ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS - 2023

CHOICE BASED CREDIT SYSTEM

M.E. SOLAR ENERGY

THE VISION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

The Department of Mechanical Engineering strives to be recognized globally for excelling in engineering education and research leading to innovative, entrepreneurial and competent graduates in Mechanical Engineering and allied disciplines.

THE MISSION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

- Providing world class education by fostering effective teaching learning process that is supported through pioneering and cutting-edge research to make impactful contribution to the society.

- Attracting highly motivated students with enthusiasm, aptitude and interest in the field of Mechanical and allied Engineering disciplines.

- Expanding the frontiers of Engineering and science in technological innovation while ensuring academic excellence and scholarly learning in a collegial environment.

- Excelling in industrial consultancy and research leading to innovative technology development and transfer.

- Serving the society with Innovative and entrepreneurially competent graduates for the national and international community towards achieving the sustainable development goals.

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PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

The Solar Energy program seeks to prepare PG students for productive and rewarding careers in the solar energy arena. The PEOs are listed below:

(i) Acquire knowledge and employability in solar energy sector with requisite skills facilitating quick progress in graduands career

(ii) Inclination towards advanced research for mitigating the shortcomings in solar energy systems.

(iii) Ascending as an solar energy consultant/entrepreneur for providing solutions towards improving the efficacy of energy systems.

(iv) Lead an ethical life by engaging in lifelong learning experiences for developing environmentally sustainable and economically affordable solar energy products for societal upliftment.

PROGRAMME OUTCOMES (POs):

(i) An ability to independently carry out research/investigation and development work to solve practical problems

(ii) An ability to write and present a substantial technical report/document

(iii) Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme.

(iv) Expertise to use various simulation software related to solar energy systems to identify research gaps and ideate innovations

(v) Design and optimize solar energy systems with environmental consciousness for sustainable development.

(vi) Awareness on Solar Energy policy and scenario at state, national and global level.

PEO - PO Mapping:

PEO	PO					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
(i)	3	3	3	3	3	1
(ii)	3	3	2	3	3	1
(iii)	3	3	3	2	3	1
(iv)	3	1	3	2	3	1

PROGRAM ARTICULATION MATRIX OF M.E. SOLAR ENERGY

Year	Sem.	Courses	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
I	I	Advanced Numerical Methods	3	-	-	1	2	-
		Thermodynamic Analysis of Energy Systems	2.4	1.8	1.5	2.6	1.6	1.3
		Fluid Mechanics and Heat Transfer	3	-	2	3	1.6	1
		Renewable Energy Systems	3	3	-	-	3	2.2
		Physics of Solar Engineering	1.5	-	2.6	2	2	-
		Measurements and Controls in Energy Systems	3	-	1	-	-	1.5
		Research Methodology and IPR						
	II	Solar Photovoltaic Technology and Systems	3	-	2	-	2	-
		Solar Engineering of Thermal Processes	2.4	-	3	2	3	1.2
		Computational Fluid Dynamics for Energy Systems	2.2	-	3	3	2	-
		Professional Elective I						
		Analysis and Simulation Laboratory for Solar Energy	3	3	3	3	3	-
		Summer Internship						
II	III	Professional Elective II						
		Professional Elective III						
		Professional Elective IV						
		Project Work - I	3	3	3	3	3	3
	IV	Project Work - II	3	3	3	3	3	3
PEC		Solar Power Generation Technologies and Policies	3	-	3	-	2	3
		Solar Energy Appliances	3	-	3	-	3	1
		Power Electronics for Renewable Energy Systems	3	-	3	-	1.6	1
		Smart Grid	`1.4	-	3	-	2	3
		Solar Passive Architecture	2.4	1.4	2.6	2	3	3
		Nanomaterials for Solar Systems	-	-	3	-	2	-
		Design of solar energy structures	3	-	3	2	3	-
		Materials for Solar Devices	1.2	-	2.8	-	2.8	1
		Solar PV Power Plant Design	3	3	3	3	3	1
		Energy Forecasting, Modelling and Project Management	2.3	1.8	2.8	2.6	2.6	3.0
		Design and Optimization of thermal energy systems	2	1.5	1.8	2.8	2.8	1.5
		Statistical Design and Analysis of Experiments	3	-	1	-	2	1
		Energy Storage Technologies	2	2	-	-	3	2.6
		Green Hydrogen and Fuel Cells	1.4	-	3	-	2	-
		Solar Energy for Industrial Process Heating	2.2	1`.8	3	-	2.6	1
		Solar Refrigeration and Air Conditioning	2.4	2	2.8	-	3	-

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS - 2023
CHOICE BASED CREDIT SYSTEM
CURRICULUM AND SYLLABI FOR SEMESTER I TO IV
M.E. SOLAR ENERGY

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY / PRACTICAL								
1.	MA3155	Advanced Numerical Methods	FC	4	0	0	4	4
2.	EY3152	Thermodynamic Analysis of Energy Systems	PCC	3	1	0	4	4
3.	EY3151	Fluid Mechanics and Heat Transfer	PCC	3	1	0	4	4
4.	EY3153	Renewable Energy Systems	PCC	3	0	2	5	4
5.	SY3101	Physics of Solar Engineering	PCC	3	0	2	5	4
6.	EY3154	Measurements and Controls in Energy Systems	FC	3	0	0	3	3
7.	RM3151	Research Methodology and IPR	MC	2	1	0	3	3
			TOTAL	**21**	**3**	**4**	**28**	**26**

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	SY3201	Solar Photovoltaic Technology and systems	PCC	3	0	2	5	4
2.	SY3202	Solar Engineering of Thermal Processes	PCC	3	0	2	5	4
3.	EY3251	Computational Fluid Dynamics for Energy Systems	PCC	3	1	0	4	4
4.		Professional Elective I	PEC	3	0	0	3	3
PRACTICAL								
5.	SY3211	Analysis and Simulation Laboratory for Solar Energy	PCC	0	0	4	4	2
6.	SY3212	Summer Internship*	EEC	*	*	*	*	2
			TOTAL	**12**	**1**	**8***	**21***	**19**

*****
(a) To be carried out in a solar energy related industry during the 2nd semester vacation
(b) Minimum period of training = 4 weeks
(c) Evaluation to be carried out on the first week of 3rd semester

SEMESTER III

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective II	PEC	3	0	0	3	3
2.		Professional Elective III	PEC	3	0	0	3	3
3.		Professional Elective IV	PEC	3	0	0	3	3
PRACTICAL								
4.	SY3311	Project Work - I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER IV

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	SY3411	Project Work - II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

Total credits for the programme = 26 + 19 + 15 +12 = 72

Students are permitted to

(i) ***Study any 2 courses - equivalent to the subjects mentioned in the curriculum - in National Programme on Technology Enhanced Learning (NPTEL), Govt. of India***

AND/OR

(ii) ***Study any 2 TECHNICAL courses for consideration under Program Electives amongst the core/elective courses offered in the University Departments***

Prior approval of (1) Faculty Adviser, (2) Professor–i/c of PG Programme, (3) HoD – Dept. of Mech. Engg., and (4) Chairperson – Faculty of Mechanical Engineering is to be obtained for the above.

FOUNDATION COURSES (FC)

Sl. No	Code No.	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	MA3155	Advanced Numerical Methods	4	0	0	4	1
2.	EY3154	Measurements and Controls in Energy Systems	3	0	0	3	1
						7	

PROGRAM CORE COURSES (PCC)

Sl. No	Code No.	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	EY3152	Thermodynamic Analysis of Energy Systems	3	1	0	4	1
2.	EY3151	Fluid Mechanics and Heat Transfer	3	1	0	4	1
3.	SY3101	Physics of Solar Engineering	3	0	2	4	1
4.	EY3153	Renewable Energy Systems	3	0	2	4	1
5.	SY3201	Solar Photovoltaic Technology and Systems	3	0	2	4	2
6.	SY3202	Solar Engineering of Thermal Processes	3	0	2	4	2
7.	EY3251	Computational Fluid Dynamics for Energy Systems	3	0	0	4	2
8.	SY3211	Analysis and Simulation Laboratory for Solar Energy	0	0	4	2	2

PROFESSIONAL ELECTIVE COURSES

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	SY3001	Solar Power Generation Technologies and Policies	PEC	3	0	0	3	3
2.	SY3002	Solar Energy Applications	PEC	3	0	0	3	3
3.	SY3003	Power Electronics for Renewable Energy Systems	PEC	3	0	0	3	3
4.	SY3004	Smart Grid	PEC	3	0	0	3	3
5.	SY3005	Solar Passive Architecture	PEC	3	0	0	3	3
6.	SY3006	Nanomaterials for Solar Systems	PEC	3	0	0	3	3
7.	SY3007	Design of Solar Energy Structures	PEC	3	0	0	3	3
8.	SY3008	Materials for Solar Devices	PEC	3	0	0	3	3
9.	SY3009	Solar PV Power Plant Design	PEC	3	0	0	3	3
10.	EY3057	Energy Forecasting, Modelling and Project Management	PEC	3	0	0	3	3
11.	EY3059	Design and Optimization of thermal energy systems	PEC	3	0	0	3	3
12.	EY3060	Statistical Design and Analysis of Experiments	PEC	3	0	0	3	3
13.	EY3061	Energy Storage Technologies	PEC	3	0	0	3	3
14.	SY3010	Green Hydrogen and Fuel Cells	PEC	3	0	0	3	3
15.	SY3011	Solar Energy for Industrial Process Heating	PEC	3	0	0	3	3
16.	SY3051	Solar Refrigeration and Air Conditioning	PEC	3	0	0	3	3

MANDATORY COURSES (MC)

SL. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1	RM3151	Research Methodology and IPR	2	1	0	3	1

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

Sl. No	Code No.	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1	SY	Summer Internship	*	*	*	2	2
2	SY	Project Work - I	0	0	12	6	3
3	SY	Project Work - II	0	0	24	12	4
					Total Credits	**20**	

Summary

S.No.	M.E. (Solar Energy)					
	Subject Area	Credits per Semester				Credits Total
		I	II	III	IV	
1.	FC	7	-	-	-	7
2.	PCC	16	14	-	-	30
3.	PEC	-	3	9	-	12
4.	MC	3	-	-	-	3
5.	EEC	-	2	6	12	20
	Total Credit	**26**	**19**	**25**	**12**	**72**

MA3155 ADVANCED NUMERICAL METHODS L T P C
4 0 0 4

OBJECTIVES:

- To impart knowledge in understanding the advantages of various solution procedures of solving the system of linear and nonlinear equations.
- To give a clear picture about the solution methods for solving the BVPs and the system of IVPs.
- To acquire knowledge in solving time dependent one and two dimensional parabolic PDEs by using various methodologies.
- To strengthen the knowledge of finite difference methods for solving elliptic equations.
- To get exposed to the ideas of solving PDEs by finite element method.

UNIT I ALGEBRAIC EQUATIONS 12

Systems of linear equations: Gauss Elimination method, pivoting techniques, Thomas algorithm for tridiagonal system – Jacobi, Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Method, Eigenvalue problems: power method, Faddeev – Leverrier Method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS 12

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, solution of stiff ODEs, shooting method, BVP: Finite difference method, collocation method, orthogonal collocation method, Galerkin finite element method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATION 12

Parabolic equations: explicit and implicit finite difference methods, weighted average approximation - Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method; First order hyperbolic equations – method of characteristics, Lax - Wendroff explicit and implicit methods; numerical stability analysis, method of lines – Wave equation: Explicit scheme-Stability of above schemes.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 12

Laplace and Poisson’s equations in a rectangular region: Five point finite difference schemes, Leibmann’s iterative methods, Dirichlet and Neumann conditions – Laplace equation in polar coordinates: finite difference schemes – approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD 12

Partial differential equations – Finite element method - collocation method, orthogonal collocation method, Galerkin finite element method.

TOTAL: 60 PERIODS

OUTCOMES:
At the end of the course, students will be able to
CO1 Get familiarized with the methods which are required for solving system of linear, nonlinear equations and eigenvalue problems.
CO2 Solve the BVPs and the system of IVPs by appropriate methods discussed.
CO3 Solve time dependent parabolic PDEs by using various methodologies up to dimension two.
CO4 Solve elliptic equations by finite difference methods.
CO5 Use the ideas of solving PDEs by finite element method.

REFERENCES:

1. Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", Cengage Learning, India Edition, New Delhi, 2010.
2. Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, 3rd Edition, New Delhi, 2015.
3. Jain M. K., Iyengar S. R. K., Jain R.K., "Computational Methods for Partial Differential Equations", New Age Publishers, 2nd Edition, New Delhi, 2016.
4. Morton K.W. and Mayers D.F., "Numerical solution of partial differential equations", Cambridge University press, Cambridge, 2005.
5. Sastry S.S., "Introductory Methods of Numerical Analysis", Prentice - Hall of India Pvt. Limited, 5th Edition, New Delhi, 2012.
6. Saumyen Guha and Rajesh Srivastava, "Numerical methods for Engineering and Science", Oxford Higher Education, New Delhi, 2010.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	2
CO2	3	3	3	3	2	2
CO3	3	3	3	3	2	2
CO4	3	3	3	3	2	2
CO5	3	3	3	3	2	2

EY3152	THERMODYNAMIC ANALYSIS OF ENERGY SYSTEMS	L	T	P	C
		3	1	0	4

OBJECTIVE:

The major objective of this course is to introduce the advanced thermodynamic concepts whi ch are useful in understanding fundamental concepts of availability, entropy generation, properties of matter and to apply in various Engineering problems involving energy transfer, chemical processing, etc. The course will focus on both energy producing and consuming thermodynamic cycle's system energy and exergy analysis.

UNIT – I FUNDAMENTAL LAWS, CLOSED and OPEN SYSTEMS 12

Zeroth, First and Second law of Thermodynamics, Fundamental equations for closed systems, Process, Relations, Second law efficiency for a closed system, Fundamental equations for open systems, Steady state operations, Flow in channel, turbine and compressors

UNIT – II ENTROPY GENERATION 12

Lost Available Work, Process – non flow and steady flow, Mechanisms for entropy generation – Heat Transfer, friction, mixing – entropy generation minimization techniques, Internal flow, heat transfer, fluid flow, electrical systems - entropy minimization to Constructional laws.

UNIT – III THERMODYNAMIC PROPERTIES of MATTER 12

General properties of perfect and ideal gases, Van der walls fluids, Virial fluids, Maxwell relations. Generalized relations for changes in entropy – internal energy and enthalpy – C_p and $C_{V.}$ Clausius Clapeyron equation, Joule – Thomson coefficient. Bridgman tables for thermodynamic relations, Fundamental property relations for systems of variable composition. Partial molar properties. Ideal and real gas mixtures

UNIT – IV THERMODYNAMIC CYCLES 12

General features of cycles, Vapour Cycles – working fluids, Rankine Cycles and its modification, Kalina Cycle, Supercritical Cycles – Gas Power Cycles – Refrigeration and Heat Pump Cycles - Combined Cycles and Cogeneration

UNIT – V ENERGY and EXERGY ANALYSIS 12

Energy and Exergy Approach, Energy and Exergy of Fuels, Combustion processes, Exergy Analysis of Heat exchangers, Boilers, Heat Pumps, Turbo machines, and Internal Combustion Engines

TOTAL: 60 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO 1 Understand the thermodynamic system, and apply various thermodynamic relations

CO 2 Analyze the entropy generation in various processes

CO 3 Predict the behavior of real gas and calculate the properties of gas mixtures

CO 4 Apply various thermodynamic cycles for various work producing and consuming systems

CO 5 Apply the thermodynamic knowledge for analyzing the energy and exergy concepts in different applications.

REFERENCES

1. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Sons, 2016.
2. Kalyan Annamalai, Ishwar K. Puri, Milind A. Jog., Advanced thermodynamics engineering, CRC press, 2011
3. Kuo, K.K., Principles of Combustion, John Wiley and Sons, 2005
4. Kenneth Wark Jr., Advanced Thermodynamics for Engineers, McGraw – Hill Inc., 1995.
5. Lucien Borel, Daniel Favrat, Thermodynamics and Energy Systems Analysis: From Energy to Exergy, CRC Press, 2010

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	1	-	3	1	1
2	1	2	1	2	2	-
3	3	2	3	3	2	1
4	2	-	1	2	1	-
5	3	2	1	3	2	2
Avg.	**2.4**	**1.8**	**1.5**	**2.6**	**1.6**	**1.3**

EY3151 FLUID MECHANICS AND HEAT TRANSFER

L	T	P	C
3	1	0	4

OBJECTIVE:

The main objective of the course is to impart knowledge to students on the concepts of fluid kinematics, boundary layer theory, incompressible and compressible fluid flow analysis. The course is also useful to enhance the student knowledge on various modes of heat transfer and the applications of heat transfer.

UNIT – I FLUID KINEMATICS AND BOUNDARY LAYER THEORY 12

Three dimensional forms of governing equations – Mass, Momentum, and their engineering applications. Rotational and irrotational flows – vorticity – stream and potential functions.
Boundary Layer – displacement, momentum and energy thickness – laminar and turbulent boundary layers in flat plates and circular pipes.

UNIT – II INCOMPRESSIBLE AND COMPRESSIBLE FLOWS 12

Laminar flow between parallel plates – flow through circular pipe – friction factor – smooth and rough pipes – Moody diagram – losses during flow through pipes. Pipes in series and parallel – transmission of power through pipes.
One dimensional compressible flow analysis – flow through variable area passage – nozzles and diffusers.

UNIT – III CONDUCTION AND CONVECTION HEAT TRANSFER 12

Conduction: Governing Equation and Boundary conditions, Extended surface heat transfer, Transient conduction – Use of Heisler-Grober charts, Conduction with moving boundaries, Stefan and Neumann problem.
Energy equation - Analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube – High speed flows – Convection with phase change – Condensation, Boiling.

UNIT – IV RADIATION HEAT TRANSFER 12

Surface radiation – View factor analysis, Gas Radiation - Radiative Transfer Equation (RTE), Radiation properties of a participating medium, Use of Hottel's Graph, Correction factor analysis - Inverse problems in radiation transfer.

UNIT – V HEAT EXCHANGER AND HEAT PIPE 12

Heat exchanger: Classification, sizing, and rating problems – Bell Delaware method - Є-NTU method – thermo-hydraulic performance of compact heat exchanger.
Heat Pipes: Classification, Thermal analysis - performance improvement techniques.

TOTAL: 60 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO 1 Identify, formulate, and analyze the governing equations for various engineering applications.
CO 2 Learn the flow concepts of incompressible and compressible flow.
CO 3 Solve the conduction and convection heat transfer problems.
CO 4 Understand the importance of radiation heat transfer in gases and inverse solution methods.
CO 5 Design a heat exchanger and heat pipe as per the industrial needs.

REFERENCES:

1. Yunus A Cengel and John M Cimbala, “Fluid Mechanics Fundamentals and Applications,” McGraw-Hill, 2018.
2. Venkateshan S P., “Heat Transfer “, Ane Books Pvt. Ltd, 2016
3. Holman J P, “Heat Transfer”, McGraw-Hill, 2010.
4. Ozisik M N., “Heat Transfer – A Basic Approach”, McGraw Hill Co, 1985.
5. Adrian Bejan, Convection Heat Transfer, Wiley, Fourth Edition, 2013
6. Bahman Zohuri, “Heat Pipe Design and Technology”, Taylor and Francis Group, LLC, 2011.

CO – PO MAPPING

CO	**PO**					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	-	3	1	1
2	3	-	-	3	1	1
3	3	-	2	3	2	1
4	3	-	2	3	2	1
5	3	-	2	3	2	1
Avg.	**3**	**-**	**2**	**3**	**1.6**	**1**

EY3153 RENEWABLE ENERGY SYSTEMS

L	T	P	C
3	0	2	4

OBJECTIVE:

Acquaintance with the Indian and Global energy scenario and to edify on the potential and prospects of various renewable energy technologies.

UNIT – I ENERGY AND ENVIRONMENT 9L

Indian energy scenario - Potential of various renewable energy sources - Greenhouse effect – Ozone depletion - Climate Change – UNFCCC - Energy Pricing – Fuel and Energy Substitution

UNIT – II SOLAR ENERGY 9L+15P

Solar radiation – Measurements of solar radiation – Solar spectrum - Solar thermal collectors – Solar thermal applications – thermal energy storage – Fundamentals of solar photo voltaic conversion – Solar cells – Solar PV Systems – Solar PV applications.

UNIT – III WIND ENERGY 9L+3P

Wind data and energy estimation – Betz limit - Site selection for windfarms – characteristics - Wind resource assessment – Windmills – Accessories – Environmental issues - Applications.

UNIT – IV BIO-ENERGY 9L+9P

Bio resources – Thermochemical Conversion: combustion, gasification, pyrolysis and carbonisation – Biochemical conversion: Biomethanation, Fermentation – Physiochemical : Biodiesel, Briquetting and Pelletisation – Applications

UNIT – V HYDRO, GEOTHERMAL & HYBRID ENERGY SYSTEMS 9L+3P

Small hydro - Tidal energy – Wave energy – OTEC – Geothermal energy – Hybrid systems – Environmental impacts

TOTAL: 75 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Comprehend on the Indian energy scenario
CO2 Design a Solar Thermal / PV system for any requirement
CO3 Estimate the available wind energy in a particular site
CO4 Suggest suitable conversion mechanism for generating power from Biomass
CO5 Elucidate on the technologies for harnessing power from ocean and geothermal energy.

REFERENCES:

1. Godfrey Boyle, “Renewable Energy, Power for a Sustainable Future”, Oxford University Press, 2017, Fourth Edition.
2. Rai.G.D., “Non-Conventional Energy Sources”, Khanna Publishers, 2014, Sixth Edition
3. S. P. Sukhatme, J K. Nayak, “Solar Energy”, McGraw Hill, 2017, Fourth Edition.
4. B H Khan, “Non-Conventional Resources”, McGraw Hill, 2016, Third Edition.
5. John Twidell, “Renewable Energy Resources”, Routledge, 2022, Fourth Edtion .

Practical

1. Study of Direct and diffused beam solar radiation
2. Performance evaluation of Solar Flat Plate Collector
3. Determining the I-V characteristics of Solar PV panel
4. Performance evaluation of solar cookers (box type and concentrating type)
5. Determining the I-V Characteristics of a Fuel Cell
6. Performance evaluation of a green hydrogen generation and storage system
7. Performance evaluation of wind turbine
8. Performance evaluation of different turbines employed in hydro power plant
9. Study of Biomethanation plant
10. Study of Biomass briquetting plant

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	-	3	-	-	3	3
2	3	3	-	-	3	2
3	3	3	-	-	3	2
4	3	3	-	-	3	2
5	3	3	-	-	3	2
Avg	**3**	**3**	**-**	**-**	**3**	**2.2**

SY3101 PHYSICS OF SOLAR ENGINEERING

	L	T	P	C
	3	0	2	4

OBJECTIVES:

The major objectives of this course is to impart the knowledge on the basics of solar radiation, solar geometry, solar system components and their significance.

UNIT – I SOLAR RADIATION 9L+12P

Basics of solar energy - Brief History of solar energy utilization - Various approaches of utilizing solar energy - Blackbody radiation - Relation between radiation field energy density and radiation spectrum - Planck's formula in energy unit - Maximum spectral density - Planck's formula in wavelength unit - Wien displacement law - Stefan - Boltzmann law – Photoelectric effect - Einstein's theory of photons - Einstein's derivation of the black-body formula.

UNIT – II SOLAR GEOMETRY AND AIR MASS 9L

Rotation and orbital motion of the Earth around the Sun - Solar time, sidereal time, universal standard time, local standard time - Equation of time - Intensity of sunlight on an arbitrary surface at any time - Interaction with the atmosphere - Air mass - Rayleigh and Mie scattering - Absorption.

UNIT – III SOLAR CELLS 9L+6P

Formation of a PN – junction - Space charge and internal field - Quasi - Fermi levels – Shockley diode equation - solar cell equation – IV Characteristics- Various electron-hole pair recombination mechanisms –Theoretical efficiency, Internal and external quantum efficiency - Structure of a solar cell – Types of PV cells

UNIT – IV SOLAR THERMAL COLLECTORS 9L+6P

Fundamentals of thermal collectors - Basics of heat transfer - Technology and Working principles - Solar flat plate collector: Collector Efficiency - Absorber plate types - Collector loss estimation - Analysis of Collector - Concentrating collector: Optical Efficiency - Concentration ratio - Collector Configurations - Classifications - Comparison - Thermal Analysis.

UNIT – V SOLAR ENERGY STORAGE MATERIALS 9L+6P

Necessity of storage for solar energy - Chemical energy storage - Thermal energy storage – Phase change materials storage – Composite phase change materials storage.

TOTAL: 75 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Enumerate the basic laws related to the solar radiation.

CO2 Predict the solar time due to the motion of the earth with respect to sun.

CO3 Provide accurate diagrams of solar cells and be able to classify solar cells and their working mechanisms.

CO4 Understand the basics of working and testing of solar thermal collectors.

CO5 Understand the need of storage for solar energy and selection of materials for solar energy storage.

REFERENCES:
1. Duffie, J.A., and Beckman, W.A, “Solar Energy Thermal Process - 4th Edition”, John Wiley and Sons, 2013.
2. Stix, M., “The Sun, An Introduction”, Springer, 2002.
3. Jenny Nelson, “The Physics of Solar Cells”, Imperial College Press, 2003.
4. Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, PHI Learning Pvt Ltd, 2015.
5. Sukhatme S.P. and Nayak J.K., “Solar Energy”, Tata McGraw Hills, 4th Edition, 2017.
6 Julian Chen, C., “Physics of Solar Energy”, John Wiley, 2011.

Practical

1. Solar radiation measurement
2. Study on solar radiation and meteorological data for the given location and mapping daily and monthly averages.
3. Estimation of IV characteristics of a PV cell
4. Performance assessment of solar thermal collectors
5. Characterisation of energy storage materials

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	-	2	-	3	-
2	1	-	2	-	3	-
3	2	-	3	-	1	-
4	2	-	3	-	1	-
5	-	-	3	2	2	-
Avg.	**1.5**	**-**	**2.6**	**2**	**2**	**-**

EY3154	MEASUREMENTS AND CONTROLS IN ENERGY SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVE:

The primary goal of this course is to enrich the students understanding of different measuring instruments, methodologies, and the significance of error and uncertainty analysis. Additionally, this course will equip students with the skills required to design appropriate control unit for a range of thermal systems.

UNIT – I BASICS OF MEASUREMENTS 9

Introduction, general measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction, Presentation of experimental data, Errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis, Transient response – zeroth, first and second order measurement systems

UNIT – II THERMOMETRY AND HEAT FLUX MEASUREMENT 9

Overview of thermometry, Thermoelectric temperature measurement, Resistance thermometry, Pyrometer, Other methods and Calibration procedure, Challenges in temperature measurements, Principles of Heat flux measurement.

UNIT – III PRESSURE, FLOW AND THERMAL PROPERTY MEASUREMENT 9

Different pressure measurement instruments and their comparison, Transient response of pressure transducers, Flow Measurement, Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, Other methods, Thermo-physical property measurement - Steady and Unsteady methods for solids, fluids and PCMs

UNIT – IV CONTROL SYSTEMS, COMPONENTS, AND CONTROLLERS 9

Introduction, Open and closed loop control systems, Transfer function. Types of feedback and feedback control system characteristics – Control system parameters – DC and AC servomotors, servo amplifier, potentiometer, synchro transmitters, synchro receivers, synchro control transformer, stepper motors - Continuous, Discontinuous and Composite control modes – Analog and Digital controllers.

UNIT – V DESIGN OF MEASUREMENT AND CONTROL SYSTEMS 9

Data logging and acquisition - Integration of industrial instrumentation systems and monitoring, sensors for error reduction, elements of computer interfacing, timers and counters, designing measurement and control systems for specific applications, fault finding, and computer-based controls.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation, and estimation of uncertainty.

CO2 Select appropriate sensors for measurement of specific parameters/properties with required accuracy.

CO3 Carry out calibration and evaluate measurement systems using uncertainty analysis

CO4 Distinguish between measurement and control systems, and use appropriate control system for an application

CO5 Construct a complete control system for a thermal application.

REFERENCES:

1. J. P. Holman, “Experimental methods for Engineers”, Tata McGraw-Hill, 8th Edition, 2018
2. S. P. Venkateshan, “Mechanical Measurements”, Springer, 2nd Edition, 2022
3. Ernest O Doebelin and Dhanesh N. Manik, “Measurement systems: Application and design”, Tata McGraw Hill publications, 7th Edition, 2019

4. Thomas G Beckwith, Roy D. Marangoni, and John H. Lienhard, "Mechanical Measurements" Pearson publications, 6th Edition, 2006
5. A. Morris, "Measurement and Instrumentation Principles," Oxford, UK, 3rd Edition, 2015
6. Nakra, B.C., Choudhry K.K., "Instrumentation, Measurements and Analysis", Tata McGraw Hill, New Delhi, 4th Edition, 2016
7. William Bolton, "Industrial Control & Instrumentation", Longman Scientific & Technical, 1991

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	1	-	-	2
2	3	-	1	-	-	-
3	3	-	-	-	-	1
4	3	--	-	-	-	-
5	3		-	-	-	-
Avg	**3**	**-**	**1**	**-**	**-**	**1.5**

RM3151 RESEARCH METHODOLOGY AND IPR

	L	T	P	C
	2	1	0	3

OBJECTIVES:

To impart knowledge on

- Formulation of research problems, design of experiment, collection of data, interpretation and presentation of result
- Intellectual property rights, patenting and licensing

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, “Business Research Methods”, Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, “Research methodology for natural sciences”, IISc Press, Kolkata, 2022,

3. Catherine J. Holland, “Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets”, Entrepreneur Press, 2007.
4. David Hunt, Long Nguyen, Matthew Rodgers, “Patent searching: tools & techniques”, Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, “Professional Programme Intellectual Property Rights, Law and practice”, September 2013.

SY3201	SOLAR PHOTOVOLTAIC TECHNOLOGY AND SYSTEMS	L	T	P	C
		3	0	2	4

OBJECTIVES:

The objective of this course is to provide in-depth understanding to students on solar photovoltaic systems, design of various PV interconnected systems, grid connected PV systems and hybrid systems. This course will also enable students to design the system components for different PV Applications

UNIT – I SOLAR PV MODULES 9L+8P

Structure and working of Solar PV modules - Types, Electrical properties and behavior of Solar PV modules - PV Cell Interconnection and Module Fabrication – Effects of de-rating factors in a PV module - Mounting structures – Recycling of solar PV panel.

UNIT – II STAND ALONE PV SYSTEMS 9L+10P

Schematics and Components - Balance of system components for DC and/or AC Applications - Maximum power point tracking (MPPT) algorithms - Interfacing PV modules to loads - Connection of PV modules to a battery and load together – Modeling and simulation of stand-alone systems - Applications.

UNIT – III GRID CONNECTED PV SYSTEMS 9L+6P

Schematics and Components - Balance of system Components - Interface Components – Net metering & Gross metering - Feasible operating region of inverter at different power factor - Active power filtering with real power injection - Modeling and simulation of grid connected systems - Floating PV panel.

UNIT – IV HYBRID SYSTEMS 9L+6P

Need for Hybrid Systems - Range and type of Hybrid systems - Case studies of Diesel-PV, Wind-PV, Microhydel-PV, PV-Hydrogen, Electric and hybrid electric vehicles - Comparison and selection criteria for a given application - Modeling and simulation of hybrid systems.

UNIT – V GRID CODE REQUIREMENTS AND STANDARDS 9L

CEA technical standard for connectivity to the grid: voltage, frequency, LVRT, HVRT, power factor, harmonics, DC injection, flicker – IEEE 2800: Q vs P and Q vs V reactive power capability, power quality, protection, low and high voltage ride through – low and high frequency ride through.

TOTAL: 60 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Apply principle of evidence-based photovoltaic technology

CO2 Provide accurate schematic of stand-alone PV systems and BOS

CO3 Provide accurate schematic of grid-connected PV systems and BOS

CO4 Select appropriate hybrid system for different applications

CO5 Design and simulate the stand-alone and grid connected system.

REFERENCES:

1. A. Goetzberger, V. U. Hoffmann, Volker Uwe, “Photovoltaic Solar Energy Generation”, Springer, 2005.
2. Jenny Nelson, “The Physics of Solar Cells”, Imperial College Press, 2003.
3. Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, PHI Learning Pvt. Ltd, 2005.
4. T. Markvart, “Solar Electricity”, John Wiley & Sons, 2000.
5. R. A. Messenger and Amir Abtahi, “Photovoltaic Systems Engineering”, CRC Press, 2017.

Practical

1. Determination of IV characteristics of Solar Cell
2. Comparative study on Solar Module Characteristics (Series and parallel configuration)
3. Performance evaluation of SPV Stand-alone Systems under various operating conditions
4. Study on Augmentation of Solar panel performance
5. Performance evaluation of Simple Hybrid Systems
6. Performance evaluation of Solar grid tied system
7. Performance evaluation of Solar PV Water Pumps
8. Study on Charging and Discharging Cycles of the batteries.
9. Investigation of Thermal management of Solar PV system
10. Testing the efficiency of a Solar Cell at Varying Wavelengths
11. Design a simple solar stand-alone system
12. Design a simple solar water pumping system
13. Study and prepare the single line diagram for a solar power plant of minimum capacity of 1 MW

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	2	-	2	-
2	3	-	2	-	2	-
3	3	-	2	-	2	-
4	3	-	2	-	2	-
5	3	-	2	-	2	-
Avg.	**3**	**-**	**2**	**-**	**2**	**-**

SY3202 SOLAR ENGINEERING OF THERMAL PROCESSES

L	T	P	C
3	0	2	4

OBJECTIVES:

The objective of this course is to enable the students to acquire knowledge on various types of solar thermal collectors and its applications. This course will also help students to carry out the design and modeling of active and passive types of solar thermal systems.

UNIT – I SOLAR THERMAL COLLECTORS 9L+10P

Flat Plate Collectors Liquid Heaters – Flat Plate Air heaters – Tubular Solar Energy Collectors - Energy Balance – Thermal Performance analysis – Evacuated tube collector.

Concentrating Collectors -Non Imaging concentrators – Linear Imaging Concentrators – Paraboloidal Concentrators – Central Receiver Collectors – Thermal Performance analysis – Optical Performance analysis - Tracking Mechanism for Solar Thermal Collectors

UNIT – II SOLAR WATER HEATING SYSTEMS 9L+10P

Forced Circulation systems – Low Flow Pumped Systems - Natural Circulation systems – Integral Collector Storage Systems – Retrofit Water Heaters – Water heating in Space Heating and Cooling Systems – Hot water and Steam for Industrial Process Heat systems – Testing and Rating of Solar Water Heaters – Economics analysis.

UNIT – III SOLAR COOLING SYSTEMS 9L

Solar Cooling: Absorption Cooling, Desiccant Cooling, Mechanical Cooling – Solar Related Air Conditioning – Passive Cooling - Combined Solar Heating and Cooling

UNIT – IV SOLAR THERMAL APPLIANCES 9L+10P

Principle, Types, Construction, Thermodynamic analysis, Performance improvement techniques, Economics, Environmental impact, Merits and Demerits of:

Direct and Indirect Solar Cooking systems – Solar food processing system – Solar Desalination, Solar powered HDH system – Solar PV/T system - Solar Furnace – Solar Chimney –Solar Thermal Power Plants.

UNIT – V DESIGN AND MODELING OF SOLAR THERMAL SYSTEMS 9L

Active Systems: The f - Chart Method for Liquid Systems and Air Systems – Utilizability Methods – The $\bar{\emptyset}$, f-chart Method

Passive System : Solar – Load Ratio Method – Unutilizability Deign method – Design of Hybrid Systems

TOTAL: 75 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

1. Elucidate the technical process of solar thermal collectors
2. Explicate the spectrum of possible water heating system to assist the industrial process
3. Articulate the technical and economic viability of solar cooling systems
4. Measure and evaluate different solar energy technologies through knowledge of the physical function of the devices
5. Design the solar thermal systems and an accessible way to a target group with basic technical skills.

REFERENCES:

1. Soteris A. Kalogirou, “Solar Energy Engineering Processes and Systems”, Academic Press, 2014
2. John A. Duffie and William A. Beckman, “Solar Engineering of Thermal Processes”, Wiley, 2013

3. HP Garg and J Prakash, “Solar Energy: Fundamentals and Applications”, Tata McGraw Hill, 2010.
4. S. P. Sukhatme, J K. Nayak, “Solar Energy”, McGraw Hill, New Delhi, 2017, Fourth Edition.
5. Goswami .D.Y, Kreith .F, Kreider .J.F, “Principles of Solar Engineering”, Taylor and Francis, 2003.

Practical

1. Evaluate the thermal performance of Solar Water Heater in Thermo-Syphon mode.
2. Evaluate the thermal performance of Solar Water Heater in forced convection mode.
3. Effect of varying wind load on Solar water heater in Thermo-Syphon and Forced Convection mode.
4. Performance of solar water heater with varying inclination angle of collector
5. Performance enhancement of solar box cooker with and without thermal energy storage system.
6. Performance evaluation of different Solar Stills.
7. Performance enhancement of Solar Air Collector for drying application (Active and passive type).
8. Augmentation of heat transfer on Parabolic Trough Collector with various absorber tubes.
9. Performance study on Solar dish collectors for various applications.
10. Performance study on PVT Air Collector using different HTF
11. Study of solar thermal system using Thermal image camera

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	-	3	2	3	1
2	2	-	3	-	3	1
3	2	-	3	-	3	1
4	2	-	3	-	3	2
5	3	-	3	2	3	1
Avg	**2.4**	**-**	**3**	**2**	**3**	**1.2**

EY3251 COMPUTATIONAL FLUID DYNAMICS FOR ENERGY SYSTEMS

L	T	P	C
3	1	0	4

OBJECTIVE:

To make students familiarize with the concepts of discretization techniques using finite difference and finite volume method for various transport phenomena related problems.

UNIT – I GOVERNING DIFFERENTIAL EQUATIONS AND DISCRETISATION TECHNIQUES 12

Basics of Heat Transfer, Fluid flow – Mathematical description of fluid flow and heat transfer – Conservation of mass, momentum, energy, and chemical species - Classification of partial differential equations – Initial and Boundary Conditions – Discretization techniques using finite difference methods – Taylor's Series - Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT – II DIFFUSION PROCESSES: FINITE VOLUME METHOD 12

Steady one-dimensional diffusion, Two and three dimensional steady state diffusion problems, Discretization of unsteady diffusion problems – Explicit, Implicit and Crank-Nicholson's schemes, Stability of schemes.

UNIT – III CONVECTION - DIFFUSION PROCESSES: FINITE VOLUME METHOD 12

One dimensional convection – diffusion problem, Central difference scheme, upwind scheme – Hybrid and power law discretization techniques – QUICK scheme. – Assessment of discretization scheme properties.

UNIT – IV INCOMPRESSIBLE FLOW PROCESSES: FINITE VOLUME METHOD 12

Discretization of incompressible flow equations – Stream Function – Vorticity methods - Pressure based algorithms, SIMPLE, SIMPLER, SIMPLEC & PISO algorithms.

UNIT – V TURBULENCE 12

Kolmogorov's Theory - Turbulence - Algebraic Models, One equation model & $k – \varepsilon$, $k – \omega$ models - Standard and High and Low Reynolds number models.

TOTAL: 60 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Know the differences between various discretization techniques.
CO2 Learn the finite volume based numerical method for solving diffusion heat transfer problems.
CO3 Learn the finite volume based numerical method for solving convection-diffusion heat transfer problems.
CO4 Understand the discretization of incompressible flow governing equations
CO5 Recognize the impact of various turbulence modelling

REFERENCES:

1. Versteeg and Malalasekera, N, "An Introduction to computational Fluid Dynamics The Finite Volume Method," Pearson Education, Ltd., Second Edition, 2014.
2. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., "Computational fluid Mechanics and Heat Transfer "Hemisphere Publishing Corporation, New York, USA,1984
3. Subas, V.Patankar, "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 1980.

4. Tapan K. Sengupta, “Fundamentals of Computational Fluid Dynamics” Universities Press, 2011.
5. Muralidhar, K., and Sundararajan, T., “Computational Fluid Flow and Heat Transfer”, Narosa Publishing House, 2nd edition, 2003.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	3	3	2	-
2	3	-	3	3	2	-
3	3	-	3	3	2	-
4	1	-	3	3	2	-
5	1	-	3	3	2	-
Avg	**2.2**	**-**	**3**	**3**	**2**	**-**

SY3211	ANALYSIS AND SIMULATION LABORATORY FOR SOLAR ENERGY	L	T	P	C
		0	0	4	2

OBJECTIVES:

Learn the simulation analysis software(s) and get expertise with the computational procedure to study the behavior of various solar photovoltaic and thermal energy systems and numerically solve the problems related to solar energy technology, heat transfer & fluid flow

LIST OF EXPERIMENTS

1. Heat transfer analysis:
   (a) Conduction
   (b) Convection – Internal flow & Velocity boundary layer
   (c) Radiation
2. Design and numerical analysis of a solar flat plate collector
3. Design and numerical analysis of a solar photovoltaic panel
4. Design and numerical analysis of a solar air dryer & solar still
5. Design and numerical analysis of a thermal energy storage tank
   (a) Sensible heat medium
   (b) Latent heat medium
6. Performance study of a solar photovoltaic panel involving shading effects
7. Numerical analysis in the receiver section of a concentrating solar collector with varying heat transfer fluids
8. Numerical analysis of critical radius of insulation in a pipe carrying hot fluid
9. Numerical heat transfer analysis in a helical coil tube
10. Study experiment on,
   (a) IoT applications for a solar farm.
   (b) Drone applications for solar farm surveying, mapping, and inspection
   (c) Rooftop PV planning and Hybrid PV system
11. Simulation of Thermal Power Plant Cycles, Configuration, Instrumentation and Controls

TOTAL: 60 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Use modern software tools to simulate, analyze and optimize any solar PV / thermal system

CO2 Investigate the various process parameters influencing the performance of the solar PV / thermal system

CO3 Illustrate the outcomes in brief containing the details of the domain analyzed in the form of a detailed report

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	-
2	3	3	3	3	3	-
3	3	3	3	3	3	-
Avg	**3**	**3**	**3**	**3**	**3**	**-**

SY3212 **SUMMER INTERNSHIP**

L	T	P	C
0	0	0	2

OBJECTIVE:

To understand, learn and apply the principles and practices of Solar Thermal and Solar Photovoltaic systems.

GUIDELINES:

- Each student has to undergo Industrial training for a minimum period of four weeks during the upcoming summer vacation (i.e., between II and III Semester).
- The Internship has to be undergone continuously for the entire period.
- The Internship must be carried out in a solar related industry
- The End Semester Examination must be conducted at the start of III Semester.
- The mark will be based on the project report (Introduction; Project or Training details; Techno Economics; Discussion; and Conclusion) and their presentation followed by oral examination on the same by internal examiner.

TOTAL: -

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Apply the solar energy principles in various systems

CO2 Assess the performance of solar PV / thermal system

CO3 Prepare and present a detailed project report professionally

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
Avg	3	3	3	3	3	3

SY3311	PROJECT WORK – I	L	T	P	C
		0	0	12	6

OBJECTIVE:
The main learning objective of this course is to prepare the students for identifying a specific problem for the current need of the society and or industry, through detailed review of relevant literature, developing an efficient methodology to solve the identified specific problem.

GUIDELINES:

- Each PG student shall work individually on a selected specific topic in the area of **SOLAR ENERGY** which shall be approved by the Head of the Division under the supervision of a Faculty Member (Guide / Supervisor) who is familiar in the selected specific topic. The selected specific topic maybe theoretical and or experimental and or simulation and or case study. The students' Project Work – Phase I shall be evaluated through Internal Examination and End Semester Examination.
- The Internal Examination must be conducted periodically (Zeroth, First, Second and Third) through Project Work Review Presentation Meetings followed by questions from the panel of Review Committee Members comprising of two expert faculty members and a project coordinator.
- At the end of the semester, a detailed report on the work done by the PG student must be submitted with the approval from the Guide/Supervisor and the Review Committee Members. The Project Work – Phase I Report must contain the Introduction with clear definition along with detailed review of relevant literature on the selected specific problem; an efficient methodology to solve the selected specific problem along with necessary hypothesis and or experimental setup and or simulation and or case study for carrying out the research project work along with preliminary results; discussions, relevant conclusions and future direction along with specified references.
- The End Semester Examination must be conducted through Project Work Presentation followed by questions from the panel of Examiners comprising an External Examiner and Project Coordinator as Internal Examiner.

TOTAL: 180 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:

CO1 Demonstrate a sound technical knowledge in their selected project topic.

CO2 Select and identify the problem statement along with scope and boundary; assimilate detailed review of relevant literature; formulate an efficient methodology to solve the selected specific problem.

CO3 Propose engineering design solutions to complex problems using a systematic approach.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
Avg	**3**	**3**	**3**	**3**	**3**	**3**

SY3411	PROJECT WORK – II	L	T	P	C
		0	0	24	12

OBJECTIVE:
The main learning objective of this course is to prepare the students for solving the specific problem for the current need of the society and or industry, through the formulated efficient methodology, and to develop necessary skills to critically analyse and discuss in detail regarding the project results and making relevant conclusions.

GUIDELINES:
- The student may continue to work on the Project Work – I's selected topic as per the formulated efficient methodology under the same Faculty Member (Guide/Supervisor). The students' Project Work – II shall be evaluated through Internal Examination and End Semester Examination.
- The Internal Examination must be conducted periodically (First, Second and Third) through Project Work Review Presentation Meetings followed by questions from the panel of Review Committee Members comprising of two expert faculty members and a project coordinator.
- At the end of the semester, a detailed report on the work done by the PG student must be submitted with the approval from the Guide/Supervisor and the Review Committee Members. The Thesis (Project Work – II Report) must contain the Introduction with clear definition along with detailed review of relevant literature on the selected specific problem; an efficient methodology to solve the selected specific problem along with necessary theoretical hypothesis and or experimentation and or simulation and or case study for carrying out the research project work along with complete results with critical analysis and detail discussions, followed by relevant conclusions, along with specified references.
- The End Semester Examination must be conducted through Project Work Presentation followed by questions from the panel of Examiners comprising an External Examiner and Project Coordinator as Internal Examiner.

TOTAL: 360 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Demonstrate a sound technical knowledge in their selected project topic.
CO2 Propose product design & development solutions to complex problems using a systematic approach.
CO3 Demonstrate the knowledge, skills and attitudes of a professional engineer to take up any challenging practical problem in the field of engineering design and find optimum solutions to it.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
Avg	**3**	**3**	**3**	**3**	**3**	**3**

SY3001 SOLAR POWER GENERATION TECHNOLOGIES AND POLICIES

L	T	P	C
3	0	0	3

OBJECTIVES:

The objective of this course is to provide in-depth knowledge to students on power generation and distribution based on solar thermal and solar PV energy conversion principles. In addition, this course is intended to impart knowledge on students about energy policies in India and across the globe.

UNIT – I SOLAR THERMAL POWER GENERATION 9

Solar Parabolic trough - Design considerations, tracking and control systems - Thermal design of receivers - Solar parabolic dish - Design considerations, Sterling engine, Brayton cycle, tracking and control systems - Solar tower concepts - Tower design - Heliostat design - Receiver types, tracking and control systems - Performance study, site selection and land requirement for the above technologies - Techno-economic analysis of solar thermal power plants.

UNIT – II SOLAR PHOTOVOLTAIC POWER GENERATION 9

Solar PV technologies overview - Stationary and concentrated PV - Inverter and control technologies - Master slave inverter system design - Standalone systems - Grid connected systems - Hybridization, synchronization, and power evacuation - Site selection and land requirements - Techno-economic analysis of solar PV power plants - Environmental considerations, Recent developments in solar PV materials.

UNIT – III SOLAR ENERGY POLICY PLANNING 9

Elements in policy making in solar energy - Components of policy making - Essentials and other requirements - Pre-requirements of policy planning - Models for planning for effective policy making - Data requirements for policy plans - Monitoring and assessments of policies - Global policy pronouncement.

UNIT – IV SOLAR ENERGY REGULATIONS AND POLICY PROGRAMMES 9

Legislations guiding solar energy sector - Critical review of various programs of government – State regulations - Jawaharlal Nehru National Solar Mission (JNNSM) - JNNSM Regulations regarding grid interconnected solar energy systems – Solar Energy policy – 2021.

UNIT – V POLICY MANAGEMENT CHALLENGES 9

Challenges for planning and policies - Issues of subsidization - Entrepreneurship development and management challenges - Issues in entrepreneurship development and management challenges in renewable energy sector in India – Production – Storage - Transmission and distribution - End-use - Pricing, etc

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Design power generation based on solar thermal power technologies.
CO2 Design power generation based on stand-alone and concentrating PV technology.
CO3 Know the Indian and global energy policy scenario.
CO4 Know the Indian and global energy policy programme
CO5 Understand the challenges in energy policy management.

REFERENCES:

1. Stefan C. W. Krauter,” Solar Electric Power Generation - Photovoltaic Energy Systems: Modeling of optical and thermal performance, electrical yield, energy balance, effect on

reduction of greenhouse gas emissions”, Springer, 2006.
2. JA Duffie and WA Beckman, “Solar Engineering of Thermal Processes”, John Wiley & Sons, 2006.
3. Jayarama Reddy, “Solar Power Generation: Technology, New Concepts & Policy”, CRC Press, 2012.
4. VVN Kishore, “Renewable Energy Engineering and Technology – A Knowledge Compendium”, TERI Press, 2008.
5. CS Solanki, “Solar Photovoltaics – Fundamentals, Technologies and Applications”, PHI Learning Pvt. Ltd., 2011.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	3	-	2	-
2	3	-	3	-	-	-
3	3	-	3	-	-	3
4	3	-	3	-	-	3
5	3	-	3	-	-	3
Avg.	**3**	**-**	**3**	**-**	**2**	**3**

SY3002 SOLAR ENERGY APPLICATIONS

	L	T	P	C
	3	0	0	3

OBJECTIVES:

The major objective of this course is to enable students to learn the working principle of different solar energy appliances such as PV cell, solar furnace, solar desalination system and solar-pumped laser technology. This course will also help students to understand the different ways of improving its operating efficiency.

UNIT – I SOLAR LIGHTING 9

Solar cell – Working principle of a solar cell – Solar home lighting systems – Solar street lighting systems - Solar lanterns – Applications - Rural electrification process – Case studies

UNIT – II SOLAR COOKING 9

Introduction – Types of solar cookers – Advantages and disadvantages - Box type – Parabolic dish cooker - Performance evaluation of solar cookers – Testing of a solar cooker – Applications of solar cooking – Institutional Solar cookers – Solar cooking promoters - Case studies.

UNIT – III SOLAR FURNACE 9

Introduction – Types of solar furnaces – Components of solar furnaces – Concentrator – Heliostat – Sun tracking – Typical solar furnace designs – Single concentrator furnace – Single heliostat solar furnace - Multiple heliostats solar furnace - Case studies on solar furnaces.

UNIT – IV SOLAR DESALINATION 9

Introduction – Necessity for desalination – Study on various desalination techniques – Comparison between conventional and solar desalination – Basics of solar still - Simple solar still– Material problems in solar still – Solar disinfection and its methods – Case studies on various desalination techniques.

UNIT – V SOLAR LASER 9

Solar-pumped solid-state laser theory - solar pumped Nd:YAG laser principle and operation, laser material selection, multi-mode solar pumped laser technology, high brightness solar pumped lasers, solar tracking errors in solar pumped laser – methods to improve efficiency, applications

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Familiar with concepts of solar home lighting and solar street lighting systems.
CO2 Identify the solar cooker technologies for suitable applications.
CO3 Design solar furnace of a known rating capacity
CO4 Aware about various desalination techniques and material problems in solar still
CO5 Apply the principles of solar-pumped laser and critically analyze the system

REFERENCES:

1. Suhatme and Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 2008.
2. HP Garg and J Prakash: Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 2010.
3. Rai, G.D., Solar Energy Utilization, Khanna Publishers, Delhi, 2010.
4. Michael Grupp, Time to Shine: Applications of Solar Energy Technology, John Wiley & Sons, 2012.

5. SM Sze, Kwok K Ng: Physics of semiconductor devices, third edition, John Wiley & Sons, 2007.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	3	-	3	1
2	3	-	3	-	3	1
3	3	-	3	-	3	1
4	3	-	3	-	3	1
5	3	-	3	-	3	-
Avg.	**3**	**-**	**3**	**-**	**3**	**1**

SY3003 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

	L	T	P	C
	3	0	0	3

OBJECTIVES:

The objective of this course to enhance the knowledge of the students on design and implementation of power electronic devices for off-grid and grid connected renewable energy systems. This course will also help students to address power quality issues in renewable energy systems.

UNIT – I INTRODUCTION TO RENEWABLE ENERGY SYSTEMS 9

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems

UNIT – II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9

Renewable energy conversion systems: fundamental principle of operation of self-excited induction generator, squirrel cage induction generator, doubly fed induction generator, synchronous generator, permanent magnet synchronous generator; Grid related problems: harmonic reduction and power factor improvement

UNIT – III POWER CONVERTERS 9

Solar: Block diagram of solar photo voltaic system - Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing

Wind: three phase AC voltage controllers – AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters. Power Quality Measurements.

UNIT – IV ANALYSIS OF WIND AND PV SYSTEMS 9

Stand-alone operation of fixed and variable speed wind energy conversion systems and solar system- Grid connection Issues -Grid integrated PMSG and SCIG Based WECS Grid Integrated solar system

UNIT – V HYBRID RENEWABLE ENERGY SYSTEMS 9

Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PV Maximum Power Point Tracking (MPPT).

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Analyze the various conversion techniques in renewable energy technologies

CO2 Apply the various mechanisms for the conversion of renewable energy sources.

CO3 Identify the appropriate power converters for renewable energy systems.

CO4 Implement the different conversion mechanisms for wind and solar systems.

CO5 Recognize the importance of various hybrid renewable energy systems

REFERENCES:

1. Leon Freris, David Infield, “Renewable energy in power systems”, John Wiley & Sons, 2008.
2. Rashid .M. H “power electronics Hand book”, Academic press, 2007.
3. Rai. G.D, “Non-conventional energy sources”, Khanna publishes, 2010.

4. Ali Keyhani, “Design of Smart Power Grid Renewable Energy Systems”, John Wiley & Sons, 2011.
5. S.N. Bhadra, D. Kastha, “Wind Electric Systems”, Oxford University press, 2005.
6. L. Umanand, “Power Electronics: Essentials and Applications”, Wiley India, 2009.
7. Erickson, Maksimovic, and Dragan “Fundamentals of Power Electronics”, Kluwer academic publishers, 2001.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	3	-	1	1
2	3	-	3	-	1	1
3	3	-	3	-	2	1
4	3	-	3	-	2	1
5	3	-	3	-	2	1
Avg.	**3**	-	3	-	1.6	1

SY3004 **SMART GRIDS**

	L	T	P	C
	3	0	0	3

OBJECTIVES:

The objective of this course is to enable the students to acquire knowledge on smart grid, different options of architectural design and communication technology for various aspects of smart grid. This course will also help students to carry out system and stability analysis in smart grid, renewable energy sources and storage integration with smart grid

UNIT – I INTRODUCTION TO SMART GRIDS 9

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid.

UNIT – II SMART GRID TECHNOLOGIES (Transmission) 9

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection, and control.

UNIT – III SMART GRID TECHNOLOGIES (Distribution) 9

DMS, Voltage control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV)..

UNIT – IV SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit (PMU), Intelligent Electronic Devices (IED) & their application for monitoring & protection.

UNIT – V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Students will develop more understanding on the concepts of Smart Grid and its present developments.

CO2 Students will study about different Smart Grid technologies.

CO3 Students will acquire knowledge about different smart meters and advanced metering infrastructure.

CO4 Students will have knowledge on power quality management in Smart Grids

CO5 Students will develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

REFERENCES:

1. Vehbi C. Güngör, Dilan Sahin, Taskin Kocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, “Smart Grid Technologies: Communication Technologies and Standards”, IEEE Transactions On Industrial Informatics, November 2011.

2. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang “Smart Grid – The New and Improved Power Grid: A Survey”, IEEE Transaction on Smart Grids.
3. Stuart Borlase “Smart Grid: Infrastructure, Technology and Solutions”, CRC Press, 2012.
4. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley, 2012
5. Fabio Toledo “Smart Metering Handbook”, PennWell Corporation, 2013.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	-	3	-	-	3
2	2	-	3	-	-	-
3	1	-	3	-	-	-
4	1	-	3	-	-	-
5	1	-	3	-	2	-
Avg.	1.4	-	3	-	2	3

SY3005	SOLAR PASSIVE ARCHITECTURE	L	T	P	C
		3	0	0	3

OBJECTIVES

To make aware of the importance and to facilitate students with the required knowledge of passive solar architecture, passive systems for both heating and cooling of buildings

UNIT – I INTRODUCTION 9

Need for passive architecture - Building form and functions – General aspects of solar passive heating and cooling of buildings – Thumb rules - Thermal comfort – Sun's motion – Building orientation and design – Heat transfer in buildings.

UNIT – II CLIMATE AND HUMAN THERMAL COMFORT 9

Factors affecting climate - Climatic zones and their characteristics – Urban climate – Microclimate - Implications of climate on building design - Principles of energy conscious design - Building materials - Embodied energy of building materials - Alternative building materials.

UNIT – III PASSIVE COOLING OF BUILDINGS 9

Passive cooling concept - Solarium Passive cooling - Ventilation cooling - Nocturnal radiation cooling - Evaporative cooling - Roof surface evaporative cooling (RSEC) - Direct evaporative cooling using drip-type (desert) coolers — Radiation cooling - Earth coupling - Basic principles and systems.

UNIT – IV PASSIVE SOLAR HEATING OF BUILDINGS 9

Direct gain – Indirect gain – Isolated gain - Passive heating concept - Thermal modeling of passive concepts – Thermal storage wall and roof – Sunspace – Prediction of heating loads in abuilding.

UNIT – V BUILDING RATING SYSTEMS 9

Zero energy building concept and rating systems - Energy conservation building codes – Energy management of buildings – Green globe assessment Standards – BREEAM – CASBEE – Greenstar– Review of CDM Techniques - GRIHA and others.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 The fundamental concepts of solar passive architecture were understood along with examples and case studies.

CO2 The concepts of passive solar heating and cooling of buildings, human comfort conditions.

CO3 Aware about various building materials.

CO4 Know the zero energy building concept and rating systems.

CO5 Learn the energy management of buildings and green globe assessment standards.

REFERENCES:

1. Jan F. Kreider, "The solar heating design process: active and passive systems", McGraw-Hill, 2007.
2. David A. Bainbridge, Ken Haggard, Kenneth L. Haggard, "Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting, and More Using Natural Flows", Chelsea Green Publishing, 2011.
3. VVN Kishore, "Renewable Energy Engineering and Technology – A Knowledge Compendium", TERI Press, 2008.

4. Givoni Baruch,"Passive and Low Energy Cooling of Buildings", Van Nostrand Reinhold, 1994
5. Sodha, M., Bansal, N. K., Bansal, P. K., KuMEB, A., and Malik, M. A. S., "Solar Passive Buildings", Pergamon Press, Oxford, 1986

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	1	3	-	-	-
2	1	1	1	-	3	-
3	3	1	3	2	3	-
4	3	1	3	2	3	-
5	2	3	3	-	3	3
Avg.	**2.4**	**1.4**	**2.6**	**2**	**3**	**3**

SY3006 NANOMATERIALS FOR SOLAR SYSTEMS

	L	T	P	C
	3	0	0	3

OBJECTIVES:

To understand the significance, need and applications of nanomaterials for solar systems and to impart the knowledge on latest cutting-edge technologies in the field of fuel cell.

UNIT – I PROPERTIES OF NANOMATERIALS 9

Introduction to nanomaterial, Structure and Bonding in Nanomaterials, Classification of nanomaterials, bulk materials and nanomaterials, nanomaterials of silicon, silver, gold. Synthesis of Nano Materials, General methods of preparation of nanomaterials, Properties and Size dependence of properties - Nanomaterial characterization techniques. Nanowires, nanostructures, nanocomposites, SWCNT, MWCNT

UNIT – II NANOMATERIALS FOR SOLAR THERMAL CONVERSION 9

Conversion of thermal energy - Nanostructures and nanomaterials, materials selection criteria, particle-scale effect. Phase compositions on nanoscale microstructures. Nanoparticles for conduction heat transfer, coatings on fins.

UNIT – III NANO APPLICATIONS IN THERMAL ENERGY STORAGE 9

Basics of thermal energy storage systems. Application of nanomaterials in solar thermal energy production and storage systems - Sensible, latent heat and chemical energy storages. Nano encapsulated phase change materials in cooling applications. Nanotechnology for electrochemical energy storage.

UNIT – IV NANOMATERIALS FOR PHOTOVOLTAICS 9

Photochemical solar cells, PV panels with nanostructures. Phase compositions on nanoscale microstructures – role of nanostructures and materials – nanomaterials in solar photovoltaic technology- band gap engineering and optical engineering - tandem structures - quantum well and quantum dot solar cells - photo-thermal cells – organic solar cells. Performance and reliability of nanomaterials based solar cells.

UNIT – V NANOMATERIALS IN FUEL CELL APPLICATIONS 9

Use of nanostructures and nanomaterials in fuel cell technology - high and low temperature fuel cells, cathode and anode reactions, fuel cell catalysts, electrolytes, ceramic catalysts. Use of nanotechnology in hydrogen production and storage.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Know the properties of nanomaterials and types

CO2 Apply the appropriate nanomaterials for thermal application

CO3 Comprehend the nanomaterial usage in thermal storage application

CO4 Understand the use of nanomaterial in photovoltaics

CO5 Recognize and choose appropriate nanomaterials for fuel cells

REFERENCES:

1. Nano Technology for Energy Challenge,Garcia-Martinez .J Wiley- H Weinheim, 2010.
2. Nano forms and Applications, Maheshwar Sharon, Madhuri Sharon,McGraw-Hill, 2010.
3. Nanotechnology for Photovoltaic"s, Tsakalakos .L,CRC, 2010.
4. Environmental Nano Technology: Applications and Impacts of nanomaterials, Wiesner .M.R and Bottero .J.Y,Tata McGraw-Hill, 2017.
5. The Physics and Chemistry of NanoSolids by Frank J. Owens and Charles P. Poole Jr, Wiley-Interscience, 2008

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	-	-	3	-	2	-
2	-	-	3	-	2	-
3	-	-	3	-	2	-
4	-	-	3	-	2	-
5	-	-	3	-	2	-
Avg.	**-**	**-**	**3**	**-**	**2**	**-**

SY3007 DESIGN OF SOLAR ENERGY STRUCTURES

	L	T	P	C
	3	0	0	3

OBJECTIVES:

The Objective of the course is to apply the structural analysis concepts and wind load calculation for solar energy system structure design.

UNIT – I PREAMBLE TO STRENGTH OF MATERIALS 9

Concepts and principles of strength of materials - Stress and strain, tension, compression, stress-strain diagram. Thermal stresses, principal plane, principal stress, maximum shearing stress. Cylinders and spherical shells.

UNIT – II PRINCIPLE OF STRUCTURES 9

Principles of structural analysis. types of structures and loads, normal force, shear force, bending moment and torsion. Analysis of pin-jointed trusses, cables, arches. Bending, shear, torsion of beams, composite beams, deflection of beams. Complex stress and strain.

UNIT – III STRUCTURAL ANALYSIS 9

Analysis of statically determinate structures. Principle of superposition, determinacy and stability. Analysis of simple diaphragm and shear wall systems, analysis of statically indeterminate structures. Influence lines, structural instability. Approximate analysis of statically indeterminate structures.

UNIT – IV ANALYSIS OF FRAMES, TRUSSES AND COMPOSITE STRUCTURES 9

Vertical and lateral loads on building frames. External work and strain energy. Force method of analysis - Frames, trusses, composite structures. Displacement method of analysis - Beams, frames. moment distribution for beams, frames. Fundamentals of the stiffness method. Matrix analysis of trusses, beams and frames by the direct stiffness method.

UNIT – V WIND LOADS 9

Wind load on building structures, wind load on solar collectors and PV panels mounted on the roof. Barriers - Varieties of materials and air barrier configuration.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Apply the concepts of strength of materials for solar structure problems

CO2 Understand the principle of structures

CO3 Analyse the structure statistically for its stability and fitness

CO4 Follow different methods of load calculation to examine the various structures for its stability

CO5 Recognize importance of wind load on solar system structures and calculate wind load

REFERENCES:

1. Rajan .S.D, “Introduction to Structural Analysis and Design”, John Wiley and Sons, 2001.
2. Dyrbye .C, “Wind Loads on Structures”, 3rd edition, John Wiley, 1997.

3. Ramamrutam .S, “Strength of Materials”, 16th edition, Danpat Rai Publ.,2010.
4. Mc Cormac .J.C, “Structural Analysis: Classical and Matrix Methods”, 4th ed., Wiley, 2007.
5. Leet .K, “Fundamentals of Structural Analysis”, 3rd edition., McGraw-Hill, 2008.
6. Al Nageim .H, “Structural Mechanics: Loads”, Analysis, Design and Materials, 7th edition, Prentice Hall, 2010.
7. Hibbeler .R.C., “Structural Analysis”, 7th edition., Prentice Hall, 2009.

CO - PO MAPPING

CO	PO					
	1	2	3	4	5	6
1	3	-	3	2	3	-
2	3	-	3	2	3	-
3	3	-	3	2	3	-
4	3	-	3	2	3	-
5	3	-	3	2	3	-
Avg.	**3**	**-**	**3**	**2**	**3**	**-**

SY3008 MATERIALS FOR SOLAR DEVICES

	L	T	P	C
	3	0	0	3

OBJECTIVES:

To comprehend the materials that has been implicated in various forms of solar energy sources and its storages and to impart knowledge on solar system balance and analysis with reference to its cost.

UNIT – I MATERIALS FOR SOLAR COLLECTORS 9

Collector Materials for Low, Medium and High Temperature Applications - Glazing Materials, Optical Materials - Absorber Coatings, Insulations, Desiccants, Use of Plastics - Reliability and Durability of Solar Collectors - Environmental Degradation of Low Cost Solar Collectors.

UNIT – II MATERIALS FOR SOLAR CELLS 9

Crystalline Structure - Fundamental Principles of Energy Bands – Band Gap – Types of Semiconductors – Doping and influence of impurities on energy levels – Element and Compound Semiconductors – Structure of Silicon solar cell – Fabrication and Optimization of solar cells – Amorphous silicon solar cells.

UNIT – III THIN FILM AND NOVEL SOLAR CELL MATERIALS 9

Cadmium Telluride, Galium-Arsenic, GaInP / GaAs / Ge - Thin Film, Single Crystalline, Polycrystalline Materials - Multi Junction and Tandem Junction Solar Cells - Low Cost and High Efficiency Materials - Conversion Efficiency of Solar Cells. – Perovskite solar cells - Dye-sensitized Organic solar cells.

UNIT – IV ENERGY STORAGE MATERIALS 9

Thermal Storage Concepts - Materials for Sensible and Latent Heat Energy Storage. Organic, Inorganic Eutectic Materials, Materials for Low and High Temperature Storage Applications. Chemical storage Concepts - Rechargeable Batteries – Types, Operating range, Comparison and suitability for various applications - Super Capacitors

UNIT – V BALANCE OF SYSTEM MATERIALS & COST ANALYSIS 9

Functional requirements of other materials for components like Inverters, Charge Controllers, Wires, Pipes, Valves, Identification of suitable materials - Simple Cost Analysis for alternative selection of materials - Case studies.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 The students will get fundamental understanding on principles of materials used in solar cells.

CO2 The students will be able to understand the structure-property relationship and appreciate novel developments in the materials.

CO3 To explain the concept and the diverse materials used for solar devices.

CO4 To explicate in depth knowledge of about solar cells, thermal energy storage and electrical energy storages.

CO5 To gather some idea of system balance and analysis with reference to its cost.

REFERENCES:

1. Ibrahim Dincer and Marc A Rosan, “Thermal Energy Storage: Systems and Applications”, John Wiley, 2003.
2. Sukhatme and Nayak , “Solar Energy: Principles Of Thermal Collection & Storage”, Tata Mc GrawHill, 2008.
3. Nelson, J, The “Physics of Solar Cells”, Imperial College Press, 2003.
4. Jef Poortmans and Vladimir Arkhipov, Thin Film Solar Cells, John Wiley and Sons, 2008. Thomas Markvart, Solar Electricity, John Wiley and Sons, 2007.
5. A.R. Jha, “Solar Cell Technology and Applications”, Aurbach Publications, 2010.

CO – PO MAPPING

CO	PO					
	1	2	3	4	5	6
1	1	-	3	-	3	1
2	1	-	3	-	3	1
3	1	-	3	-	3	1
4	1	-	3	-	3	1
5	2	-	2	-	2	1
Avg.	**1.2**	**-**	**2.8**	**-**	**2.8**	**1**

SY3009 **SOLAR PV POWER PLANT DESIGN**

L	T	P	C
3	0	0	3

OBJECTIVE:

The objective of this course is to provide in-depth knowledge to students on design of Solar Photovoltaic power plant along with its system components.

UNIT – I SELECTION OF SITE AND SHADOW ANALYSIS 9

PV module structure inter row spacing calculation - Pitch analysis - Selection of PV module tilt angle - Near shading object calculation - Site survey and plant assessment - Type of solar radiation – Irradiance assessment and comparison - Solar Radiation Data - Sun path Diagram - Defining the Position of the Sun - Solar Altitude - Geometric Effects - Tilting Solar Modules

UNIT – II SELECTION OF PV MODULE (CELLS AND BOM) AND SIZING 9

Types Crystalline module cells - Manufacturing process of PV cells - Comparison between mono crystalline - Selection of PV cells - Selection of front and rear sheet - Selection of PV module glass - Selection of EVA sheet , Bus bar and frame - Characteristics of a Solar Cell

Power Characteristics of a Solar Cell - Fill factor and Equivalent Solar cell Circuit - STC and NOCT – Solar cable selection.

UNIT – III INVERTERS SELECTION AND SIZING (GRID CONNECTION AND OFF GRID) 9

Types of solar inverter - Selection of string /central / off grid inverter - Selection of power conditioning unit (PCU) - Sizing of solar inverter for roof top and grid connected projects - Selection and sizing of string inverter - Selection and sizing of central inverter - AC/DC overloading calculation and losses - Protection requirement of solar inverter - Passive and active protection - Anti- islanding protection - Mounting arrangement of string inverter - IEC/IEEE /Grid Compliance of inverters - Grid-Connected Inverters vs. Stand-Alone Inverters - Inverter Communication and remote monitoring - Inverter Products For Use In India – BoS Selection.

UNIT – IV SOLAR POWER PLANT SUBSTATION AND SWITCHYARD 9

Preparation of Protection SLD - Selection and sizing of Substation - Preparation of ring main and redial feeder SLD - Selection and sizing of Power transformer - Selection and sizing of Current transformer - Selection and sizing of PT/Isolator/Breaker - Construction of 33KV/132 KV substation - Construction of four pole structure - Construction of metering switchyard - Selection sizing of switchyard earthing

UNIT – V SOLAR POWER SYSTEM YIELD PERFORMANCE 9

Determining the Size of the DC and AC Cables - Losses in a Grid-Connected PV System - Preliminary Planning - Calculating the Energy Yield for a PV Grid-Connected System - Specific Yield - Performance Ratio - CUF Calculation - System Maintenance – Troubleshooting – Simple pay back calculation – Life cycle costing.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Analyse the site selection and impact of shadow
CO2 Selection and sizing of PV module for Solar Power Plant
CO3 Provide the details on selection of inverter for the suitable applications
CO4 Select proper selection and design for substation and switchyard
CO5 Design and simulate the performance and economic projection of PV plants

REFERENCES:

1. Peter Gevorkian, "Large-Scale Solar Power System Design: An Engineering Guide for Grid-Connected Solar Power Generation", The McGraw-Hill Companies, 2011
2. A. Goetzberger, V. U. Hoffmann, Volker Uwe," Photovoltaic Solar Energy Generation", Springer-Verlag Berlin Heidelberg, 2005.
3. Chetan Singh Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", PHI, 2011.
4. Davood Naghaviha, Hassan Nikkhajoei, Houshang Karimi, "Step-by-Step Design of Large-Scale Photovoltaic Power Plants", Wiley Publishers.
5. Rabindra Kumar Satpathy, Venkateswarlu Pamuru, "Solar PV Power: Design, Manufacturing and Applications from Sand to Systems", Academic Press Inc, 2020

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1		3	-	-	3	3
2	3	3	-	-	3	2
3	3	3	-	-	3	2
4	3	3	-	-	3	2
5	3	3	-	-	3	2
Avg	**3**	**3**	-	-	**3**	**2.2**

EY3057 ENERGY FORECASTING, MODELLING AND PROJECT MANAGEMENT

L	T	P	C
3	0	0	3

OBJECTIVE:

Gain an understanding of the energy situation at both the national and global levels and utilize available resources to predict and model energy demand while considering current policies.

UNIT – I ENERGY STRUCTURE 9

Role of energy in economic development and social transformation: GDP, GNP and its dynamics – Energy Sources and its Overall demand – Energy Consumption in various sectors and its changing pattern – National & State Level Energy Issues – Status of Renewable Energy: Present and future.

UNIT – II FORECASTING MODEL 9

Qualitative & Quantitative Forecasting Techniques – Regression Analysis – Double Moving Average – Double and Triple Exponential Smoothing – ARIMA model – Delphi technique – Methods for renewable energy forecasting – Application of forecasting to power system management and markets.

UNIT – III OPTIMIZATION MODEL 9

Principles of Optimization – Formulation of Objective Function – Constraints – Multi Objective Optimization – Semi-Empirical Satellite Models, Physically Based Satellite Methods – Satellite–Based Irradiance and Power Forecasting – Concept of Fuzzy Logic.

UNIT – IV PROJECT MANAGEMENT 9

Project Preparation – Feasibility Study – Detailed Project Report – Project Appraisal – Social–cost benefit Analysis – Project Cost Estimation – Project Risk Analysis, Evaluation of Resource Risk in Solar Project Financing.

UNIT – V ENERGY POLICY & SCHEMES 9

Electricity act: Features & its amendments – National Energy Policy – Energy Security – Framework of Central Electricity Authority (CEA), Central Electricity Board (CEB), Central & States Electricity Regulatory Commission (CERC & SERC) – National Power Commission – Tariff and duty of electricity supply in India.

Ministry of New and Renewable Energy (MNRE): ENCON Schemes.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Gain knowledge on the National and Global energy scenario.
CO2 Use various techniques to perform Energy Forecasting and modeling.
CO3 Develop optimization model for energy planning.
CO4 Caliber to execute a project with detailed economic analysis.
CO5 Understand the National and state energy policies.

REFERENCES:

1. George Kariniotakis, “Renewable energy forecasting – From models to applications”, A volume in woodhead publishing series in energy, 2017.
2. William Holderbaum, “Energy Forecasting and Control Methods for Energy Storage Systems in Distribution Networks: Predictive Modelling and Control Techniques”, Springer, 1st Edition, 2023.
3. Jan Kleissl, “Solar Energy Forecasting and Resource Assessment”, Elsevier, 1st Edition, 2013.

4. Dhandapani Alagiri, "Energy Security in India Current Scenario", The ICFAI University Press, 2006.
5. Spyros G. Makridakis, Steven C. Wheelwright, Rob J. Hyndman, "Forecasting: Methods and Applications, John Wiley & Sons, 4th Edition, 2003.
6. Yang X.S., "Introduction to mathematical optimization: From linear programming to Metaheuristics", Cambridge, Int. Science Publishing, 2008.
7. Armstrong J.Scott (ed.), "Principles of forecasting: a hand book for researchers and practitioners", Norwell, Massachusetts: Kluwer Academic Publishers, 1st Edition, 2001.

CO – PO MAPPING:

CO	**PO**					
	1	**2**	**3**	**4**	**5**	**6**
1	–	2	3	1	3	–
2	1	–	2	3	1	–
3	3	1	3	3	3	–
4	3	1	3	3	3	3
5	2	3	3	3	3	3
Avg	**2.3**	**1.8**	**2.8**	**2.6**	**2.6**	**3.0**

EY3059 DESIGN AND OPTIMIZATION OF THERMAL ENERGY SYSTEMS

L	T	P	C
3	0	0	3

OBJECTIVE:

Understand the design principles of any thermal energy system and develop a model to arrive at the optimal solution and study the dynamic behavior of the same with a tradeoff between capital and operating cost using pinch point analysis.

UNIT – I DESIGN CONCEPTS 9

Design Principles, Workable Systems, Optimal Systems, Matching of System Components, modeling overview – levels and steps in model development – Examples of models – curve fitting and regression analysis.

UNIT – II MODELLING AND SYSTEMS SIMULATION 9

Modelling of thermal energy systems – heat exchanger – solar collectors – distillation – refrigeration systems – information flow diagram – solution of set of nonlinear algebraic equations – successive substitution – Newton Raphson method – examples of thermal systems simulation.

UNIT – III OPTIMIZATION 9

Objective function – constrained and unconstrained formulations – necessary and sufficiency conditions. Constrained optimization – Lagrange multipliers, constrained variations, sensitivity analysis – Examples, single and multi–objective problem.

UNIT – IV DETERMINISTIC SEARCH METHODS 9

Non–linear least square minimization – Levenberg-Marquardt, Conjugate gradient algorithm – case studies with deterministic search algorithms.

UNIT – V STOCHASTIC SEARCH METHODS 9

Introduction to random search methods – advantages and disadvantages, Genetic Algorithm. Other advanced algorithms – simulated annealing, Particle Swarm Optimization.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Understand basic design principles of the thermal systems and the type of models suitable for further analysis.

CO2 Carry out the Simulation and Modelling of typical thermal energy systems.

CO3 Analyze the effect of constraints on the performance of thermal energy systems.

CO4 Develop the dynamic analysis of the thermal system with control system feedback arrangement.

CO5 Design, optimize and perform the Energy-Economic Analysis for any thermal system.

REFERENCES:

1. Arora J.S., “Introduction to optimum design”, McGraw Hill, 4th Edition, 2016.
2. Bejan A., George Tsatsaronis, Michael J. Moran, “Thermal Design and Optimization”, Wiley, 1996.
3. Kapur J. N., “Mathematical Modelling”, Wiley Eastern Ltd, New York, 1989.
4. Rao S. S., “Engineering Optimization Theory and Practice”, New Age Publishers, 2010.
5. Stoecker W. F., “Design of Thermal Systems”, McGraw Hill Edition, 2011.
6. Yogesh Jaluria, “Design and Optimization of Thermal Systems”, CRC Press, 2016.
7. Balaji. C, “Thermal System Design and optimization”, Springer, 2021.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	–	2	3	3	–
2	2	2	2	3	3	1
3	3	–	1	3	3	–
4	1	–	–	2	2	–
5	3	1	2	3	3	2
Avg	**2**	**1.5**	**1.8**	**2.8**	**2.8**	**1.5**

EY3060	STATISTICAL DESIGN AND ANALYSIS OF EXPERIMENTS	L	T	P	C
		3	0	0	3

OBJECTIVE:

The objective of this course is to provide a holistic view on design of experiments and statistical analysis of experimental data obtained from laboratory or industrial processes.

UNIT – I INTRODUCTION TO RANDOM VARIABLES AND PROBABILITY FUNCTIONS 9

Introduction to probability, Bayes' theorem, Random variables - discrete and continuous, mean and variance, probability distribution functions - Binomial, Poisson, Normal, Weibull, Lognormal, Student-t, Joint probability distributions - marginal and conditional probability, covariance and correlation, bi-variate normal distribution function.

UNIT – II SAMPLING DISTRIBUTIONS AND ANALYSIS OF STATISTICAL INTERVALS 9

Sampling distribution and central limit theorem, General concept of point estimation - unbiased estimators, variance of point estimator, method of point estimation - maximum likelihood, Bayesian estimation, Confidence intervals with known and unknown variance, choice of sample size, guidelines for constructing confidence intervals.

UNIT – III HYPOTHESIS TESTING: SINGLE AND MULTIPLE SAMPLES 9

Statistical hypothesis - tests of statistical hypothesis, General procedure for hypothesis tests
Single sample case: tests on the mean of a normal distribution with known and unknown variance, testing for goodness of fit.
Two sample case: inference on the difference in means of two normal distributions with known and unknown variance, inference on the variances of two normal distributions and population proportions.

UNIT – IV ANALYSIS OF SIMPLE AND MULTIPLE LINEAR REGRESSION MODELS 9

Empirical models, simple linear regression, least square estimators, prediction of new observations and adequacy checking, correlation between parameters.
Multiple linear regression model, prediction of new observations and adequacy checking, multicollinearity.

UNIT – V DESIGN AND ANALYSIS OF SINGLE AND MULTIPLE FACTOR EXPERIMENTS 9

Completely randomized single-factor experiment - analysis of variance, multiple comparisons following ANOVA, residual analysis, and model checking, determining sample size. Random effect model - fixed Vs random effects, ANOVA and variance components. Randomized Complete Block Design (RCBD) - design and statistical analysis, multiple comparisons, residual analysis and model checking, Two-factor factorial experiments, 2^k factorial design - blocking and confounding, fractional replication, response surface methods.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Statistically analyse experimental data obtained from laboratory/industrial process
CO2 Structure engineering decision-making problems as hypothesis tests
CO3 Structure comparative experiments involving two samples as hypothesis tests
CO4 Develop empirical models from engineering data using linear regression, predict future observations, and establish a suitable prediction interval.
CO5 Design and conduct engineering experiments involving single and multiple factor.

REFERENCES:
1. D.C. Montgomery and G.C. Runger, “Applied Statistics and Probability for Engineers”, John Wiley & Sons Inc., 6th Edition, 2016
2. R.A. Johnson, I. Miller and J. Freund, “Probability and Statistics for Engineers”, Prentice Hall Inc., 9th Edition, 2017.
3. R.L. Mason, R.F. Gunst and J.L. Hess, “Statistical Design and Analysis of Experiments – with applications to engineering and science”, John Wiley & Sons Inc., 2nd Edition, 2003
4. B.J. Winer, “Statistical Principles in Experimental Design”, McGraw-Hill, 3rd Edition, 1991
5. A. Dean, D Voss and D. Draguljic, “Design and Analysis of Experiments”, Springer, 2nd Edition, 2017

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	-	-	-	-	1
2	3	-	-	-	-	1
3	3	-	1	-	-	-
4	3	-	1	-	2	1
5	3	-	1	-	-	-
Avg	**3**	**-**	**1**	**-**	**2**	**1**

EY3061 ENERGY STORAGE TECHNOLOGIES L T P C
3 0 0 3

OBJECTIVE:
To understand the significance and need for various types of energy storage technologies and their uses for real world applications. This course will also enable students to understand the Green Energy Storage of Hydrogen and the challenges associated

UNIT – I INTRODUCTION TO ENERGY STORAGE 9

Necessity of Energy Storage – Types of Energy Storage – Thermal, Mechanical, Chemical, Electrochemical and Electrical - Comparison of Energy Storage Technologies.

UNIT – II THERMAL ENERGY STORAGE SYSTEM 9

Thermal Energy Storage – Types – Sensible, Latent and Thermo-chemical – Sensible Heat Storage - Simple water and rock bed storage system – pressurized water storage system – Stratified System - Latent Heat Storage System - Phase Change Materials – Simple units, packed bed storage units - Other Modern Approaches.

UNIT – III ELECTRICAL ENERGY STORAGE 9

Batteries - Fundamentals and their Working – Battery performance, Charging and Discharging - Storage Density - Energy Density - Battery Capacity - Specific Energy - Memory Effect - Cycle Life - SOC, DOD, SOL - Internal Resistance - Coulombic Efficiency and Safety issues. Battery Types - Primary and Secondary – Lead Acid, Nickel – Cadmium, Zinc Manganese dioxide, Zinc-Air, Nickel hydride, Lithium Ion.

UNIT – IV HYDROGEN ENERGY STORAGE 9

Hydrogen Storage Options – Physical and Chemical Methods - Compressed Hydrogen – Liquefied Hydrogen – Metal Hydrides, Chemical Storage - Other Novel Methods - comparison - Safety and Management of Hydrogen - Applications - Fuel Cells.

UNIT – V ALTERNATE ENERGY STORAGE TECHNOLOGIES 9

Flywheel, Super Capacitors - Pumped Hydro Energy Storage System - Compressed Air Energy Storage System, SMES - Concept of Hybrid Storage – Principles, Methods, and Applications - Electric and Hybrid Electric Vehicles.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Identify the energy storage technologies for suitable applications.
CO2 Apply the appropriate thermal energy storage methods suitably.
CO3 Introduce the concepts, types and working of various batteries.
CO4 Understand the use of Hydrogen as Green Energy for our Future.
CO5 Recognize and choose appropriate methods of Energy Storage and Hybrid Systems.

REFERENCES:

1. Ibrahim Dincer and Mark A. Rosen, “Thermal Energy Storage Systems and Applications”, John Wiley & Sons 2002.
2. James Larminie and Andrew Dicks, “Fuel cell systems Explained”, Wiley publications, 2003.
3. Luisa F. Cabeza, “Advances in Thermal Energy Storage Systems: Methods and Applications”, Elsevier Woodhead Publishing, 2015.
4. Robert Huggins, “Energy Storage: Fundamentals, Materials and Applications”, 2nd edition, Springer, 2015.
5. Ru-shiliu, Leizhang, Xueliang sun, “Electrochemical technologies for energy storage and conversion”, Wiley publications, 2012.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	2	3	-	-	3	2
2	2	3	-	-	3	2
3	2	3	-	-	3	3
4	2	3	-	-	3	3
5	2	3	-	-	3	3
Avg	**2**	**2**	**-**	**-**	**3**	**2.6**

SY3010 GREEN HYDROGEN AND FUEL CELLS

L	T	P	C
3	0	0	3

OBJECTIVES:

To study the basics of production and storage techniques of Green Hydrogen. This course will enable the student to gain knowledge on classifications, construction, working and applications of fuel cells.

UNIT – I HYDROGEN – BASICS AND PRODUCTION TECHNIQUES 9

Hydrogen – physical and chemical properties, salient characteristics. Production of green hydrogen – steam reforming – water electrolysis – biological hydrogen production – photo dissociation – direct solar thermal or catalytic splitting of water.

UNIT – II HYDROGEN STORAGE AND APPLICATIONS 9

Hydrogen storage options – Physical and Chemical - compressed gas – liquid hydrogen – Hydride – chemical Storage – comparisons. Safety and management of hydrogen. Applications of Hydrogen – Green hydrogen policy at National and International level.

UNIT – III THERMODYNAMICS AND KINETICS OF FUEL CELL 9

Principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell.

UNIT – IV CLASSIFICATION OF FUEL CELLS 9

Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, MFC – principle, construction and working – relative merits and demerits.

UNIT – V FUEL CELL APPLICATIONS AND ECONOMICS 9

Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells. – Green

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Analyze the techniques of Green Hydrogen generation.

CO2 Apply the various options for Hydrogen storage.

CO3 Recognize the principle operations of fuel cell, types, its thermodynamics and kinetics.

CO4 Comprehend the different types of fuel cells.

CO5 Apply the fuel cells for domestic, automotive, space craft power generations and evaluate the techno-economics of a fuel cells.

REFERENCES:

1. Barclay F.J., “Fuel Cells, Engines and Hydrogen”, Wiley, 2009.
2. Bent Sorensen (Sørensen), “Hydrogen and Fuel Cells: Emerging Technologies and Applications”, Elsevier, UK 2005.
3. Hart A.B. and G.J.Womack, “Fuel Cells: Theory and Application”, Prentice Hall, New York Ltd., London 1989.
4. Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA 2002.
5 Kordesch K. and G.Simader, “Fuel Cell and Their Applications”, Wiley-Vch, Germany 1996.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	1	-	3	-	2	-
2	1	-	3	-	2	-
3	3	-	3	-	2	-
4	1	-	3	-	2	-
5	1	-	3	-	2	-
Avg.	**1.4**	**-**	**3**	**-**	**2**	**-**

SY3011 **SOLAR ENERGY FOR INDUSTRIAL PROCESS HEATING**

L	T	P	C
3	0	0	3

OBJECTIVES:

The objectives of this course is to expose the students in learning about industrial process heat and methods of using solar energy to supply heat for these processes, Also to apply techno-economic details for the related process heat industries.

UNIT – I INTRODUCTION **9**

Solar energy – Availability and utilization - Historical background of solar industrial process heat (IPH) - Need of the day – Opportunities and challenges of industrial process heat - Characteristics of industrial process heat.

UNIT – II SOLAR ENERGY COLLECTORS FOR INDUSTRIAL PROCESS HEATING **9**

Flat plate collector - Materials for flat plate collector and their properties– Evacuated tube collector - Solar point collector - Concentrating collectors - types and applications of concentrating collectors - Thermal Analysis of Collectors and Useful Heat Gained by the fluid - fin efficiency - collector efficiency factor - Heat Removal Factor.

UNIT – III INDUSTRIAL PROCESS HEATING SYSTEM **9**

Introduction – Hot water industrial process heat system – Hot air industrial process heat system – Steam industrial process heat system – Problems involved with industrial process heat system – Case studies on industrial process heat.

UNIT – IV APPLICATIONS OF SOLAR INDUSTRIAL PROCESS HEAT **9**

Industrial sectors and processes with the potential for solar thermal uses - Food and beverage industries - The textile and chemical industries - Power generation applications – Washing process – Drying process – Distillation and chemical process.

UNIT – V TECHNO ECONOMIC ANALYSIS **9**

Elements of economic principle, economic calculation. Energy economics-basic concepts, unit cost of power generation from different sources, payback period, NPV, IRR and benefit cost analysis. Conventional and solar energy resources and costs. Direct and indirect costs, pricing system and project management.

Total : 45 Periods

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 The basic concepts of solar energy-related industrial process heat systems.
CO2 Students will have knowledge on materials for flat plate collector and their properties.
CO3 Students will acquire knowledge about industrial hot water, hot sir and steam heat system.
CO4 Learn the various applications of solar industrial process heat.
CO5 The techno-economic details for the related process heat industries were incorporated.

REFERENCES:

1. HP Garg and J Prakash, “Solar Energy: Fundamentals and Applications”, Tata McGraw Hill,2010.
2. JA Duffie and WA Beckman, “Solar Engineering of Thermal Processes”, John Wiley & sons,2006.
3. Soteris A. Kalogirou, “Solar Energy Engineering: Processes and Systems”, Academic Press,2009.

4. Tom P. Hough, “Solar energy: recent developments:, Nova Publishers, 2007.
5. G. N. Tiwari, “Solar Energy: Technology Advances”, Nova Publishers, 2006.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	3	3	-	1	1
2	3	1	3	-	3	-
3	1	1	3	-	3	-
4	1	1	3	-	3	-
5	3	3	3	-	3	1
Avg.	**2.2**	**1.8**	**3**	**-**	**2.6**	**1**

SY3051 SOLAR REFRIGERATION AND AIR-CONDITIONING

L	T	P	C
3	0	0	3

OBJECTIVES:

The major objective of this course is to learn about the utilization of solar energy for cooling applications in both buildings and industries in economical way through the systems such as absorption, adsorption, desiccant and organic Rankine Cycles.

UNIT I THERMODYNAMIC CYCLES FOR SOLAR COOLING 9

Carnot cycles for refrigeration and Heat Pumps, Vapour compression cycle, Absorption Cycle, Adsorption Cycle, Desiccant cycle, Organic Rankine Cycle and Super Critical CO_2 Cycle

UNIT 2 SOLAR THERMAL COLLECTORS AND STORAGE SYSTEMS 9

Non-concentrating solar collectors, concentrating solar collectors, Collector applications – Medium and high temperature – Sensible and Latent heat Storage, Heat transfer enhancement techniques, Thermal Chemical storages

UNIT 3 SOLAR THERMAL COOLING TEHCNOLOGIES 9

Absorption Systems, Adsorpion systems, Desiccant systems and Ejector Jet systems – Working fluids, Process modeling, Types, Applications, Energy and environment analysis – Thermo economic analysis for both cooling and heating applications

UNIT 4 PV DRIVEN COOLING AND HEATING SYSTEMS ` 9

PV cell, Design of PV systems for Vapour compression cycles, Thermo electric cycle, Solar PV based chillers, Photvoltatic thermal systems - Energy and environment analysis – Thermo economic analysis for cooling applications

UNIT 5 ALTERNATE AND HYBRID COOLING SYSTEMS 9

Alternate cooling systems – humidification, Stirling, thermo chemical cooling, electro chemical, Hybrid cooling systems – desiccant compression cycle, compression-absorption cycle, adsorption-compression, Organic Rankine – absorption cycle, absorption-desiccant, ejector - compression cycles.

Total : 45 Periods

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Analyze the performance of different thermodynamic solar cooling cycles.
CO2 Design the different types of solar collectors for a given cooling load.
CO3 Understand and Analyze the performance of solar thermal based chillers.
CO4 Design the solar PV powered cooling system
CO5 Apply various alternate and hybrid systems for cooling applications

REFERENCES

1. Sotirios Karellas, Tryfon C Roumpedakis, Nikolaos Tzouganatos, Konstantinos Braimakis, “Solar Cooling Technologies (Energy Systems)”, CRC Press, 2019
2. Alefeld G. and Radermacher R., “Heat Conversion Systems”, CRC Press, 2004.
3. ASHRAE Hand Book–HVAC Systems & Equipment, ASHRAE Inc. Atlanta, 2008.
4. McVeigh J.C. and Sayigh A.A.M. “ Solar Air Conditioning and Refrigeration”, Pergamon Press,1992.

5. Reinhard Radermacher, S AKelin and K Herold, “Absorption chillers and heat pumps”, CRCPress, 1996.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	2	2	-	3	-
2	3	2	3	-	3	-
3	2	2	3	-	3	-
4	2	2	3	-	3	-
5	2	2	3	-	3	-
Avg.	**2.4**	**2**	**2.8**	**-**	**3**	**-**