth W Ragland, “Combustion Engineering”, McGraw Hill, 2011.
5. Winterbone D and Elesaier, “Advanced Thermodynamics for Engineers”, 2015.

18SE06/18ED03 MODELLING AND CONTROL OF POWER CONVERTERS

3 0 0 3

INTRODUCTION TO STATE SPACE MODELLING: Review of basic control theory, control design techniques such as P, PI, PID and lead lag compensator design, state space control design approach, modeling of physical systems, solution to vector differential equations and state transition matrix, Controllability and Observability. (8)

SMALL SIGNAL MODEL OF POWER CONVERTERS: Linearizing averaged power stage dynamics, frequency response of converter power stage, small-signal gain of PWM block, small-signal model for PWM, DC to DC converters. (9)

TRANSFER FUNCTIONS AND STATE SPACE MODEL OF POWER CONVERTER: Bode plot for transfer functions, power stage transfer functions and state space modeling of buck converter, boost converter, and buck/boost converter, empirical methods for small-signal analysis. (9)

DYNAMIC PERFORMANCE AND CLOSED LOOP PERFORMANCE OF POWER CONVERTERS: Frequency domain performance criteria, time-domain performance criteria; Stability of power converters - nyquist criterion; Relative stability: gain margin and phase margin. (6)

Asymptotic analysis method, frequency domain performance, voltage feedback compensation and loop gain, compensation design and closed-loop performance. (5)

Introduction to nonlinear systems: Phase plane analysis of nonlinear system using linear approximation - Limit cycle and periodic solutions - Singular points and qualitative behavior; Stability of nonlinear systems - Lyapunov direct and indirect methods. (8)

Total L: 45

REFERENCES:

1. Pulsewidth Modulated DC-to-DC Power Conversion Circuits, Dynamics, and Control Designs, Byungcho Choi, IEEE Press, Published by John Wiley & Sons, Inc, 2013.
2. Sira -Ramirez, R.Silva Ortigoza, ‘Control Design Techniques in Power Electronics Devices’, Springer, 2006.
3. Ogata, K., ‘Modern Control Engineering’, Prentice Hall of India, 2010.
4. Chen C.T., ‘Linear Systems Theory and Design’’ Oxford University Press, 1999.
5. Hassan K. Khalil, ‘Nonlinear Systems’, Pearson Educational International Inc. Upper Saddle River, 2001.
6. Applied Nonlinear Control, Jean-Jacques E. Slotine, Weiping Li, Prentice Hall, 1991 -Technology & Engineering.

CORE ELECTIVE 2

18SE09 THERMAL SYSTEMS DESIGN

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To familiarize on design methodologies of thermal systems and facilitate analysis and optimization for performance enhancement • To impart knowledge on waste heat recovery technologies and facilitate performing cost benefit analysis	**CO1**	**Evaluate** the performance of thermal systems and their design considerations	A
	CO2	**Model and analyze** various thermal systems for the effective use of energy	B
	CO3	**Apply** different techniques to enhance heat transfer in the thermal systems	A
	CO4	**Suggest** heat recovery technologies based on their performance and financial considerations	E

THERMAL SYSTEMS: Energy systems, heat exchangers – classification, review of different design methodologies, pressure drop analysis, thin fin analysis, fouling, corrosion, and erosion, design and operational issues, exergy analysis, surface comparisons, size and weight relationships. (12)

MODELLING OF THERMAL SYSTEMS: Design of energy systems- mathematical analysis - thermodynamic modeling and analysis of energy conversion equipments - heat exchangers, motors, fans, pumps, compressors, turbines, piping, ducts, etc. and efficiency analysis. (12)

HEAT TRANSFER ENHANCEMENT TECHNIQUES: Flow misdistribution and header design, reduction of non-uniform heat transfer in heat exchangers, reduction of fouling, role of pitch analysis in a thermal system. (11)

WASTE HEAT RECOVERY SYSTEMS: Sources of waste heat, selection of waste heat recovery technologies and financial considerations, design aspects of waste heat recovery systems. (10)

Total L: 45

REFERENCES:

1. Stoecker W G, “Design of Thermal Systems”, McGraw Hill, 2011.
2. Robert F Boehm, “Developments in the Design of Thermal Systems”, Cambridge University Press, 2016.
3. Ramesh K Shah and Dusan P Sekulic, “Fundamentals of Heat Exchanger Design”, Wiley Publications, 2007.
4. SadikKakac and Hongtanliu, “Heat Transfer Enhancement of Heat Exchangers”, Kluwer academic publishers, 1998.
5. Ralph L WebbandNae – Hywn Kim, “Principles of Enhanced Heat Transfer”, Taylor and Francis, 2005.

18SE10/18ED06 MODELING AND ANALYSIS OF ELECTRICAL MACHINES

3 0 0 3

GENERALIZED THEORY & LINEAR TRANSFORMATION: Conversions, basic two pole machine, transformer with movable secondary, transformer voltage and speed voltage, kron’s primitive machine, invariance of power, transformation from displaced brush axis three phases to two phases, rotating axes to stationary axes, transformed impedance matrix, torque calculations. (11)

INDUCTION MACHINES: Generalized representation, performance equations, steady state analysis, transient analysis, single phase induction motor, transfer function formulation, double cage machine, harmonics. (11)

SYNCHRONOUS MACHINES: Generalized representation, steady state analysis, transient analysis, electromechanical transient. (11)

DC & SPECIAL MACHINES: Generalized representation, operation with displaced brushes, motor (shunt type only) operation, steady state and transient analysis, generalized representation and steady state analysis of reluctance motor, brushless DC motor, variable reluctance motor. (12)

Total L : 45

REFERENCES:

1. Bimbhra P.S., "Generalised Circuit Theory of Electrical Machines", Khanna Publishers, Delhi, 2002.
2. Adkins B., "The Generalized Theory of Electrical Machines", Dover Publishers, 1980.
3. Chee- Mun Ong "Dynamic simulation of electrical machinery using MATLAB" Prentice – Hall, Inc, 1998.
4. Krishnan R., "Electric Motor & Drives: Modeling, Analysis and Control", Prentice Hall of India, 2001.
5. Krause, P.C., O. Wasynczuk, and S.D. Sudhoff, "Analysis of Electric Machinery", IEEE Press, 2002.

CORE ELECTIVE 3

18SE11 DESIGN OF RENEWABLE ENERGY SYSTEMS

3 2 0 4

Course objectives	Course outcomes		Related program outcomes
• To familiarize on the availability of renewable energy resources for sustainable conversion of energy • To impart knowledge on energy conversion systems in solar, wind and biomass and facilitate developing systems for different applications	**CO1**	**Apply** physical principles of solar insolation to develop solar thermal systems	C
	CO2	**Estimate** the wind potential and perform forecast analysis	A
	CO3	**Apply** design concepts to develop wind energy systems with a minimal impact on environment	C
	CO4	**Demonstrate an understanding of** producing useful energy from bio-mass	E

SOLAR THERMAL CONVERSION: Properties of solar radiation, absorption of light by the atmosphere, spectral distribution of sunlight, thermo-dynamical description of solar collectors, optical properties of solar collectors, technologies for fabrication of solar collectors, design of solar thermal systems for different applications. (12)

WIND AND WIND RESOURCE: The nature of the wind, geographical variation in the wind resource, long-term wind-speed variations, annual and seasonal variations, Synoptic and Diurnal variations; Turbulence - the boundary layer; Wind-speed prediction and forecasting. (11)

WIND POWER CONVERSION: Aerodynamic concepts, Betz's law of maximum power, rotor blade theory, design of blade Geometry and rotor diameter, performance curves, wind turbine siting and issues.. (11)

BIOMASS AND BIOGAS: Concepts and systems, sources, energy plantations; Design: pyrolysis, gasification and liquefaction systems; biogas, fermentation and wet processes, chemicals from biomass and biotechnology, biofuels. (11)

Total L:45+T:30=75

REFERENCES:

1. Frank Kreith and Yogi Goswami D, "Handbook of Energy Efficiency and Renewable Energy", CRC Press, 2017.
2. Kothari P, Singal K C and RakeshRanjan, "Renewable Energy Sources and Emerging Technologies", PHI Pvt. Ltd., 2011.
3. Sukhatme S P and Nayak J K, "Solar Energy - Principles of Thermal Collection and Storage", Tata McGraw Hill, 2017.
4. Rai G D, "Non Conventional Sources of Energy", Khanna Publishers, 2009.
5. Bent Sorensen, "Renewable Energy", Academic Press, 2011.
6. Abbasi S A and NaseemaAbbasi, "Renewable Energy Sources and their Environmental Impact", PHI Private Limited, 2010.
7. Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, "Wind Energy Handbook", John Wiley and Sons, 2011.

18SE12/18ED09 POWER ELECTRONICS IN WIND AND SOLAR POWER CONVERSION

3 2 0 4

SOLAR PV AND WIND POWER: Trends in energy consumption, world energy scenario, energy sources and their availability, conventional and renewable sources, solar PV and wind potential in india and world, solar and wind data, policies and regulations, standards and codes used for renewable energy systems. (11)

SOLAR PHOTOVOLTAIC ENERGY CONVERSION: Solar radiation and measurement, solar cells and their characteristics, classification of solar PV panels, influence of insolation and temperature, PV arrays, maximum power point tracking algorithms, power conditioning schemes, charge controllers, inverters – classifications and design, analysis of PV systems, BOS components, stand alone and grid integrated solar PV systems, building integrated PV (BIPV), synchronized operation with grid supply, harmonic standards, harmonic problems. (12)

WIND ENERGY CONVERSION SYSTEMS: Basic principle of wind energy conversion, nature of wind, power in the wind, components of wind energy conversion system (WECS), wind farm and its accessories, generators used in wind energy conversion systems, performance of induction generators for WECS, power conditioning schemes, controllable DC power from seigs, system performance, grid connected WECS, concepts of grid integration, grid related problems, generator control , performance improvements, different schemes, ac voltage controllers, harmonics and PF improvement. (11)

HYBRID POWER SYSTEMS: wind / solar PV integrated systems – other alternate systems – requirements - optimization of system components power conditioning schemes for hybrid power systems (HPS) – design of HPS using software - storage types and selection methods - applications of HPS. (11)

Total L:45+T:30=75

REFERENCES:

1. Mukund R Patel, “Wind and Solar Power Systems”, CRC Press, 2004.
2. Rai, G.D., "Non-conventional Energy Sources", Khanna Publishers, 2002.
3. Daniel, Hunt, V., "Wind Power - A Handbook of WECS", Van Nostrend Co., 1998.
4. S Sumathi, Ashok Kumar L, S Sureka, “Solar PV and Wind Energy Conversion Systems - An Introduction to Theory, Modeling with MATLAB/SIMULINK, and the Role of Soft Computing Techniques”, Green Energy and Technology, Springer; 2015.
5. Thomas Markvart and Luis Castaser, “Practical Handbook of Photovoltaics”, Elsevier Publications, 2003.
6. Roger A. Messenger, Jerry Ventre,” Photovoltaic System Engineering” CRC Press, 2004.

PROFESSIONAL ELECTIVE THEORY COURSES

15SE21 CLEANER PRODUCTION AND CLEAN DEVELOPMENT MECHANISM

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on concepts of cleaner production and facilitate developing strategies for emission control • To impart knowledge on carbon credit and facilitate estimating energy savings and GHG emissions reductions	**CO1**	**Perform** life cycle analysis and **suggest** strategies for cleaner production	
	CO2	**Assess** the industrial process to reduce environmental impacts with efficient operation	
	CO3	**Assess and analyze** cleaner development opportunities in small and medium scale industries	
	CO4	**Perform** CDM analysis of large scale projects to estimate energy savings and GHG emission reductions	

CLEANER PRODUCTION (CP): Industrial and commercial sector development and related energy and environmental issues, energy economy interactions in stabilizing greenhouse gases emission, long term strategies for reducing GHG emission, CP in industrial and commercial sectors, sustainability, life cycle analysis, pollution prevention and control, overview, approaches and technologies, industrial waste evaluation, sankey diagram for CP processes and case studies. (11)

PROCESS INTEGRATION: Process optimization by integrating energy and environmental aspects, energy management concepts and measures to improve energy efficiency. Energy and water pinch as waste minimization tool, occupational health and safety, quality of product, and other aspects of CP. (11)

CLEAN DEVELOPMENT MECHANISM (CDM): Carbon credit, CER, Baselines in CDM, its context, key elements and concepts, additionality assessment, investment analysis, barrier analysis, common practice analysis, impact of CDM registration, baseline for small scale CDM projects, small scale CDM project criteria and types, project categories and approved methodologies. (11)

CDM PROJECTS AND EVALUATION: Establishing baselines for large scale CDM projects, procedures for the submission and approval of new methodologies. Baselines for a forestation and reforestation projects, sequestration projects, determining eligibility and establishing the baseline tools and models for estimating baseline emissions, estimation of energy savings and GHG emissions reductions, carbon credit, case study - Green energy concept. (12)

Total L: 45

REFERENCES:

1. Anne Offit, Pollution Prevention and Sustainability, Syrawood Pub House, 2018.
2. Biagio F. G, Cecilia M. V. B. A, Feni A, "Advances in Cleaner Production", Nova Science Publishers Inc, 2016.
3. Klemes J, Handbook of Process Integration, Woodhead Publishing, 2013.
4. Ian C. K, Pinch Analysis and Process Integration, Butterworth-Heinemann, 2006.
5. Ram M. S, Sudhir Sharma, Govinda R. T, Kumar S, Baseline Methodologies For Clean Development Mechanism Projects, UNEP Risø Centre, 2005.

18SE22 GREEN BUILDINGS

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To familiarize the concepts of green buildings and energy utilization • To familiarize the codes and standards of green buildings and mitigate energy usage from renewable	CO1	**Demonstrate knowledge on** green building concepts to reduce carbon emission	
	CO2	**Evaluate** methods of building assessment for green buildings	
	CO3	**Select** appropriate materials for the development of green buildings	
	CO4	**Demonstrate knowledge on** green building codes and standards to perform life cycle analysis	

GREEN BUILDING CONCEPTS: High-performance green buildings - Impacts of building construction, operation, and disposal - Methods and tools for building assessment, LEED, Green Globes, Living Building Challenge, Green Building Coalition. (10)

BUILDING ASSESSMENT AND THE GREEN BUILDING PROCESS: Design and construction relationships -project management- BREEAM, CASBEE, green star, DGNB - site and landscape strategies, building energy system strategies, low energy buildings, renewable energy systems, building hydrologic cycle strategies, case studies on energy assessment. (11)

GREEN MATERIALS AND STRATEGIES: Materials selection strategies - multi-attribute standards (MAS) - life cycle assessment - indoor environmental quality (IEQ) analysis and strategies - construction team responsibilities and controls - building commissioning strategies - site operations. (12)

COST ANALYSIS AND STANDARDS: Carbon Accounting - economic issues and analysis - life cycle costing - business case for green buildings - green building codes and standards - International Green Construction Code ASHRAE 189P, ANSI/GG 01 - green building specifications - future directions in green high performance building technologies. (12)

Total L: 45

REFERENCES:

1. Abe Kruger, Carl Seville, “Green Building: Principles and Practices in Residential Construction”, Wiley, 2012.
2. Francis D. K. Ching, Ian M. Shapiro, “Green Building Illustrated” Wiley-2014.
3. Charles J. Kibert,” Sustainable Construction: Green Building Design and Delivery” John Wiley and Sons 2016.
4. The World Business Council on Sustainable Development (WBCSD) website: http://www.wbcsd.org.

18SE23 DESIGN OF SOLAR SYSTEMS

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on solar radiation and methods of solar radiation measurement to design solar PV and thermal systems • To impart knowledge on solar thermal analysis to develop energy storage and solar thermal utilities	**CO1**	**Estimate** the energy available to select and size solar thermal systems for real time applications	A
	CO2	**Select and evaluate** the performance of photovoltaic systems for different needs	A, E
	CO3	**Analyze** solar thermal systems and **assess** the performance of thermal energy storage systems	B
	CO4	**Demonstrate knowledge** on the utilization of solar energy for various applications	B, E

DESIGN OF SOLAR COLLECTORS: Solar constant, penetration depth, characteristics of radiation, classification - air, liquid heating collectors, testing of flat plate collectors, analysis of concentric tube collector, concentrator collectors – classification, concentrator mounting, focusing solar concentrators, heliostats, parabolic and dish. (12)

SELECTION OF PHOTO-VOLTAIC SYSTEMS: Physics, material, characteristics, cell arrays, power electric circuits for output of solar panels, choppers, inverters, batteries, charge regulators, thermoelectric, stand alone, off/on grid, hybrid systems and construction concepts, performance analyzer and applications. (11)

ANALYSIS OF SOLAR THERMAL SYSTEMS: Steady state and dynamic analysis, solar pond, modeling of solar thermal systems and simulations in process design of active systems by f-chart and utilization methods. Water heating systems: active and passive, passive heating and cooling of buildings, solar distillation, solar drying. (10)

SOLAR ENERGY UTILIZATION: Solar powered vapor absorption air condition system, solar cooler, solar power station, water pump, chimney, dryer, dehumidifier, still, desalination, furnaces, cooker, swimming pool, and solar energy economic analysis, performance analysis and system design. (12)

Total L: 45

REFERENCES:

1. Sukhatme S. P., “Solar Energy - Principles of thermal collection and storage” Tata McGraw-Hil, 2017.
2. Duffie J. A. and Beckman W. A., “Solar Engineering of Thermal Processes”, John Wiley, 2013.
3. Goswami D. Y., Kreith F. and Kreider J. F., “Principles of Solar Engineering”, Taylor and Francis, 2000.
4. Sodha M. S., Bansal N. K., Bansal P. K., and Malik M. A. S., “Solar Passive Building: science and design”, Pergamon Press,1986.
5. Malik M. A. S., Tiwari G. N., Kumar A. and Sodha M.S., “Solar Distillation”, Pergamon Press, 1982.

18SE24 WASTE MANAGEMENT AND ENERGY RECOVERY

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on methods of waste management and facilitate selection of waste handling processes • To familiarize on energy recovery and facilitate performing economic analysis of waste disposal and recovery methods	**CO1**	**Characterize** different types of waste and **select** suitable operations and conversion technologies	
	CO2	**Select** appropriate methods for waste management and **apply** transformation techniques for densification	
	CO3	**Compare and select** suitable energy recovery technology for a given application	
	CO4	**Evaluate** the cost and credit benefits of waste management and recovery methods	

WASTE CHARACTERISTICS AND OPERATIONS FOR WASTE HANDLING: Sources, types, composition, generation, estimation techniques, characterization, types of collection system, transfer stations, transfer operations. Separation and Processing: Size reduction - separation through density variation, magnetic/electric field; Densification - physical, chemical and biological properties and transformation technologies. (11)

WASTE DISPOSAL TECHNIQUES, TRANSFORMATION TECHNOLOGIES AND VALUE ADDITION OF WASTES: Landfill , landfill gas - generation, extraction, gas usage techniques, leachates formation, UNFCCC model for land fill gas prognosis and reclamation; Physical Transformation: Component separation and volume reduction; Chemical Transformation: combustion, gasification, pyrolysis; Energy Recovery: biological transformation, aerobic composting, anaerobic digestion. (12)

HAZARDOUS WASTE MANAGEMENT AND WASTE RECYCLING: Definition, sources and classification; incineration vs combustion technology; RDF / mass firing, material recycling, disposal of white goods and E-wastes, carbon credit calculations and economic analysis of waste disposal and transformation techniques. (11)

MANAGEMENT OF LIQUID AND GASEOUS WASTES: Liquid Waste: Sewage treatment - Dilution, mechanical treatments, biological treatments and chemical treatments, removal of ammonia; Gaseous waste management and control measures. (11)

TOTAL: 45

REFERENCES:

1. Tchobanoglous, Theisen and Vigil, “Integrated Solid Waste Management”, McGrawHill,1993.
2. Howard S. Peavy et al, “Environmental Engineering”, McGraw Hill International Edition, 2013.
3. Stanley E. Manahan. “Hazardous Waste Chemistry, Toxicology and Treatment”, Lewis Publishers, 1990.
4. Parker, Colin and Roberts, “Energy from Waste – An Evaluation of Conversion Technologies”, Elsevier Applied Science, 1985.
5. Manoj Datta, “Waste Disposal in Engineered Landfills”, Narosa Publishing House,1997.

18SE25 HYDROGEN ENERGY AND FUEL CELLS

3 0 0 3

Course objectives		Course outcomes	Related program outcomes
• To impart knowledge on use of hydrogen for achieving sustainable growth and facilitate analysis of the challenges in transition to hydrogen economy • To impart knowledge on fuel cells and facilitate evaluation for performance enhancement	**CO1**	**Demonstrate knowledge** on strategies and technologies to achieve sustainable development	
	CO2	**Demonstrate an understanding of** hydrogen production technologies, storage methods and strategies for transition to hydrogen economy	
	CO3	**Demonstrate knowledge** on the construction and working of fuel cells and **compare** their characteristics and process parameters	
	CO4	**Estimate and analyze** the performance characteristics of fuel cells	

SUSTAINABLE DEVELOPMENT: Definition of sustainable development, factors affecting sustainable development like air pollution, water source degradation, population explosion, agriculture and land degradation, global warming and climate change, strategies for sustainability, energy and climate change. (11)

HYDROGEN ENERGY: Introduction to hydrogen economy, production, storage and transportation systems, hydrogen from fossil fuels, electrolysis of water, thermo chemical cycles, transmission and infrastructure requirements, safety and environmental impacts, economics of transition to hydrogen systems. (11)

FUEL CELLS: Concept, key components, physical and chemical phenomena in fuel cells, advantages and disadvantages, different types of fuel cells and applications, characteristics, Nernst equation, relation of the fuel consumption versus current output. (11)

FUEL CELL DESIGN AND PERFORMANCE: Stoichiometric coefficients and utilization percentages of fuels and oxygen, mass flow rate calculation for fuel and oxygen in single cell and fuel cell stack, total voltage and current for fuel cells in parallel and serial connection, over-potential and polarizations, DMFC operation scheme, general issues-water flooding and water management, polarization in PEMFC. (12)

Total L: 45

REFERENCES:

1. John Wiley and sons., “Fuel cell fundamentals”, Willey 2016.
2. Viswanathan B and Aulice Scibioh, “Fuel cells: Principles and Applications”, University Press, 2008.
3. Peter Hoffman, “Tomorrow’s Energy – Hydrogen Fuel Cells and the Prospects for Cleaner Planet”, MIT, 2012.
4. Prashukumar G P, “Hydrogen – A fuel for Automatic Engines”, ISTE, 1999.
5. Hart A B and Womack G J, “Fuel Cells: Theory and Applications”, Chapman and Hall, 1967.

18SE26 BIO-ENERGY CONVERSION TECHNOLOGIES

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on bio energy and facilitate feasibility evaluation • To familiarize methods of conversion and facilitate performance evaluation of various bio energy systems	**CO1**	**Identify** the need and the various sources of bioenergy, perform feasibility study for a bioenergy conversion plant under given conditions.	
	CO2	**Select and analyze** a suitable process for a pyrolyser plant based on local biomass availability.	
	CO3	**Select and analyze** a suitable process for a gasifier plant based on local biomass availability.	
	CO4	**Select and analyze** a combustor for an energy conversion plant based on local biomass availability.	

ANALYSIS OF BIOMASS: Biomass resources and biomass properties, biomass classification, availability, estimation of availability, consumption and surplus biomass ; energy plantations, proximate analysis, ultimate analysis, thermo gravimetric analysis and summative analysis of biomass and briquetting. (12)

PYROLYSIS: A pyrolysis plant, pyrolysis products, pyrolyser types, pyrolysis product yields and its influencing factors, pyrolysis kinetics, kinetic models. (10)

GASIFICATION: Biomass gasification plant, gasifiers, fixed bed system, downdraft and updraft gasifiers, fluidized bed gasifiers design, construction and operation, gasifier burner arrangement for thermal heating, gasifier engine arrangement and electrical power, equilibrium and kinetic consideration in gasifier operation, gasifier product yields and its influencing factors. (12)

COMBUSTION: Biomass combustion, fixed bed combustors, inclined grate combustors fluidized bed combustors, design, construction and operation and operation of all the above biomass combustors, biomass stoves, improved challahs, types. (11)

Total L: 45

REFERENCES:

1. Prabir Basu, "Biomass Gasification and pyrolysis, a practical guide", Academic press, 2018.
2. Desai and Ashok V, "Non Conventional Energy", Wiley Eastern Ltd., 2008.
3. Khandelwal K C and Mahdi S S, "Biogas Technology - A Practical Hand Book - Vol. I and II", Tata McGraw Hill Publishing Co. Ltd.,1989.
4. Challal D S, "Food, Feed and Fuel from Biomass", IBH Publishing Co. Pvt. Ltd., 1992.
5. WereKo-Brobby C Y and Hagan E B, "Biomass Conversion and Technology", John Wiley and Sons, 1996.

18SE27 ENERGY STORAGE SYSTEMS

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To provide an insight into the various modes of energy storage • To impart knowledge on construction, working principle and performance analysis of electrochemical, electric and thermal storage systems	**CO1**	**Identify** various means of energy storage and demonstrate knowledge on energy storage modes	
	CO2	**Demonstrate knowledge** on the storage behavior in electro chemical systems and identify the parameters affecting their performance	
	CO3	**Demonstrate an understanding** of electrical energy storage systems and evaluate their performance parameters	
	CO4	**Compare and select** sensible and latent heat storage systems for a given application	

ENERGY STORAGE MODES: Potential energy, Pumped hydro storage; KE and Compressed gas system: Flywheel storage, compressed air energy storage; Electrical and magnetic energy storage: Capacitors, electromagnets; Chemical Energy storage: Thermo-chemical, photo-chemical, bio-chemical, Superconducting Magnet Energy Storage (SMES) systems. (12)

ELECTROCHEMICAL ENERGY STORAGE SYSTEMS: Batteries- primary, secondary, Lithium;Solid-state and molten solvent batteries; Lead acid batteries; Nickel Cadmium batteries; Advanced batteries, Role of carbon nano-tubes in electrodes. (11)

ELECTRIC ENERGY STORAGE SYSTEMS: Capacitor and Batteries: Comparison and application; Super capacitor: Electrochemical Double Layer Capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nano-tube. (10)

SENSIBLE AND LATENT HEAT STORAGE: SHS mediums; Stratified storage systems; Rock-bed storage systems; Thermal storage in buildings; Earth storage; Energy storage in aquifers, Phase Change Materials (PCMs); Selection criteria of PCMs; solar thermal LHTE systems. (12)

Total L: 45

REFERENCES:

1. Ibrahim Dincer and Mark A Rosen, “Thermal Energy Storage Systems and Applications”, John Wiley and Sons 2011.
2. James Larminie and Andrew Dicks, “Fuel cell systems Explained”, Wiley Publications, 2003.
3. Ru-shiliu, Leizhang, Xueliang sun, “Electrochemical technologies for energy storage and conversion”, Wiley Publications, 2012.
4. Yves Brunet., “Energy storage”, Wiley publications,2013.
5. Luisa F.Cabeza.,Advances in thermal energy storage systems, Woodhead publications 2014.

18SE31 FUNDAMENTALS OF TURBULENCE AND BOUNDARY LAYER THEORY

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on the concept of boundary layers and the mechanisms in various flow regimes	**CO1**	**Demonstrate** an understanding of boundary layer and apply the concepts for solving flow problems	
	CO2	**Demonstrate** an understanding of the phenomenon of turbulence and its impact on fluid flow and heat transfer characteristics in systems	
• To impart knowledge on turbulence modeling and facilitate understanding of turbulent flows for different conditions	**CO3**	**Select and apply** appropriate turbulence models for a given application	
	CO4	**Analyze and estimate** the characteristics of turbulent flow and its effect on flow parameters	

BOUNDARY LAYER THEORY: Boundary layer concept, displacement thickness, momentum thickness, laminar boundary layer on a flat plate, turbulent boundary layer on a flat plate, boundary layer thickness using Blasius solution and Von Karman approach, effect of pressure gradient and separation, Flow past bluff bodies and airfoil, concept of lift and drag. (11)

TURBULENT BOUNDARY LAYERS: Fully developed turbulent flow in a pipe, turbulent shear stress, turbulent velocity profile, internal flows – couette flow – two-layer structure of the velocity field – universal laws of the wall– friction law – channel flow, couettee – poiseuille flows. (11)

TURBULENCE AND TURBULENCE MODELS: Nature of turbulence – averaging procedures – characteristics of turbulent flows – scales of turbulence, integral length scale, energy spectra, Kolmogorov's theory, Kolmogorov's scales, eddy viscosity and Prandtl's mixing length, Reynolds Average Navier Stokes equation (RANS), Two-equation models, low – reynolds number models, large eddy simulation. (11)

STATISTICAL THEORY OF TURBULENCE AND TURBULENT FLOWS: Ensemble average – isotropic turbulence and homogeneous turbulence – kinematics of isotropic turbulence – Taylor's hypothesis – dynamics of isotropic turbulence –grid turbulence and decay – turbulence in stirred tanks.

Turbulent flows: Wall Turbulent shear flows – structure of wall flow – turbulence characteristics of boundary layer – free turbulence shear flows – jets and wakes – plane and axi-symmetric flows. kinetic energy budget in a turbulent flow, turbulence production and cascade. (12)

Total L: 45

REFERENCES:

1. Biswas G. and Eswaran E., "Turbulent Flows, Fundamentals, Experiments and Modelling", Narosa Publishing House, 2002.
2. Schlichting H and Klaus Gersten, "Boundary Layer Theory", Springer 2017.
3. Garde R.J. and Turbulent Flow, "New Age International (p) Limited", Publishers, 2013.
4. Rajaratnam N. and Turbulent Jets, "Elsevier Scientific Publishing Company", 1976.
5. Hinze J.O., "Turbulence", McGraw-Hill Book Company, 1975.
6. Launder B. E. and Spalding D. B., "Mathematical Models of Turbulence", Academic Press, 1972.

18SE32 ENERGY CONSERVATION IN HVACR SYSTEMS

3 0 0 3

Course objectives		Course outcomes	Related program outcomes
• Impart knowledge on the refrigeration and air-conditioning process and estimate the loads on the system to select appropriate components • Impart knowledge on international standards and methods of energy management, conservation to minimize energy utilization for sustainable development	**CO1**	**Demonstrate knowledge** on refrigerants and refrigeration process to develop suitable systems based on the requirement	
	CO2	**Assess** heat load and **select** suitable equipments for refrigeration and air-conditioning system	
	CO3	**Demonstrate knowledge** on IS codes and standards to assess quality of the systems	
	CO4	**Identify, assess and apply** energy conservative techniques in HVAC systems	

REFRIGERATION EQUIPMENT: Refrigerants-refrigeration cycles-refrigeration equipments-reciprocating, rotary, scroll, screw, centrifugal systems –refrigeration system components expansion coils and valves, evaporators, condensers and other auxiliary elements- sizing and selection of components. (12)

AIR CONDITIONING AND AIR SYSTEMS: Psychrometrics -thermal comfort-air conditioning process, classification, systems and sub systems, components selection- air systems, fans, coils, filters and humidifiers, air handling units(AHU),air ducts and space diffusion systems. (13)

HEATING AND VENTILATING SYSTEMS: Heat pumps and heat recovery systems, air-source heat pump, ground water heat pump systems, ground water coupled surface water heat pump, gas cooling and cogeneration, basics and constant-volume systems-variable-air-volume systems, VAV systems- fan combination, system pressure and smoke control- minimum ventilation and VAV systems controls- indoor air quality. (10)

I S STANDARDS, ENERGY MANAGEMENT AND CONTROL: IS code and standards: Air-condition equipments, pipes and fittings, pumps and valves, refrigeration and lubricants, insulation, ventilation, International codes and practices, automatic control systems-control loop and control methods-control modes-sensors and transducers- controllers and actuators-system architecture-interoperability-artificial network-functional controls and fault detection and diagnostics, BMS. (10)

Total L: 45

REFERENCES:

1. Shan.K.Wang, “Handbook of air conditioning and refrigeration” McGraw-Hill,2000.
2. ISHRAE “HVAC Data book” ISHRAE 2017.
3. Arora C.P., “Refrigeration and Air Conditioning”, Tata McGraw Hill Pub. Company, 2010.
4. Plant Engineers and Manager’s Guide to Energy Conservation, Fair Mount Press, 2011.
5. Edward Hartmann, “Maintenance Management, Productivity and Quality Publishing Pvt. Ltd”., 1995.
6. Carrier Air conditioning Co., “Hand Book of Air conditioning System Design”, McGraw-Hill, 2001.

15SE33 AERODYNAMICS OF STREAMLINED AND BLUFF BODIES

3 0 0 3

Course objectives	Course Outcomes		Related Program outcomes
• To impart knowledge on flows over airfoils, bluff bodies and facilitate analyzing aerodynamic characteristics • To impart knowledge on performance enhancement of aerodynamic bodies for various applications	CO1	**Demonstrate** knowledge on fluid dynamics and estimate the lift and drag	
	CO2	**Formulate** governing equations for incompressible flow simulation over airfoils	
	CO3	**Evaluate** the aerodynamic performance for design of aero systems	
	CO4	**Demonstrate an understanding of** performance enhancement of aerodynamic systems using wind tunnel	

INVISCID AND INCOMPRESSIBLE FLOW: Lift, Drag, Moment and related coefficients conservation equations, flow lines, velocity functions, boundary layer, Bernoulli's equation, low-speed wind tunnel flows; Governing equations and boundary conditions; Elementary flows (uniform, sources, sinks and vortex); Ideal flow past a cylinder, conformal mapping, Kutta-Joukowski theorem and lift generation; Source panel method for non-lifting flows; D'Alembert's paradox. (13)

INCOMPRESSIBLE FLOW OVER AIRFOILS: Kutta condition; Thin airfoil theory (symmetric, cambered); Aerodynamic centre; Vortex panel method for lifting flows; Effect of viscosity and Stokes' second problem. (10)

FINITE WING THEORY: Downwash and induced drag; Biot-Savart Law and Helmholtz's theorems; Prandtl's lifting line theory; Numerical lifting-line method. (10)

AERODYNAMICS AND WIND TUNNEL EXPERIMENTATION: Aerodynamics of horizontal-axis wind turbines, aerodynamics of bluff bodies, building aerodynamics, wind tunnel experiments, case studies. (12)

Total L: 45

REFERENCES:

1. Houghton E. L., Carpenter P. W. and Daniel T. Valentine, "Aerodynamics for Engineering students", Elsevier Ltd., 2013.
2. Lawson T, "Builing Aerodynamics", Imperial College Press, 2010.
3. John D Anderson., "Fundamentals of Aerodynamics", McGraw Hill Book Co., 2011.
4. Hucho W H, "Aerodynamic of Road vehicles ", Butterworth Co. Ltd., 1998.
5. Pope A, "Wind Tunnel Testing ", John Wiley and Sons, 1974.
6. Tom L. Building Aerodynamics, World Scientific; 2010.

18SE34 DESIGN OF WIND ENERGY SYSTEMS

3 0 0 3

Course objectives	Course outcomes		Related program outcomes
• To impart knowledge on wind energy systems, components and able to design systems for wind energy conversion.	**CO1**	**Demonstrate** knowledge on wind aerodynamics and to facilitate selection and design of airfoils for wind systems.	
	CO2	**Design** systems for conversion of energy from available wind sources	

• To impart knowledge on the operations, maintenance and financial implication of wind energy systems to evaluate the feasibility of energy produced from wind.	**CO3**	**Demonstrate knowledge on** electrical and control systems of wind energy systems and propose suitable systems for integration with wind energy systems	
	CO4	**Analyze** the economic viability of wind energy systems and plan for possible wind energy generation	

DESIGN OF WIND TURBINE ROTOR: Basic aerodynamics-wind turbine model-blade element method-airfoil aerodynamics-boundary conditions-aerodynamic design of rotor-numerical simulation of wind turbine flow, rotor blades- polymer materials-processing technology-sandwich materials-material characterization**.** (11)

DESIGN OF MECHANICAL SYSTEMS: Rotor hub, blade pitch mechanism, rotor bearing concepts, rotor brake, gear box, nacelle, yaw system, assembly and performance testing, tower design. (11)

SELECTION OF ELECTRICAL AND CONTROL SYSTEMS: Synchronous and asynchronous generator, assessment criteria for electrical generators, fixed speed generators, variable speed generator systems, directly rotor-driven systems, total electrical system of wind turbine, control systems and operation sequence control, wind measurement system, yaw control, power and speed control by blade pitching, power limiting by aerodynamic stall, supervisory control and operational states, simulation and hardware of control systems. (11)

WIND TURBINE OPERATION, MAINTENANCE AND ECONOMICS: Wind farms, project development, planning, transportations, erection, grid connection, commissioning, operation and monitoring, safety aspects, maintenance and repair offshore wind energy, power optimization, power curve, annual energy yield, environmental impact, economics: factors influencing the wind energy, the present worth approach, cost of wind energy, benefits of wind energy, Case studies; yard sticks and tax advantages, carbon credit. (12)

Total L: 45

REFERENCES:

1. Hau E, von Renouard H, “Wind turbines: fundamentals, technologies, application, economics”. Springer,2003.
2. Burton T, Jenkins N, Sharpe D, Bossanyi E. “Wind energy handbook” John Wiley and Sons,2011 .
3. Mathew S, Philip GS, “Advances in wind energy and conversion technology” Berlin, Springer, 2013.
4. Johnson GL. Wind energy systems, Englewood Cliffs (NJ): Prentice-Hall,1985
5. Hansen MO,”Aerodynamics of wind turbines”, Routledge, 2015.

18SE41/18ED27 SOFT COMPUTING TECHNIQUES FOR RENEWABLE ENERGY SYSTEM

3 0 0 3

INTRODUCTION TO SOFT COMPUTING TECHNIQUES: Fundamentals – biological neural network – artificial neuron – activation function – learning rules - single layer feedback networks - unsupervised learning networks - membership functions - features of membership function - standard forms and boundaries - fuzzification - membership value assignments. - toolboxes of MATLAB – programming and file processing in MATLAB - model definition and model analysis using SIMULINK - S-functions - converting S-functions to blocks. (11)

OPTIMISATION TECHNIQUES FOR PHOTOVOLTAIC ENERGY CONVERSION: Passive filter design using genetic algorithm, harmonic elimination in inverters, tuning of controllers, GA, PSO, DE, optimized fuzzy logic for the maximum power point tracking, MATLAB/SIMULINK models of MPPT techniques. (11)

OPTIMISATION TECHNIQUES FOR WIND ENERGY CONVERSION SYSTEMS: MATLAB/SIMULINK model of wind turbine and wind turbine generators. prediction of wind turbine power factor, pitch angle control, MPPT algorithms, economic dispatch for wind power system – related MATLAB/SIMULINK models-FLC based STATCOM - prediction of wind speed based on FLC - Fuzzy logic controlled SPWM converter for WECS. (11)

GRID INTEGRATION: Integration of small scale generation into distribution grids, different types of grid interfaces, issues related to grid integration systems - phase locked loop for grid connected power system, grid connected inverters, current controllers for PWM inverters, MATLAB/SIMULINK model of grid integration, and PLL grid connected power system.

HYBRID ENERGY SYSTEMS: Need for hybrid energy system, MATLAB/SIMULINK models of hybrid solar PV and wind energy system- - CUK-SEPIC converter, boost converter, hybrid model of solar PV and diesel energy system,– hybrid solar PV and wind energy conversion systems. (12)

Total L: 45

REFERENCES:

1. Laurene Fausett, “Fundamentals of neural networks”, Pearson Education India, New Delhi, 2004.
2. Randall Shaffer., “Fundamentals of power electronics with MATLAB” Charles River Media Boston Massachusetts, 2007.
3. Rao S S., "Optimization theory and applications", Wiley Eastern Limited, New Delhi, 2003.
4. S. Sumathi, Ashok Kumar.L, P.Sureka, “Solar PV and wind energy conversion systems - An introduction to theory, modeling with MATLAB/SIMULINK, and the role of soft computing techniques” – Green Energy and Technology, Springer, 2015 edition (20 April 2015).
5. H.P.Garg and J.Prakash, “Solar energy, fundamentals and applications”, Tata McGraw Hill Publishing Company Ltd., New Delh, 1997.

18SE42/18ED35 VIRTUAL INSTRUMENTATION SYSTEMS

3 0 0 3

INTRODUCTION: Concept of virtual instrumentation, virtual instrumentation model, design flow with graphical system design, graphical data flow programming - modular programming, repetition and loops, arrays, clusters, plotting data, structures, strings, state machines –file I/O- creating LabVIEW executables and projects. (12)

DATA ACQUISITION: DAQ hardware configuration, DAQ hardware– Sampling and grounding techniques- analog I/O, digital I/O, counter/timer, DAQ software architecture, network data acquisition. Application design using real time targets: PXI, cRIO. (11)

INSTRUMENT INTERFACES: Virtual instrumentation software architecture (VISA), instrument drivers, serial and parallel interfaces: RS232, USB, firewire, controller area network (CAN), GPIB, industrial ethernet. OLE for process control (OPC) (11)

ADVANCED FEATURES IN LabVIEW: System identification and control design, signal processing, image acquisition and processing, data logging and supervisory control, LabVIEW Interface for Arduino, case studies on machine vision, motion control, GSD applications. (11)

Total: L: 45

REFERENCES:

1. Gary Johnson and Richard Jennings, “LabVIEW Graphical Programming”, McGraw Hill Inc., 2006.
2. Rick Bitter, Taqi Mohiuddin and Matt Nawrocki, “LABVIEW Advanced Programming Techniques”, CRC Press, 2009.
3. Jovitha Jerome, “Virtual Instrumentation using LabVIEW”, PHI Learning Pvt. Ltd, New Delhi, 2010.
4. Sanjay Gupta and Joseph John, “Virtual Instrumentation Using LabVIEW”, Tata McGraw-Hill, 2008.
5. Mathivanan, N. “PC-Based Instrumentation”, PHI Learning Pvt. Ltd, New Delhi, 2009.

18SE43/18ED33 OPTIMIZATION TECHNIQUES

3 0 0 3

LINEAR PROGRAMMING: Statement of optimization problems, principles of single and multi-objective optimization, graphical method, simplex method, revised simplex method, two phase simplex method, duality in linear programming, sensitivity analysis. (12)

NON-LINEAR PROGRAMMING (UNCONSTRAINED OPTIMIZATION): Direct search methods - univariate method, pattern search method, simplex method, descent methods - steepest descent method, conjugate gradient method, Quasi Newton method. (11)

NON-LINEAR PROGRAMMING (CONSTRAINED OPTIMIZATION): Direct methods - The complex method, Zoutendijk’s method of feasible directions, Rosen’s gradient projection method , indirect method - transformation techniques, basic approach of the penalty function method, interior penalty function method, exterior penalty function method. (11)

DYNAMIC PROGRAMMING: Multistage decision process, Suboptimization and principle of optimality, computational procedure, final value problem to initial value problem, linear programming as a case of dynamic programming, continuous dynamic programming. (11)

Total L: 45

REFERENCES:

1. Hamdy A Taha, “Operations Research: An Introduction”, Pearson Education, New Delhi, 2012.
2. Singaresu S Rao, “Engineering Optimization: Theory and Practice”, New Age International, New Delhi, 2011.
3. Nash S G and Ariela Sofer, "Linear and Nonlinear Programming", McGraw Hill, New York, 1996.
4. Gupta C B, “Optimization Techniques in Operations Research”, I K International, New Delhi, 2012.
5. Sharma J K, “Operations Research: Theory and Applications”, Macmillan Company, New Delhi, 2013.

18SE44/18ED40 HYBRID ELECTRIC VEHICLES

3 0 0 3

INTRODUCTION TO HYBRID ELECTRIC VEHICLES: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. basics of vehicle performance, vehicle power source characterization, transmission characteristics and mathematical models to describe vehicle performance. (11)

DRIVE –TRAIN TOPOLOGIES: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. basic concepts of electric traction, introduction to various electric drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. (11)

ELECTRIC COMPONENTS IN HYBRID AND ELECTRIC VEHICLES: Electric drives in HEV/EVs, classification and characteristics, configuration and control of DC motor drives, induction motor drives, permanent magnet motor drives and switched reluctance motor drives for HEV/EVs applications, drive system efficiency. Performance matching of electric machine and the internal combustion engine (ICE), sizing the propulsion motor, sizing of power electronic devices and energy storage systems. (12)

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. (11)

Total L: 45

REFERENCES:

1. Iqbal Hussein, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 2010.
2. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, "Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design", CRC Press, 2009.
3. James Larminie, John Lowry," Electric Vehicle Technology Explained", Wiley, 2003.
4. Sira -Ramirez, R. Silva Ortigoza, "Control Design Techniques in Power Electronics Devices", Springer, 2006.

18SE45/18ED39 DISTRIBUTED GENERATION AND MICROGRIDS

3 0 0 3

DISTRIBUTED GENERATION : Energy Sources and their availability -trends in energy consumption, conventional and non-conventional energy sources – review of solar photovoltaic – wind energy systems – fuel cells , energy storage systems: batteries – ultra capacitors – fly wheels – captive power power plants. distributed generation – concept and topologies, renewable energy in distributed generation. IEEE 1547 Standard for interconnecting distributed generation to electric power systems – DG installations – siting and sizing of DGs – optimal placement – regulatory issues. (11)

ISSUES IN GRID INTEGRATION OF DISTRIBUTED ENERGY RESOURCES : Basic requirements of grid interconnections – operational parameters – voltage, frequency and THD limits – grid interfaces – inverter based DGs and rotary machines based DGs – reliability, stability and power quality issues on grid integration – impact of DGs on protective relaying and islanding issues in existing distribution grid. (11)

MICROGRIDS : Introduction to microgrids – types – structure and configuration of microgrids – AC and DC microgrids – power electronic intefaces for microgrids – energy management and protection control strategies of a microgrid - case studies. (11)

CONTROL AND OPERATION OF MICROGRID : Modes of operation and control of microgrid: grid connected and islanded mode, active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, power quality issues in microgrids, regulatory standards, microgrid economics, introduction to smart microgrids. (12)

Total L : 45

REFERENCES:

1. Gregory W. Massey, "Essentials of Distributed Generation Systems", Jones & Bartlett Publishers, 2011.
2. Math H. Bollen, "Integration of Distributed Generation in the Power System", John Wiley & Sons, 2011.
3. N. Jenkins, Nicholas Jenkins, "Distributed Generation" IET Press, 2010.
4. S. Chowdhury, P. Crossley, "Micrograds and Active Distribution Networks", IET Press, 2010.
5. Ali Keyhani, "Design of Smart Power Grid Renewable Energy Systems", John Wiley & Sons, 2011.

18SE46/18ED38 SMART GRID TECHNOLOGIES

3 0 0 3

SMART GRID ARCHITECTURE AND COMPONENTS: Introduction to smart grid, evolution of electric grid, concept of smart grid, definitions, need of smart grid, concept of robust & self-healing grid, present development & international policies in smart grid, smart grid architecture models, components of smart grid: smart generation systems, Smart Transmission Grid : Geographic Information System (GIS). Intelligent Electronic Devices (IED) & their application for monitoring & protection. wide area monitoring protection and control (WAMPAC), phasor measurement unit (PMU) and its applications in smart grid. (11)

MICROGRIDS AND DISTRIBUTED ENERGY RESOURCES: Micro grid: concept of micro grid, need & applications of micro grid. micro grid architecture, issues of interconnection, protection & control of micro-grid. distributed energy resources: plastic & organic solar cells, thin film solar cells. variable speed wind generators, fuel cells, micro turbines, captive power plants, integration of renewable energy sources. power quality issues of grid connected renewable energy sources. power quality conditioners for smart grid. web based power quality monitoring and power quality audit. (12)

SMART METERING AND DISTRIBUTION MANAGEMENT SYSTEM: Smart distribution systems: Smart Meters, automatic meter reading (AMR), advanced metering infrastructure (AMI), real time pricing, smart appliances. smart substations : substation automation, feeder automation, outage management system (OMS). Smart sensors: home & building automation, plug in hybrid electric vehicles (PHEV), algorithms for vehicle to grid and grid to vehicle management, smart charging stations. energy storage for smart grids: battery energy storage systems (BESS), superconducting magnetic energy storage (SMES), compressed air energy storage (CAES). (11)

COMMUNICATION NETWORKS AND CYBER SECURITY FOR SMART GRID: Communication architecture for smart grids, home area network (HAN) : IEEE 802.11, IEEE 802.15.4, 6LoWPAN, Neighborhood Area Network (NAN) / Field Area Network (FAN): Radio over Power-Lines (BPL/PLC), IEEE P1901, Wide Area Network (WAN) : optical fiber communication, cellular networks, Wi-Max and wireless sensor networks. big data analytics in smart grid, cyber security challenges in smart grid - load altering attacks - false data injection attacks - defense mechanisms. (11)

Total L : 45

REFERENCES:

1. Stuart Borlase, “Smart Grid: Infrastructure, Technology and Solutions”, CRC Press, 2012.
2. Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley, 2012.
3. Ali Keyhani, “Design of Smart Power Grid Renewable Energy Systems”, Wiley, 2016
4. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press , 2009
5. IEEE Transactions on Smart Grid.

18SE47/18ED28 FLEXIBLE AC TRANSMISSION SYSTEM

3 0 0 3

INTRODUCTION: Fundamentals of AC power transmission, transmission problems and needs, emergence of FACTS- FACTS control considerations, FACTS controllers, concepts of voltage sourced and current sourced converters for FACTS devices. (11)

SHUNT COMPENSATOR: Principle of operation - types - Variable impedance type & switching converter type - static synchronous compensator (STATCOM) - configuration, characteristics and control-applications. (11)

SERIES COMPENSATOR: Principles of operation- types - static series compensation using GCSC, TCSC and TSSC, static synchronous series compensator (SSSC) – characteristics and control-applications.
VOLTAGE AND PHASE ANGLE REGULATORS: Principles of operation-types-steady state model and characteristics of a static voltage regulators and phase shifters- thyristor controlled voltage and phase angle regulators. switching converter based voltage and phase angle regulators-applications. (12)

UNIFIED POWER FLOW CONTROLLER: Principles of operation – characteristics- independent active and reactive power flow control-applications. Comparison of UPFC with the controlled series compensators and phase shifters. Coordinated control of FACTS Devices. Use of FACTS devices under deregulated environment. (11)

Total L: 45

REFERENCES:

1. Song, Y.H. and Allan T. Johns, “Flexible AC transmission systems (FACTS)”, Institution of Electrical Engineers Press, London, 1999.
2. Hingorani ,L.Gyugyi, “Understanding FACTS - concepts and technology of flexible AC transmission systems”, IEEE Press New York, 2000.
3. Mohan R .Mathur and Rajiv Varma K. , “Thyristor - based FACTS controllers for electrical transmission systems”, IEEE Press, Wiley Inter science , 2002.
4. Padiyar K.R., “FACTS controllers for Transmission and distribution systems”, New Age International Publishers, 2007.
5. Loi Lei Lai, ‘Power system restructuring and deregulation’, John Wiley & Sons Ltd. 2003.