



**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA**  
**KAKINADA - 533 003, Andhra Pradesh, India**  
**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

**COURSE STRUCTURE & SYLLABUS**

**M.Tech. RENEWABLE ENERGY PROGRAMME**

*(Applicable for batches admitted from 2025-2026)*



**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA**



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**Vision and Mission of the University**

**Vision**

The University is primarily promoting quality of education in the areas of Science, Technology, Engineering and Mathematics (STEM) as four academic pillars of education, to excel in teaching, learning, research, consultancy and placements through innovative practices with global perspective.

**Mission**

1. Design an Industry relevant curriculum from time to time with a Global perspective
2. Promoting quality education by embracing ICT delivery mechanism with continuous pedagogy through e-learning mechanism
3. Spread across for industry collaborations with a focus to pre-training and placements for technology transfer to society
4. Establishing centers of excellence to promote research and innovations in multidisciplinary areas to bring in patent culture and consultancy practices
5. International Collaborations for student outreach
6. Facilitating international students to study in JNTUK to infuse cross culture learning practices.

**Vision and Mission of the Institute**

**Vision and Mission of the Department**



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**Programme Education Objectives (PEOs) of the M.Tech(Renewable Energy) 2025**

### **Mapping of Mission statements to PEOs**

#### **Programme Outcomes (POs)**

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems

**PO2:** An ability to write and present a substantial technical report/document

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

**PO4:**

**PO5:**

**PO6:**

*Note: Program may add up to three additional POs*

#### **Mapping of Programme Outcomes to PEOs**

#### **Mapping of Programme Outcomes to GAs**



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**PROGRAMME STRUCTURE**

**I Semester**

S. No.	Course Title	L	T	P	C
1	Solar Photovoltaics	3	1	0	4
2	Solar Thermal Systems	3	1	0	4
3	Distributed Energy Technologies	3	1	0	4
4	Program Elective – I	3	0	0	3
5	Program Elective – II	3	0	0	3
6	Energy Systems Simulation Laboratory - I	0	1	2	2
7	Renewable Energy Laboratory - I	0	1	2	2
8	Seminar -I	0	0	2	1
	<b>TOTAL</b>	<b>15</b>	<b>5</b>	<b>6</b>	<b>23</b>

**List of Professional Elective Courses in I Semester (Electives – I & II)**

S.No.	Course Title
	Elective - I
1	Basics of Energy Engineering
2	Power Quality
3	Cogeneration & Energy Efficiency
	Elective - II
4	Waste to Energy
5	Modeling, Analysis and Economics of Energy systems
6	Computational Fluid dynamics

@ Minimum 2/3 themes per elective



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**II – Semester**

Sl. No.	Course Title	L	T	P	C
1	Energy Storage Technologies	3	1	0	4
2	Hydrogen and Fuel Cells	3	1	0	4
3	Integration of Renewable Energy Sources	3	1	0	4
4	Program Elective – III	3	0	0	3
5	Program Elective - IV	3	0	0	3
6	Energy Systems Simulation Laboratory - II	0	1	2	2
7	Renewable Energy Laboratory - II	0	1	2	2
8	Seminar – II	0	0	2	1
	<b>TOTAL</b>	<b>15</b>	<b>5</b>	<b>6</b>	<b>23</b>

\*During the summer break, students need to pursue Summer Internship/ Industrial Training; it will be evaluated in the III Sem.

**List of Professional Elective Courses in II Semester (Electives III & IV)**

S.No.	Course Title
	Elective - III
1	Instrumentation for Energy Systems
2	Smart Grid Systems and Technologies
3	Energy Auditing and Demand Side Management
	Elective - IV
4	Energy Efficiency and Green Buildings
5	Solar Refrigeration and Air- conditioning
6	Wind Energy Systems

@ Minimum 2/3 themes per elective



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**III Semester**

Sl. No.	Course Title	L	T	P	C
1	Research Methodology and IPR / <i>Swayam 12 week MOOC course – RM&amp;IPR</i>	3	0	0	3
2	Summer Internship/ Industrial Training (8-10 weeks)*	-	-	-	3
3	Comprehensive Viva <sup>#</sup>	-	-	-	2
4	Dissertation – A <sup>§</sup>	-	-	20	10
	<b>TOTAL</b>	<b>3</b>	<b>-</b>	<b>20</b>	<b>18</b>

\* Student attended during summer / year break and assessment will be done in 3<sup>rd</sup> Sem.

# Comprehensive viva can be conducted courses completed upto second sem.

§ Dissertation – Part A, internal assessment

**IV Semester**

Sl. No.	Course Title	L	T	P	C
1	Dissertation – B <sup>%</sup>	-	-	32	16
	<b>TOTAL</b>	<b>-</b>	<b>-</b>	<b>32</b>	<b>16</b>

% External Assessment



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<b>I Semester</b>	<b>SOLAR PHOTOVOLTAICS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**Pre-requisite:** Basic knowledge on semiconductor physics, electrical and electronic circuits.

**Course Objectives:**

1. To learn solar energy fundamentals
2. To gain knowledge on solar cell technologies
3. To become skilled at components involved and sizing of solar power generation
4. To familiarize advances in solar cell technologies

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand photovoltaics and analyze the technologies and developments in photovoltaics.	
<b>CO2</b>	Develop concepts of photovoltaic technologies in hybrid electrical power generation.	
<b>CO3</b>	Understand various design configurations, troubleshooting.	
<b>CO4</b>	Analyze/Understand components required for photovoltaic power generation.	
<b>CO5</b>	Analyze PV system design and applications and to understand techno- economic- environmental evaluation.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT –1</b>	<b>Photovoltaics and Semiconductor Physics</b> Review of world energy scenario of photovoltaics - availability of energy from the sun - concept of solar radiation - air mass - solar geometry and related terms -Types of PV cells Semiconductor physics of a solar cell - charge carriers and their motion in semiconductors - charge carriers concentration levels - electric field and energy band bending (density of states, drift, and diffusion).	12
<b>UNIT –2</b>	<b>Solar Cell Design</b>	12



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	Solar cell and module manufacturing process - Solar cell parameters - short circuit current - open circuit voltage - fill factor - efficiency - losses in solar cells - equivalent models of basic solar cell - effect of resistances, solar radiation and temperature on efficiency - solar cell design for higher $I_{sc}$ , $V_{oc}$ , Fill factor - measurement of minority carrier life time, diffusion length, quantum efficiency, I-V and P-V characteristics under uniform and non-uniform insulations using solar simulator- STC, NOC and SOC of a solar cell - series and parallel connection of PV modules - mismatch in series and parallel connections - need for bypass and blocking diodes.	
UNIT – 3	<b>MPPT Techniques for PV systems</b> Batteries for PV Systems - factors impacting battery performance - application of DC - DC converters in PV - charge controllers - MPPT - off grid and grid tied hybrid inverters - variable frequency drive - types - mounting structures-single axis - dual axis - junction boxes - array combiner boxes - cables - protection devices - earthing - lightning arrestor and other safety issues.	12
UNIT – 4	<b>PV Based Hybrid Systems Design and Applications</b> PV system sizing - standalone PV systems - lighting - water pumping - hybrid PV Systems - PV wind and PV diesel - grid connected PV Systems - PV power plants - roof top and ground mounted small and large power plants.	12
UNIT – 5	<b>Evaluations of PV Systems and Advance concepts in PV</b> PV data acquisition system - ambient temperature measurement - DC and AC energy meters - I-V curve tracers (or array testers) - IR thermal imager-latest and emerging trends in solar cell technologies (organic, dye sensitized, quantum dots, thermo-photovoltaic)-laser grooved buried contact(LGBC) - passive emitter rear locally diffused(PERL) - passive rear contact cells selecting emitter(PERC) - perovskite cells - graphene based solar cells - environmental impact of photovoltaic - economic analysis (net present value - simple payback - capital recovery factor - discounted cash flow analysis) - life cycle costing.	12
	<b>Total</b>	60

\*Note:

#### Text Books:

1. Solar Photovoltaics: Fundamentals, Technologies and Applications, Chetan Singh Solanki, PHI Learning Private Limited 2011 (or later edition).
2. Solar Cells: Operating Principles, Technology and System Applications, Martin A, Green, Prentice Hall Inc.
3. Modelling of Photovoltaic Systems using MATLAB, WileyTamer Khatib, Wilfried Elmeried. Solar Photovoltaic Technology and Systems-A Manual for Technicians and Engineers, Chetan Singh Solanki.
4. Solar Energy Fundamentals, Technology, and Systems, Klaus Jäger, OlindoIsabella, Arno, H.M.SmetsRené A.C.M.M. van SwaijMiroZeman, Delft University of Technology, 2014.
5. Photovoltaic System Design: Procedures, Tools and Applications, Suneel Deambi, CRC press, 2016.



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**Reference Books:**

1. A guide to the Photovoltaic Revolution, Paul D. Maycock and Edward N. Stirewalt, Rodale Press, Emmaus, Pa.
2. Energy Systems Engineering, Evaluation and Implementation, Francis M. Vanek, Louis D. Albright, LARGUS T. ANGENENT, Second Edition, McGraw Hill.
3. Renewable Energy Sources, Twidell and Weir, CRC Press (Taylor & Francis).
4. Solar Electricity, Tomas Markvart, John Wiley & Sons, Ltd.



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<b>I Semester</b>	<b>SOLAR THERMAL SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**Pre-requisite:** Basic knowledge on solar thermal system, thermal energy storage and solar thermal applications.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Identify solar thermal system components.	
<b>CO2</b>	Identify different technologies for power generation	
<b>CO3</b>	Identify different solar thermal devices.	
<b>CO4</b>	Explain different storage techniques.	
<b>CO5</b>	Identify applications in various fields.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

UNIT	CONTENTS	Contact Hours
<b>UNIT – 1</b>	<b>Introduction and Solar Energy collectors</b> Solar energy option - specialty and potential - Sun - Earth - solar radiation – solar constant - beam and diffuse - measurement - estimation of average solar radiation on horizontal and tilted surfaces – applications. Collection devices - types - liquid flat plate collectors - evacuated tube collectors - construction details - performance analysis - concentrating collection - classification - flat plate collectors with plane reflectors -cylindrical parabolic collectors - orientation and tracking - parabolic dish collector.	12
	<b>Power generation from Solar Thermal</b>	12



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<b>UNIT –2</b>	Power generation - low, medium, high temperature systems - power generation using liquid flat plate - solar chimney - cylindrical parabolic concentrating collector - solar central receiver system - heliostats and receiver - tower design - heat transfer fluids - molten salts - storage system.	
<b>UNIT –3</b>	<b>Thermal Energy Storage</b> Introduction - need for - size and duration of storage - methods of energy storage - sensible heat storage using solids and liquids - packed bed storage - latent heat storage – Thermochemical reaction storage - stratified storage – solar ponds - working principle - construction - application and limitations.	12
<b>UNIT – 4</b>	<b>Solar thermal devices</b> Solar devices - solar stills - air heaters - dryers - furnaces - Direct Solar Furnace - Heliostat-Based Solar Furnace - Parabolic Trough Solar Furnace - water heaters - Flat Plate Collector Solar Water Heater - Evacuated Tube Collector (ETC) Solar Water Heater - solar cookers - solar pumps - introduction - design - working.	12
<b>UNIT – 5</b>	<b>Solar thermal applications</b> Applications - distillation - solar refrigeration and space cooling - air heating -water heating - space heating - cooking - solar green houses - agricultural and industrial applications - solar energy for industrial process heat.	12
	<b>Total</b>	60

\*Note:

**Text Books/Reference Books:**

1. Principles of solar engineering, Kreith and Kerider, Taylor and Franscis, 2nd edition .
2. Solar energy thermal processes, Duffie and Beckman, John Wiley & Sons.
3. Solar energy: Principles of Thermal Collection and Storage, Sukhatme, TMH, 2nd edition .
4. Solar energy, Garg&Prakash, H. P, Garg, Tata McGraw-Hill Education, 2000.
5. Solar energy,B.S. Magal, McGraw-Hill Education (India) Pvt Limited, 01-Nov-1999.
6. Solar Thermal Engineering Systems, Tiwari and Suneja,Narosa Publishing House, 1997.
7. Power plant Technology, M. M. El-Wakil, McGraw-Hill, 1984.



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<b>I Semester</b>	<b>DISTRIBUTED ENERGY TECHNOLOGIES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**Pre-requisite:** Basic knowledge of non- conventional energy sources like solar energy, wind energy, biomass energy, ocean energy, tidal energy, wave energy, hydro power and geo thermal energy.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Identify alternate energy sources.	
<b>CO2</b>	Classify and analyze different renewable energy systems.	
<b>CO3</b>	Adopt different alternate energy sources for power generation.	
<b>CO4</b>	Adopt optimal usage of different sources and interconnection with grid.	
<b>CO5</b>	Understand significance of renewable energy technologies.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Solar and Wind Energy</b> Availability of solar radiation – solar radiation measurement instruments - estimation of average solar radiation - basics of solar thermal systems, solar PV systems - solar energy applications. Nature of wind - wind characteristics - power in wind - wind energy extraction - wind energy	12



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	conversion devices - horizontal axis wind turbine (HAWT) - vertical axis wind turbine (VAWT) - aerodynamics of wind rotor - blade element theory - aerodynamic efficiency - wind turbine control system - tower shadow - rotor selection - wind power generation modes-wind farms.	
<b>UNIT – 2</b>	<b>Biomass Energy</b> Bio fuel classification - examples of thermo chemical - pyrolysis - biochemical and agrochemical systems - energy farming - direct combustion for heat - process heat and electricity - ethanol production and use - anaerobic digestion for biogas - different digesters - digester sizing - applications of biogas - operation with I.C.Engine.	12
<b>UNIT – 3</b>	<b>Ocean, Tidal and Wave Energy</b> Ocean energy fundamental concepts- ocean thermal energy conversion - open cycle and closed cycle - hybrid OTEC systems-advantages and disadvantages of OTEC - environmental impacts of OTEC – <b>tidal power</b> - Components of tidal power plant - power generation from barrages - environmental considerations for tidal barrages - turbines for tidal power - estimation of energy - integration of electrical power from tidal barrages - economics of tidal barrages - environmental impact – <b>wave energy</b> – linear generators - concept of energy and power from waves - wave characteristics - period and wave velocities - different wave energy conservation devices (Saltor duck, oscillating water column and dolphin types) - operational experience.	12
<b>UNIT – 4</b>	<b>Small and Medium Hydro Power sources</b> Hydro power potential - types of hydroelectric projects-run of river scheme, storage schemes, pumped storage schemes - power plant classification - low, medium and high head micro hydro - main parts (weir, intake, canal, fore bay, tank penstock, power house and trail race, types of turbines), efficiency of small hydro power sources.	12
<b>UNIT – 5</b>	<b>Geo thermal Energy</b> Introduction to geothermal energy - structure of the Earth’s interior - geothermal sites - earthquakes and volcanoes - geothermal resources - hot springs - steam ejection - principle of working of geothermal plants - types of geothermal station schematic representation - site selection for geothermal power plants - advanced concepts.	12
	<b>Total</b>	<b>60</b>

\*Note:



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**Text Books**

1. Renewable Energy Resources Basic Principles and Applications, G.N.Tiwari and M.K.Ghosal, *Narosa Publishing House*, New Delhi, India, 2005.
2. **Solar Energy - Principles of thermal collection and storage**, S.P. Sukhatme, *Tata McGraw Hill Publishing Company Limited*, New Delhi : First Edition.
3. **Wind Energy Handbook** / Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi / **Wiley publications.**
4. **Wind Electrical Systems** / S.N.Bhadra, D.Kastha and S.Banerjee / **Oxford Press.**
5. Biogas Technology - A Practical Hand Book / K.Khendelwal & S.S. Mahdi / McGraw-Hill.
6. Energy Resources Utilization and Technologies, Anjaneyulu Yerramilli and Francis Tului publications.
7. "Ocean wave Energy - Current Status & Future Prepectives", by Crug Joao Springer, 2008.
8. Renewable Energy Sources and Emerging Technologies, D.P.Kothari, K.C.singal, Rakesh Ranjan, 2013.

**Reference Books:**

- 1.Renewable Energy Resources, John Twidell, Tony Weir, M.A.Laughton, Anthnoy D. Weir, Paperback, Published 1990 by E. & F.N. Spon, London.
- 2.study materials in Renewable - Trainers Text book (SHP) module, MNRE, India.
- 3.NPTEL: Module 5: Hydro Power Engineering (Principles of Hydro Power Engineering).



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<b>I Semester</b>	<b>BASICS OF ENERGY ENGINEERING</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0.</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on power systems, power electronics, electrical machines, fundamentals of thermodynamics, mechanical systems and concepts of heat transfer.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand basics of power generation and load characteristics.	
<b>CO2</b>	Explain power electronic converters used in renewable systems.	
<b>CO3</b>	Describe working of electrical machines and special motors.	
<b>CO4</b>	Apply thermodynamic principles in energy systems.	
<b>CO5</b>	Analyze modes of heat transfer in thermal applications.	
<b>CO6</b>		

*#Based on suggested Revised BTL*

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Electrical Power System Concepts</b> Basics of electrical Power Generation: thermal, hydro, solar, wind and nuclear – overview only – Transmission and distribution systems overview – type of loads, load curves, load factor, diversity factor – Active, reactive and apparent power – power factor and improvement techniques.	
<b>UNIT –</b>	<b>Power Electronic Energy Conversion</b>	



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2	Role of converters in renewable energy systems – Classification of converters – Principle operation of DC-DC converters – Types of DC/DC Converters: Buck, Boost – Principle of Operation of DC/AC inverters – Types of DC/AC inverters: Single phase and three phase (Voltage source and current source) – Pulse width modulation Techniques: Sinusoidal PWM, SPWM Techniques	
UNIT – 3	<b>Electrical Machines and Mechanical systems:</b> <b>Electrical Machines:</b> Over view of DC generators, induction generators, Synchronous Generators – Special generators: BLDC, PMDC, Stepper and Servo Motors – Applications in various renewable sources. <b>Mechanical systems:</b> Steam nozzles - steam turbines - steam condensers - gas turbines - pumps and compressors - classification and working principle with schematic diagrams.	
UNIT – 4	<b>Thermodynamic Concepts</b> Thermodynamic system - types of systems - reversible and irreversible processes - thermodynamic and mechanical cycles - point and path function - heat and work - examples of heat and work - zeroth - first and second law of thermodynamics Carnot cycle and its specialties – Entropy - P-V and T-S diagrams of Rankine - Brayton, Otto, Diesel, Sterling cycles.	
UNIT – 5	<b>Heat Transfer</b> Modes and mechanisms of heat transfer - steady - unsteady and periodic heat transfer - basic laws and applications - conduction heat transfer - Fourier equation - application of conduction heat transfer to infinite slab - composite systems - hollow cylinder - coaxial cylinder and spherical geometries - convection heat transfer - types of convective heat transfer - condensation and boiling heat transfer.	
	<b>Total</b>	

\*Note:

**Text Books:**

1. **Modern Power System Analysis** by D. P. Kothari & I. J. Nagrath Thermal Engineering, M.L.Mathur& Mehta, Jain brothers Publishers.
2. **Fundamentals of Power Electronics** by Robert W. Erickson & Dragan Maksimović (Springer, 3rd edition 2020)
3. **Electrical Machines, and Power Systems Engineering** by D. P. Kothari & I. J. Nagrath
4. Heat transfer, P.K.Nag, TMH publishers.
5. Heat transfer and mass transfer, R.C. Sachdeva, New International Publishers.

**Reference Books:**

1. Heat and Mass Transfer, Arora and Domkundwar, Dhanpatrai Publishers.
2. Electric machines by S.K.Sahdev



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<b>I Semester</b>	<b>POWER QUALITY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on transient voltages, harmonics and distributed generation networks.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Analyze causes of power quality, power quality parameters.	
<b>CO2</b>	Understand sources of transient over voltages and providing protection to transient over voltages.	
<b>CO3</b>	Understand effects of harmonics, sources of harmonics and harmonic minimization.	
<b>CO4</b>	Analyze long duration voltage variations and regulation of voltage variations.	
<b>CO5</b>	Describe power quality aspects in distributed generation and develop solutions to wiring and grounding problems.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<p><b>Introduction</b>            Overview of power quality - concern about the power quality - general classes of power quality problems - transients - long duration voltage variations - short duration voltage variations - voltage unbalance - waveform distortion - voltage fluctuation - power frequency variations - power quality terms - voltage sags and interruptions - sources of sags and interruptions - nonlinear loads.</p>	12



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<b>UNIT – 2</b>	<b>Transient over Voltages</b> Source of transient over voltages - principles of over voltage protection - devices for over voltage protection - utility capacitor switching transients - utility lightning protection - load switching transient problems - computer tools for transient analysis.	12
<b>UNIT – 3</b>	<b>Harmonic Distortion and solutions</b> Voltage vs. current distortion - harmonics vs. transients - power system quantities under non sinusoidal conditions - harmonic indices - sources of harmonics - locating sources of harmonics - system response characteristics - effects of harmonic distortion - inter harmonics - harmonic solutions - harmonic distortion evaluation - devices for controlling harmonic distortion - harmonic filter design - standards on harmonics.	12
<b>UNIT – 4</b>	<b>Long Duration Voltage Variations</b> Principles of regulating the voltage - device for voltage regulation - utility voltage regulator application - capacitor for voltage regulation - end user capacitor application - regulating utility voltage with distributed resources - flicker.	12
<b>UNIT – 5</b>	<b>Distributed Generation and Power Quality</b> Resurgence of distributed generation - DG technologies - interface to the utility system - power quality issues - operating conflicts - DG on low voltage distribution networks - interconnection standards - wiring and grounding - typical wiring and grounding problems - solution to wiring and grounding problems.	12
	<b>Total</b>	<b>60</b>

\*Note:

**Text Books:**

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.

**Reference Books:**

1. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
2. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
3. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
4. Power Quality, C.shankaran, CRC Press, 2001.
5. Harmonics and Power Systems Franciso C.DE LA Rosa-CRC Press (Taylor & Francis).
6. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>I Semester</b>	<b>COGENERATION AND ENERGY EFFICIENCY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on cogeneration technologies, waste heat recovery sources, energy efficiency and energy efficient electrical systems.

**Course Objectives:**

- 1.
- 2.
- 3.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand the importance of cogeneration in improving the overall efficiency, economy and limiting global warming.	
<b>CO2</b>	Analyze the basic energy generation cycles.	
<b>CO3</b>	Design of cogeneration technologies, its types and probable areas of applications.	
<b>CO4</b>	Explain the significance of waste heat recovery systems and carry out its economic analysis.	
<b>CO5</b>	Analyse the importance of energy efficiency in electrical system.	
<b>CO6</b>		

*#Based on suggested Revised BTL*

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Introduction</b> Introduction - principles of thermodynamics - The cogeneration concept design - parameters for cogeneration - cycles - topping - bottoming - combined cycle - organic Rankin cycles - performance indices of cogeneration systems - waste heat recovery - sources and types - concept of trigeneration.	12
<b>UNIT – 2</b>	<b>Cogeneration Technologies</b> Configuration and thermodynamic performance - steam turbine	12



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	cogeneration systems - gas turbine cogeneration systems - reciprocating IC engines cogeneration systems - combined cycles cogeneration systems - advanced cogeneration systems - Stirling engines - thermodynamic evaluation.	
<b>UNIT – 3</b>	<b>Issues and Applications of Cogeneration Technologies</b> Cogeneration plants - electrical interconnection issues - utility and cogeneration plant interconnection issues - applications of cogeneration in utility sector - industrial sector - building sector - rural sector - impacts of cogeneration plants - fuel-electricity and environment-case studies.	12
<b>UNIT – 4</b>	<b>Energy Efficiency</b> Energy conservation - need for energy efficiency - Indian energy conservation act 2001 and its features - energy star rating of buildings and equipments - bureau of energy efficiency guidelines and programs - energy building code - guidelines - thermal insulation - heating - ventilation and air conditioning system.	12
<b>UNIT – 5</b>	<b>Energy Efficiency Improvement in Electrical Systems</b> Improving energy efficiency in electrical systems - electrical load management - maximum demand control - energy efficient motors - factor affecting motor performance - energy saving opportunities in motors - soft starter with energy savers - energy efficient transformers - factor affecting the performance of transformers	12
	<b>Total</b>	<b>60</b>

\*Note:

#### Text Books:

1. Energy Cogeneration hand book for Central Plant Design, GeorgePolimeros, Industries Press inc, New York, 1981.
2. Power Plant Technology, M. M. El- Wakil, McGraw Hill,1984.
3. Combined-cycle gas & steam turbine power plants, 3rd Edition, R.Kehlhofer, B. Rukes,F. Hannemann, F. Stirnimann, PennWell Books, 2009.
4. Industrial Energy Management and Utilization, LC Witte, PS Schmidt, DR Brown Hemisphere Publication, Washington, 1988.

#### Reference Books:

1. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982 .
2. The Efficient Use of Energy, IGC Dryden, Butterworths (Ed), London, 1982 34.
3. Energy Management Handbook, WC Turner (Ed), Wiley, New York, 1982.
4. Technology Menu for Efficient energy use- Motor drive systems, Prepared by National Productivity Council and Centre for Environmental Studies- Princeton University, 1993.
5. Hand Book of Energy Efficiency, Frank, Kreith, Ronald E West, CRC Press.
6. Bureau of Energy Efficiency Study Material for Energy Managers and Auditors Examination Paper I to IV.
7. Savings Electricity in Utility Systems of Industrial Plants Efficient use of electricity in industries, BG Desai, BS Vaidya DP Patel and R Parman.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>I Semester</b>	<b>WASTE TO ENERGY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on conventional as well as non-conventional energy generation, transmission and distribution of power along with fundamental mathematics and economics.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand the classification of waste and basic energy conversion devices like incinerators, gasifiers, and digesters.	
<b>CO2</b>	Analyze the process of biomass pyrolysis and assess the yields and applications of its products.	
<b>CO3</b>	Understand the working of different gasifiers and assess their use in thermal and electrical energy applications.	
<b>CO4</b>	Analyze various biomass combustion systems and assess their operational efficiency.	
<b>CO5</b>	Understand the properties of biogas and acquire knowledge of anaerobic digestion and biogas plant technologies.	
<b>CO6</b>	Assess the potential of biomass energy in India and analyze conversion processes like biodiesel, alcohol, and urban waste-to-energy.	

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Introduction to Energy from Waste:</b> Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors.	
<b>UNIT – 2</b>	<b>Biomass Pyrolysis:</b> Pyrolysis – Types, slow fast – Types of pyrolizers -	



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	Manufacture of charcoal – Methods – Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.	
<b>UNIT – 3</b>	<b>Biomass Gasification:</b> Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.	
<b>UNIT – 4</b>	<b>Biomass Combustion:</b> Biomass stoves – Improved chullahs, types, some exotic designs, Fixedbed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.	
<b>UNIT – 5</b>	<b>Biogas Plant Technologies:</b> Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion – Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.	
	<b>Total</b>	

#### REFERENCES:

1. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>I Semester</b>	<b>MODELING, ANALYSIS AND ECONOMICS OF ENERGY SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on conventional as well as non-conventional energy generation, transmission and distribution of power along with fundamental mathematics and economics.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand basic linear programming and interpretation techniques.	
<b>CO2</b>	Acquire knowledge on economics of energy systems.	
<b>CO3</b>	Assess energy economic trends.	
<b>CO4</b>	Analyze the effect of energy demand and consumption patterns.	
<b>CO5</b>	Understand application of energy optimization methods and economic evaluation approaches to current trends.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	Modelling over view - levels of analysis - steps in model development - examples of models - quantitative techniques - interpolation polynomial - Lagrangian - curve fitting - regression analysis - solution of transcendental equations.	
<b>UNIT – 2</b>	System simulation - information flow diagram - solution of set of nonlinear algebraic equations - successive substitution - NR techniques - examples of energy systems simulation optimization - linear	



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	programming - simplex tableau - pivoting - sensitivity analysis.	
<b>UNIT – 3</b>	Tradeoffs between capital and energy using pinch analysis - energy economy models - scenario generation - input output models – numerical solution of differential equations -overview - convergences and accuracy - transient analysis - application example.	
<b>UNIT – 4</b>	Analysis of system load curve- plant load factor - availability - loss of load probability calculations for a power system - maintenance scheduling pricing of power - project cost components - analysis of power purchase agreements debt equality ratio - return on investment.	
<b>UNIT – 5</b>	Overview of Indian energy scenario - trends in energy use patterns - energy and development linkage - calculation of simple payback period - time value of money - net present value - internal rate of return -life cycle cost - cost of saved energy - cost of energy generated - examples from energy generation and conservation - energy chain - primary energy analysis.	
	<b>Total</b>	

\*Note:

**Text Books:**

1. Energy and the environment, 2<sup>nd</sup> edition. Fowler,J.M., McGraw Hill, New York,1984.
2. Energy /management Handbook, W.C.Turner,Wiley, New York, 1982.
3. Design of Thermal Systems,W.F.Stoecker, McGraw Hill, 1981.
4. Optimization theory and applications, S.S.Rao, Wiley Eastern, 1990.

**Reference Books:**

1. Introductory methods of numerical analysis, S.S.Sastry Prentice Hall, 1988.
2. Energy Systems analysis for developing countries, P.Meier, Springer Verlag,1984.
3. Applied System Analysis, R.DeNeufville, McGraw Hill, International Edition, 1990.
4. Optimization Theory and Practice, Beveridge and Schechter, MCgraw Hill,1970.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>I Semester</b>	<b>COMPUTATIONAL FLUID DYNAMICS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on Flow simulation & modelling in Computational Fluid Dynamics.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Explain know fundamentals of Computational Fluid Dynamics and governing equations of fluid flow.	
<b>CO2</b>	Develop simulation and modelling of fluid flow for variety of flow situations and boundary conditions.	
<b>CO3</b>	Understand various methods in finite difference, finite volume and finite element methods.	
<b>CO4</b>	Understand the type of flow, its boundary conditions.	
<b>CO5</b>	Use the appropriate meshing technique for the particular flow situation and get optimum solution.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Introduction to Fluid Dynamics and its Applications</b> Introduction to fluid dynamics - Types of fluid flows - factors affecting the type of flow - introduction to CFD - definition - applications - steps involved in CFD analysis - advantages and limitations - components of numerical solutions - properties of numerical solution methods - conservative and non-conservative form of governing equations of fluid	12



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	flow - mass, momentum, energy equations of fluid flow.	
<b>UNIT – 2</b>	<b>Various methods in discretization approaches</b> Discretization approaches - finite difference method - forward difference method - backward difference method - central difference method - finite volume method - upwind interpolation - linear interpolation - quadratic upwind interpolation - application of finite volume method and finite difference methods to fluid flow problems.	12
<b>UNIT – 3</b>	<b>Multi grid methods and boundary conditions</b> Introduction to multi grid methods - multi grid cycles - boundary conditions – inlet boundary conditions - outlet boundary conditions - wall boundary conditions - Dirichlet boundary conditions - Newmen boundary conditions - robin boundary conditions - applications in the field of renewable energy.	12
<b>UNIT – 4</b>	<b>Various methods in Finite element methods</b> Finite element methods - stiffness matrix - variational method - Galerkin’s method - least square method - Laplace equation - diffusion or wave equation - iterative methods - Gauss Siedel - Gauss Jordan - Gauss elimination methods - turbulent flows - turbulent flow models.	12
<b>UNIT – 5</b>	<b>Mesh generation and its types</b> Structured - blocked structured - unstructured mesh - body fitted meshes - algebraic meshes - partial differential equation mesh generation - surface meshing - analysis of simple internal flows in pipes - external flows over a solar collector.	12
	<b>Total</b>	

\*Note:

**Text Books:**

1. An Introduction to Computational Fluid Dynamics - The finite volume approach by H. K. Versteeg & W. Malalasekara.
2. Applied Finite Element Analysis, by L. J Segerlind, John Wiley & Sons, 2nd edition.
3. Computational Methods for Fluid Dynamics by Joel H.Ferziger/MilovanPeric.
4. Finite element mesh generation by Daniel.S.H.Lo

**Reference Books:**

1. Computational Fluid Dynamics by John. D. Anderson, McGraw Hill Company.
2. Frontiers of Computational Fluid Dynamics by D.A. Caughey and M.M. Hafez



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>I Semester</b>	<b>ENERGY SYSTEMS SIMULATION LABORATORY-I</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>0</b>	<b>1</b>	<b>2</b>	<b>2</b>

**List of Experiments:**

1. Review of simulation software fundamentals.
2. Development of Solar Cell model and simulation of performance curves and their variation with temperature and irradiation.
3. Development of model for PV module and simulation of performance curves and their variation with temperature and irradiation.
4. Development of model for PV array and simulation of performance curves and their variation with temperature and irradiation.
5. Write a C/C++ programme to calculate the load current of a solar cell using relevant mathematical equations for the given data.
6. Write a C/C++ programme to calculate efficiency of a wind turbine using relevant mathematical equations for the given data.
7. Study the Characterization of the Resistance Temperature Detector (RTD)
8. Study the Characterization of the Linear variable differential transformer (LVDT)
9. Study the Characterization of the Thermocouple.
10. Solar cell simulation using simulator.

**Reference Text:**

1. D. Patranabis, "Sensors and Transducers"
2. Doebelin, "Measurement Systems Applications and Design"



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<b>I Semester</b>	<b>RENEWABLE ENERGY LABORATORY-I</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>0</b>	<b>1</b>	<b>2</b>	<b>2</b>

**List of Experiments:**

1. Identifying PV modules of different technologies and measure the performance parameters (outdoor).
2. Measurement of current-voltage characteristics of two solar cells connected in series and parallel.
3. Series and parallel connection of PV modules.
4. Carrier life time measurement of a solar cell using RRT and OCVD methods.
5. Spectral Response Measurement of a solar cell.
6. White LED lighting systems (solar PV powered)-home lighting and street lighting: Study, Design and evaluation.
7. Dependence of solar cell I-V characteristics on irradiance and temperature.
8. Study and analysis of a solar still / distillation plant.
9. Performance evaluation of a solar flat plate thermo syphon water heating system
10. Conversion efficiency of a solar flat plate forced circulation water heating system
11. Conversion efficiency of a solar Concentrating water heating system.
12. Testing the efficiency of solar dryer.

**Reference Books (Practical)**

1. ***Solar Photovoltaics: A Lab Training Manual***, Chetan S. Solanki et al, IIT Bombay, Cambridge University Press India Pvt. Ltd, 2013.
2. **System Technician Training Manual Part II, Solar Photovoltaic Training Programme, CEC, IIT Madras, (under IREDA/World Bank/Siemens/IITM programme).**
3. ***SPV Training rogram***.IREDA/World Bank/Siemens.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>II Semester</b>	<b>ENERGY STORAGE TECHNOLOGIES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**Pre-requisite:** Basic knowledge on conventional and non-conventional energy sources and integration of electrical and electronic circuits.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand the concept of energy storage and market economics of various sustainable energy storage system.	
<b>CO2</b>	Understand various types of battery energy storage systems.	
<b>CO3</b>	Have basic knowledge on thermoelectric and superconductivity magnetic energy storage system.	
<b>CO4</b>	Know the importance of super capacitors.	
<b>CO5</b>	Understand the developments in new energy storage technologies.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Overview: Energy and Grand challenges on energy storage</b> Overview of current development in energy storage technologies - historic and current trends (global, regional and domestic energy storage trends, storage growth to date, future storage growth, drivers and key dynamics, supply & demand dynamics-trends), grand challenges. Classification of energy storage systems, energy storage system sizing.	
<b>UNIT – 2</b>	<b>Battery (Electrochemical energy storage)</b>	



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### R25 M.TECH RENEWABLE ENERGY SYLLABUS

	Explore the fundamental concept of batteries - measuring of battery performance - charging and discharging of a battery - storage density - energy density and safety issues particularly classical batteries, such as (i) Lead acid (ii) Nickel – Cadmium (iii) Zinc Manganese dioxide and modern batteries. Flow batteries, comparison and economic features of different battery technologies.	
<b>UNIT – 3</b>	<b>Electrical/Electromagnetic Energy Storage - Thermoelectric and Super Conducting Magnetic Energy Storage Systems (SMES)</b> Explain the fundamental concept of thermoelectric, such as electron conductor and photon glass concept - introduce several classical thermoelectric materials and the measurements related with thermoelectric such as (i) four-probe resistivity measurement (ii) see beck coefficient measurement and (iii) thermal conductivity measurement - concept of SMES and its application.	
<b>UNIT – 4</b>	<b>Electrical Energy Storage - Supercapacitor</b> Examine the basic components of supercapacitors, including several types of electrodes and some electrolytes - the electrode materials are : high surface area activated carbons, metal oxide and conducting polymers - the electrolyte may be aqueous or organic - advantages and disadvantages of super capacitors and comparison with battery systems and their applications in public transport vehicles - private vehicles and consumer electronics - discussion on aspects of energy density - power density -price and market.	
<b>UNIT – 5</b>	<b>Thermochemical energy storage/ Emerging Storage Technologies</b> Hydrogen and fuel cells, hybrid electrical energy storage, solar hydrogen and solar metals -solar fuels, synthetic natural gas, power to gas – Novel and Modern Energy Storage Technologies.	
	<b>Total</b>	

\*Note:

#### Text Books:

1. Energy storage systems in electronics, Volume 1 of new trends in electrochemical Technology by Tetsuya Osaka, Madhav Datta, Published by Taylor & Francis, 2000.
2. Understanding Batteries y R. M. Dell, David Anthony James Rand - 2001, published by RSC Paper backs.
3. Fuel Cell Systems Explained, Larminie, James/ Dicks, Andrew John Wiley & Sons.
4. Energy storage, S Huggins Robert, 2010, springer.
5. Thermo electrics Handbook: Macro to Nano, ISBN # 084932 2642.
6. Fuel Cell and Their Applications, Kordesch. K, and Simader.G, Wiley-Vch, Germany 1996.
7. Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas. B. Reddy, McGraw Hill Book Company, N.Y. 2002.
8. Thermal Energy Storage Systems and Applications, Ibrahim Dincer and Mark A. Rosen,



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John Wiley & Sons 2010.

9. "Hand book of energy engineering", 6th Edition, A.Thumann, D. Paul Mehta, The Fairmont Press, Inc., 2008.

10. World Energy Investment, 2019.

### **Reference Books:**

1. Solar energy storage, Bent Sorensen, 2015, Academic press.

2. Energy storage technologies and applications, Ahmed faheemzobaa, Intech open, 2013.

3. Thermal Energy Storage Technologies for Sustainability Systems Design, Assessment and Applications, Kalaiselvam .S & R. Parameshwaran , First edition, 2014, academic press.

4. Energy Storage at Different Voltage Levels: Technology, integration, and market aspects, Ahmed F. Zobaa et al, 2018, The Institution of Engineering and Technology.

5. Essentials of Energy Technology: sources, transport, storage and conservation, Jochen Fricke and Walter L. Borst, Wiley-VCH, 2013.

6. Design and Management of Energy-Efficient Hybrid Electrical Energy Storage Systems, Younghyun Kim & Naehyuck Chang, 2014, Springer international publishing.

7. Synthetic Natural Gas from Coal, Dry Biomass, and power-to -gas applications, Tilman J. Schildhauer Serge M.A. Biollaz, 2016, John Wiley & Sons.



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<b>II Semester</b>	<b>HYDROGEN AND FUEL CELLS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**Pre-requisite:** Basic knowledge on various technological advancements, benefits and prospects of utilizing hydrogen/ fuel cell.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Explain the hydrogen production methodologies, possible applications and various storage options.	
<b>CO2</b>	Analyze the working principle of a typical fuel cell, types of fuel cells.	
<b>CO3</b>	Understand the challenges in the applications of fuel cell.	
<b>CO4</b>	Analyse the cost effectiveness and eco-friendliness of fuel cells.	
<b>CO5</b>	Understand the working of fuel cell vehicle.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Hydrogen Fundamentals, Energy Landscape, Production Technologies</b> Hydrogen as an energy carrier: Properties, advantages, challenges - Hydrogen in the energy transition - Sources of hydrogen: Grey, blue, green, turquoise; lifecycle and comparative analysis vs. batteries, fuels - Global policies, roadmaps, and market outlook - Electrolytic production: Alkaline, PEM, Solid Oxide Electrolyzers; principles, components, system design, and emerging technologies - Thermochemical, biological, and photo-electrochemical pathways – Steam Reforming, pyrolysis hydrogen production	



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<b>UNIT – 2</b>	<b>Hydrogen Storage, Transportation, and Safety</b> Physical storage: Compressed gas, liquid hydrogen—materials, design, filling, boil-off, efficiency - Chemical and solid-state storage: Metal hydrides, amines, LOHCs, advanced composites - Hydrogen distribution: Pipelines, tankers, on-site generation, infrastructure - Safety protocols, risk mitigation, fire/explosion handling - applications of hydrogen.	
<b>UNIT – 3</b>	<b>Fuel Cell fundamentals</b> Historical background, basic principles, and classification of fuel cells – Alkaline Fuel Cell – Phosphoric Acid Fuel Cell – Solid Oxide Fuel Cell – Molten Carbonate Fuel Cell – Direct Methanol Fuel Cell - Proton Exchange Membrane Fuel Cell- relative merits and demerits- Comparison of fuel cells with batteries.	
<b>UNIT – 4</b>	<b>Application of Fuel Cell and Economics</b> Techno – Economic analysis of fuel cell - Fuel cell usage for domestic power systems - automobile – space - economic and environmental analysis on usage of hydrogen and fuel cell - future trends in fuel cells.	
<b>UNIT – 5</b>	<b>Fuel cell vehicles and its Constituents</b> Concept of fuel cell vehicles – operating principle – fuel cell Stack – fueling option for fuel cell vehicle – fuel cell vehicle integration – technical issues – case study fuel cell vehicle Vs hybrid vehicle.	
	<b>Total</b>	

\*Note:

#### Text Books:

##### Text Books:

1. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorenson, Sorenson B, Academic Press (2005).
2. Hydrogen and Fuel Cells: Advances in Transportation and Power, Horddeski MF, The Fairmont Press, Inc. (2009).
3. Hydrogen and Fuel Cells: A Comprehensive Guide, Busby RL, PennWell Books (2005)
4. Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M, Universities Press, 2006.
5. Principles of Fuel Cells, by Xianguo Li, Taylor & Francis, 2006 .

##### Reference Book:

1. “Transport Phenomena in Multiphase Systems”, AFaghri& Y Zhang, Elsevier 2006
2. “Fuel Cells: From Fundamentals to Applications”, SSrinivasan, Springer 2006
3. “Fuel Cell Fundamentals”, O’Hayre, SW Cha, W Colella and FB Prinz, Wiley, 2005
4. “Principles of Fuel Cells”, Xianguo Li, Taylor and Francis, 2005



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5. “Fuel Cell Systems Explained, J.Larminie and A Dicks, 2nd Edition”, Wiley,2003
6. “Power, Energy, & Industry Applications”, IEEE Journals.
7. “Fuel Cell and Their Applications”, Kordesch. K and Simader.G, Wiley-Vch, Germany, 1996.



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<b>II Semester</b>	<b>INTEGRATION OF RENEWABLE ENERGY SOURCES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**Pre-requisite:** Basic knowledge on renewable energy sources, isolated systems and hybrid systems.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Identify key challenges in integrating renewable energy sources into the grid.	
<b>CO2</b>	Explain power generation strategies and MPPT techniques for various renewable systems.	
<b>CO3</b>	Analyze converter topologies and their roles in grid synchronization.	
<b>CO4</b>	Design hybrid renewable systems considering load curves and energy storage.	
<b>CO5</b>	Understand voltage/frequency control in isolated systems and microgrids.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Issues in integration of renewable energy sources</b> Overview of challenges in integrating renewable sources to the grid - impact of harmonics on power quality - need to maintain voltage within a band and fluctuations in voltage because of renewable integration - power inverter and converter technologies - mechanism to synchronize power from renewable sources to the grid - overview of challenges faced in	



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	designing power injection from offshore generation sources - challenges in modelling intermittent nature of renewable power in a power system.	
<b>UNIT – 2</b>	<b>Renewable Energy Sources: Characteristics and generation challenges and</b> Basic review of Power generation from wind, solar PV, Biomass, Small hydro -Power generation strategies for Each Renewable Energy Systems - Review of maximum Power Point techniques - PV and wind: Perturb & observe, - Hill climbing, Incremental conductance Case Examples: Indian Renewable installations.	
<b>UNIT – 3</b>	<b>Power Electronics and Converter topologies:</b> DC-DC Converters: Buck, Boost, Buck-Boost - DC-AC Inverters: Sine, Square wave, PWM Converters - Phase Locked Loop (PLL) and Synchronization - grid-following Vs grid-forming Converters	
<b>UNIT – 4</b>	<b>Hybrid Renewable Energy Systems:</b> Types: PV-Wind-Diesel, PV-Wind-Battery - Advantages of hybrid Power Systems - Importance and advantages of Hybrid Power Systems - Importance of Energy Storage Systems - Design of hybrid systems using load curves - Sizing of hybrid systems	
<b>UNIT – 5</b>	<b>Isolated Systems and Microgrids:</b> Voltage & frequency stability in isolated system - Islanded operation of microgrids - Load shedding and demand response techniques	
	<b>Total</b>	

\*Note:

**Text Books:**

1. *Renewable Energy Integration: Challenges and Solutions* by Jahangir Hossain & Apel Mahmud
2. *Renewable Electricity and the Grid: The Challenge of Variability*, edited by Godfrey Boyle
3. *Smart Power Systems and Renewable Energy System Integration* edited by D. Jayaweera et al.
4. *Hybrid Renewable Energy Systems* by Djamila Rekioua (Green Energy & Technology)
5. *Modeling Power Electronics and Interfacing Energy Conversion Systems* by Farret & Simões
6. *Smart Power Systems and Renewable Energy System Integration* edited by D. Jayaweera et al.



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<b>II Semester</b>	<b>INSTRUMENTATION FOR ENERGY SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on instruments used in various industries, analog to digital and digital to analog converters and various types of sensors.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand the fundamentals of instrumentation, measurement errors, and characteristics of various transducers.	
<b>CO2</b>	Apply knowledge of process instrumentation to measure physical parameters in energy systems such as pressure, flow, and environmental conditions.	
<b>CO3</b>	Evaluate instruments used for wind, water, and environmental monitoring, including air and water quality assessment.	
<b>CO4</b>	Design and interpret signal conditioning circuits for energy system instrumentation.	
<b>CO5</b>	Analyze control systems and SCADA applications in renewable energy systems for real-time monitoring and control.	
<b>CO6</b>		

*#Based on suggested Revised BTL*

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Introduction to Instrumentation and Transducers</b> - Basic concept of measurement - Errors in measurement - Classification of transducers - Static and dynamic characteristics of transducers - Strain gauge, LVDT, RVDT, Thermocouples, RTDs, Piezoelectric sensors	
<b>UNIT –</b>	<b>Process Instrumentation in Energy systems</b> - Pressure flow and level	



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2	measurement instruments - Humidity sensors and temperature measurement - Environmental data logging and Automatic dusk to dawn sensors - Measuring instruments for wave energy - surface acoustic wave sensor, geophone, hydrophone, seismometer, gyroscope energy, surface acoustic wave sensor	
UNIT – 3	<b>Instrumentation for Environment and Energy Measurements</b> Wind measurement instruments: wind-vane, anemometer, laser-based wind sensors - Measurement of air and water quality: SO <sub>x</sub> , NO <sub>x</sub> , CO, CO <sub>2</sub> , hydrocarbons, ozone - Determination of organic and inorganic substances - Water and solid waste sampling techniques	
UNIT – 4	<b>Instrumentation circuits and signal conditioning</b> Phase difference measurement using XOR, Phase detectors - SR flip-flop, Photo-interrupter sensor - Sample and hold circuit, Clipping circuit, opto-Couplers - Voltage-to-frequency and frequency-to-voltage converters	
UNIT – 5	<b>Control Systems in Renewable Energy:</b> A/D and D/A Converters- Real-time data Processing- SCADA in Renewable Energy monitoring -Instruments for Electrical Parameters monitoring (Voltage, Current, Power, harmonics)- Feed back control System-PID control in PV, wind, and hybrid Systems	
	<b>Total</b>	

\*Note:

#### Text Books:

1. John P Bentley, “Principles of Measurement Systems”, Pearson Education.
2. David A Bell, “Electronics Instrumentation and Measurements”, Oxford Higher Education.

#### Reference Books:

1. H S Kalsi, “Electronic Instrumentation”, McGraw-Hill Education (India) Private limited.
2. Helfrick A D, Cooper W D, “Modern Electronic Instrumentation and Measure Techniques”, Prentice Hall India.
3. Shawhney A K, “A Course In Electrical and Electronics Measurements and Instrumentation”, DhanpatRai.
4. Rangan C S, Sarma G R, Mani V S V, “Instrumentation Devices And Systems”, Tata McGraw-Hill.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>I Semester</b>	<b>SMART GRID SYSTEMS AND TECHNOLOGIES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to :

		Knowledge Level (K)#
<b>CO1</b>	Understand smart grids and analyze the smart grid policies and developments in smart grids.	
<b>CO2</b>	Develop concepts of smart grid technologies in hybrid electrical vehicles.	
<b>CO3</b>	Understand smart substations, feeder automation and GIS etc.	
<b>CO4</b>	Analyze micro grids and distributed generation systems	
<b>CO5</b>	Analyze the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.	
<b>CO6</b>		

*#Based on suggested Revised BTL*

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Introduction to Smart Grid</b> Evolution of electric grid, concept of smart grid, definitions, need of smart grid, functions of smart grid, opportunities & barriers of smart grid, difference between conventional & smart grid, concept of resilient &self	



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	healing grid, present development & international policies on smart grid. case study of smart grid.	
<b>UNIT – 2</b>	<b>Smart Grid Technologies: Part 1</b> Introduction to smart meters, real time pricing, smart appliances, Automatic Meter Reading (AMR), Outage Management System (OMS), Plug in Hybrid Electric Vehicles(PHEV), vehicle to grid, smart sensors, home & building automation, phase shifting transformers.	
<b>UNIT – 3</b>	<b>Smart Grid Technologies: Part 2</b> Smart substations, substation automation, feeder automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, smart storage like battery, SMES, pumped hydro, compressed air energy storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).	
<b>UNIT – 4</b>	<b>Microgrids and Distributed Energy Resources</b> Concept of microgrid, need & applications of microgrid, formation of microgrid, issues of interconnection, protection & control of microgrid. Captive power plants, integration of renewable energy sources.	
<b>UNIT – 5</b>	<b>Power Quality Management in Smart Grid</b> Power quality & EMC in smart grid, power quality issues of grid connected renewable energy sources, power quality conditioners for smart grid, web based power quality monitoring, power quality audit. <b>Information and Communication Technology for SmartGrid</b> Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).	
	<b>Total</b>	

\*Note:

**Text Books:**

- 1.Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley
2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press

**Reference Books:**

- 1.JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, kihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley
- 2.Jean Claude Sabonnadière, NouredineHadjsaïd, “Smart Grids”, Wiley Blackwell 19
- 3.Peter S. Fox Penner, “Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities”, Island Press; 1 edition 8 Jun 2010
- 4.S. Chowdhury, S. P. Chowdhury, P. Crossley, “Microgrids and Active Distribution Networks.” Institution of Engineering and Technology, 30 Jun 2009
- 5.Stuart Borlase, “Smart Grids (Power Engineering)”, CRC Press



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6.Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability: 1”,  
Artech House Publishers July 2011



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## R25 M.TECH RENEWABLE ENERGY SYLLABUS

II Semester	<b>ENERGY AUDITING AND DEMAND SIDE MANAGEMENT</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on conventional as well as non-conventional energy generation, transmission and distribution of power along with fundamental mathematics and economics.

### Course Objectives:

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand the concepts of energy auditing, conservation, policies and codes in India	
<b>CO2</b>	Understand and apply energy auditing procedures in utilities.	
<b>CO3</b>	Acquire knowledge on energy measuring instruments for data collection	
<b>CO4</b>	Understand the concept of demand side management	
<b>CO5</b>	Analyze and develop energy efficient programs for demand side management in utilities.	
<b>CO6</b>		

#Based on suggested Revised BTL

### Mapping of course outcomes with program outcomes

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

UNIT	CONTENTS	Contact Hours
<b>UNIT – 1</b>	<b>INTRODUCTION TO ENERGY AUDITING</b> Energy situation – World and India, energy consumption, conservation, codes, standards and legislation energy audit- definitions and Concept, Types of audit, energy index, cost index, pie charts, sankey diagrams and load profiles, energy conservation schemes. Measurements in energy audits, presentation of energy audit results. Modern/recent energy	



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	policies & codes.	
<b>UNIT – 2</b>	<b>ENERGY EFFICIENT MOTORS AND POWER FACTOR IMPROVEMENT</b> Energy efficient motors, factors affecting efficiency, loss distribution , constructional details, characteristics - variable speed, variable duty cycle systems, RMS Hp-voltage variation-voltage unbalance- over motoring- motor energy audit. Power factor - methods of improvement, power factor with nonlinear loads.	
<b>UNIT – 3</b>	<b>LIGHTING AND ENERGY INSTRUMENTS FOR AUDIT</b> Illumination requirements for task and non-task areas, good lighting system design and practice, lighting control, lighting efficiency, lighting energy audit - energy instruments- watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers, application of PLC's.	
<b>UNIT – 4</b>	<b>INTRODUCTION TO DEMAND SIDE MANAGEMENT</b> Introduction to DSM, concept of DSM, benefits of DSM, different techniques of DSM – time of day pricing, multi-utility power exchange model, and time of day models for planning. Load management, load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient equipment. Management and organization of energy conservation awareness programs.	
<b>UNIT – 5</b>	<b>ECONOMICS AND COST EFFECTIVENESS TESTS OF DSM PROGRAMS</b> Basic payback calculations, depreciation, net present value calculations. Taxes and tax credit – numerical problems. Importance of evaluation, measurement and verification of demand side management programs. Cost effectiveness test for demand side management programs - ratepayer impact measure test, total resource cost, participant cost test, program administrator cost test, numerical problems: Participant cost test, total resource cost test and ratepayer impact measure test.	
	<b>Total</b>	

\*Note:

#### Text Books:

1. Industrial Energy Management Systems, Arry C. White, Philip S. Schmidt, David R. Brown, Hemisphere Publishing Corporation, New York, 1994.
2. Fundamentals of Energy Engineering - Albert Thumann, Prentice Hall Inc, Englewood Cliffs, New Jersey, 1984.

#### Reference Books:

1. Economic Analysis of Demand Side Programs and Projects – California Standard Practise Manual, June 2002 – Free download available online
2. Integrated Energy Policy, August 2006, Planning Commission, Government of India.
3. New Technologies for Energy Efficiency - Michael F. Hordeski, Fairmont press, 2002.



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<b>II Semester</b>	<b>ENERGY EFFICIENCY AND GREEN BUILDINGS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Students require basic concepts of electrical appliances, and building plans.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand energy-efficient electrical and mechanical systems.	
<b>CO2</b>	Analyze green manufacturing practices and their benefits.	
<b>CO3</b>	Understand green and ecological building design concepts.	
<b>CO4</b>	Assess sustainable building systems and LEED/IGBC standards.	
<b>CO5</b>	Acquire knowledge on green building implementation and waste management.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Introduction to Green Buildings and Sustainability Principles:</b> Fundamentals: Definitions of sustainable development, green buildings, and their necessity in the context of climate change, resource depletion, and urbanization - Benefits: Environmental, economic, and social benefits of green buildings - Green Building Movement: Historical context, key milestones, and the current global and national scenario - Life Cycle Assessment - Policy and Regulations: Examination of energy codes, national and international policies	



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### R25 M.TECH RENEWABLE ENERGY SYLLABUS

<b>UNIT – 2</b>	<b>Climate-Responsive Design and Building Envelope:</b> Climatology: The relationship between climate, sun path, wind patterns, and building design - Passive Design Strategies: Techniques like solar passive cooling and heating, natural ventilation, daylighting, and shading systems to minimize energy consumption - Building Envelope: The role of walls, roofs, windows, and insulation in thermal performance - Sustainable Materials & Construction Techniques	
<b>UNIT – 3</b>	<b>Energy Systems and Renewable Energy Integration</b> Energy Audits and Management - HVAC Systems: Design and selection of energy-efficient heating, ventilation, and air conditioning systems - Integration of renewable energy sources such as solar photovoltaics (PV), solar water heating, and wind energy into building design - Smart Buildings: Introduction to building automation systems (BAS), Smart and Net-Zero Energy Buildings, Internet of Things in buildings for optimized energy use and performance monitoring.	
<b>UNIT – 4</b>	<b>Sustainable Materials and Resource Management</b> Green Building Materials - Water Efficiency: Strategies for water conservation, including rainwater harvesting, water-efficient fixtures, and wastewater treatment and reuse systems - Waste Management: Planning for construction and demolition waste management - Indoor Environmental Quality: factors that contribute to a healthy indoor environment (air quality, lighting, acoustics, and the use of low-VOC materials).	
<b>UNIT – 5</b>	<b>Green Building Rating Systems and Case Studies</b> Rating Systems: green building rating systems such as LEED, BREEAM, IGBC and GRIHA - Certification Process: Understanding the criteria, point systems, and documentation required for green building certification - Case Studies: Analysis of real-world green building projects, Local, national, and international best-practices.	
	<b>Total</b>	

\*Note:

#### Text Books:

1. "Sustainable Technologies for Energy Efficient Buildings" by Meena, Kumar, Singh, Ghosh (Routledge, 2024): Covers advanced materials, energy optimization, net-zero design, urban infrastructure, data-driven evaluation, and global case studies.
2. "Handbook of Energy Efficiency in Buildings: A Life Cycle Approach" (ScienceDirect, 2025): Focuses on life-cycle methodology, complete building assessment, and policy context.
3. "Toward Energy-Efficient Buildings: Envelope Technologies and Sustainable Energy Systems" by Vivien L. Lu, Xi Chen (ScienceDirect, 2025): Emerging envelope and system technologies.
4. "Energy-efficient buildings in India" by Mili Majumdar (TERI): Comprehensive Indian perspective on climatic design and implementation, with real project examples.
5. "Design Professional's Guide to Zero Net Energy Buildings" by Charles Eley: Practical approaches to net-zero, design strategies, renewables integration.
6. LEED v4 Reference Guide, and IGBC Green New Buildings Rating System.



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**Reference Books:**

1. *Green Building Fundamentals* by G. Harihara Iyer (A recent book providing insight into green building as a solution to climate change.)
2. *Green Building Handbook* by Tom Woolley and Sam Kimings (A practical guide to the principles and applications of green building.)
3. *Handbook on Green Practices* by the Indian Society of Heating, Refrigerating and Air-conditioning Engineers (ISHRAE).



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>II Semester</b>	<b>SOLAR REFRIGERATION AND AIRCONDITIONING</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:** Basic knowledge on solar cooling, types of solar cooling systems, solar collectors and storage systems for solar refrigeration and air-conditioning.

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Review on solar collectors and storage systems for refrigeration and air conditioning.	
<b>CO2</b>	Equip the students with the necessary information pertaining to the application of solar energy for refrigeration and air conditioning purposes.	
<b>CO3</b>	Acquire knowledge on advanced cooling systems.	
<b>CO4</b>	Explain various types of refrigeration systems and cooling systems.	
<b>CO5</b>	Understand the thermal modelling and simulation of various refrigeration and air conditioning systems.	
<b>CO6</b>		

#Based on suggested Revised BTL

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	Concept of solar energy - review of solar collectors - solar concentrators - potential and scope of solar cooling - types of solar cooling systems - solar collectors and storage systems for solar refrigeration and air-conditioning.	
<b>UNIT – 2</b>	Solar operation of vapor absorption and vapor compression refrigeration	



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	cycles and their thermodynamic assessment - Rankine cycle - Sterling cycle based on solar cooling systems - Jet ejector solar cooling systems - Fuel assisted solar cooling systems - solar desiccant cooling systems.	
<b>UNIT – 3</b>	Open cycle absorption / desorption solar cooling alternatives - Advanced solar cooling systems - working principles - Energy analysis and performance.	
<b>UNIT – 4</b>	Thermal modelling and computer simulation for continuous and intermittent solar refrigeration and air-conditioning systems - performance evaluation and case studies.	
<b>UNIT – 5</b>	Refrigerant storage for solar absorption cooling systems - solar thermoelectric refrigeration and air-conditioning - solar thermo acoustic cooling and hybrid air- conditioning - solar economics of cooling systems - numerical examples.	
	<b>Total</b>	

\*Note:

**Text books:**

1. Solar Refrigeration and space conditioning, Kaushik S.C., Divyajyoti publications, Jodhpur (India).1989.

**Reference Books:**

1. “Solar air conditioning and refrigeration”, M. Sayigh, J. C. McVeigh,Pergamon Press, 1992.
2. “Low Energy Cooling for Sustainable Buildings”, Ursula Eicker, John Wiley and Sons,2009.
3. “Solar-assisted air conditioning in buildings: a handbook for planners”, Hans-Martin Henning, Springer, 2007.
4. “Passive cooling of buildings”, M. Santamouris, D. Asimakopoulos,Earthscan, 1996.



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**R25 M.TECH RENEWABLE ENERGY SYLLABUS**

<b>II Semester</b>	<b>WIND ENERGY SYSTEMS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Pre-requisite:**

**Course Objectives:**

- 1.
- 2.
- 3.
- 4.

**Course Outcomes:** At the end of the course, student will be able to (Four to Six )

		Knowledge Level (K)#
<b>CO1</b>	Understand wind energy availability, wind characteristics, and site selection.	
<b>CO2</b>	Explain wind turbine types, blade design, and mechanical components.	
<b>CO3</b>	Analyze electrical generators and power control strategies in wind systems.	
<b>CO4</b>	Apply power electronics and control techniques for efficient wind energy conversion.	
<b>CO5</b>	Evaluate wind farm integration, hybrid systems, and power quality challenges.	
<b>CO6</b>		

*#Based on suggested Revised BTL*

**Mapping of course outcomes with program outcomes**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>
<b>CO1</b>						
<b>CO2</b>						
<b>CO3</b>						
<b>CO4</b>						
<b>CO5</b>						
<b>CO6</b>						

(Please fill the above with Levels of Correlation, viz., L, M, H)

<b>UNIT</b>	<b>CONTENTS</b>	<b>Contact Hours</b>
<b>UNIT – 1</b>	<b>Fundamentals of Wind Energy</b> Wind energy resources: availability, global and Indian scenario - Wind characteristics: wind profile, wind shear, turbulence, gusts - Wind speed measurements and site selection - Aerodynamics of wind turbines: lift and drag	



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	- Types of wind turbines: horizontal vs vertical axis, upwind vs downwind	
<b>UNIT – 2</b>	<b>Wind Turbine Components and Mechanics</b> Blade design and materials - Rotor dynamics and blade pitch control - Yaw control and tower structure - Gearboxes, bearings, and mechanical drive systems Brake systems – mechanical and aerodynamic	
<b>UNIT – 3</b>	<b>Electrical Aspects of Wind Energy Systems</b> Wind electric generators (WEGs): Squirrel cage induction, wound rotor induction, doubly-fed induction, permanent magnet synchronous generators - Generator selection criteria - Power control strategies: stall regulation, pitch regulation, active and passive controls - Grid-connected and standalone wind systems - Reactive power compensation and voltage control.	
<b>UNIT – 4</b>	<b>Power Electronics and Control</b> Power converters for WEGs: AC-DC-AC, back-to-back converters - Maximum Power Point Tracking (MPPT) techniques - Control of DFIG and PMSG in wind turbines - Protection and fault management - SCADA systems in wind energy farms	
<b>UNIT – 5</b>	<b>Integration and Hybrid Systems</b> Wind farm layout and optimization- -Grid integration challenges and standards (IEC, Indian standards) - Power quality issues, harmonic mitigation, low voltage ride-through (LVRT) - Wind-diesel, wind-PV hybrid systems - Economic and environmental aspects of wind energy	
	<b>Total</b>	

\*Note:

**Text Books**

1. “Wind Energy: Theory and Practice”By *S. Rao and B. B. Parulekar*
2. “Wind Power Plants: Fundamentals, Design, Construction and Operation” By *R. Gasch and JTwele*
3. “Wind Energy Handbook” By *Tony Burton, Nick Jenkins, David Sharpe, Ervin Bossanyi*
4. “Renewable Energy Engineering and Technology: Principles and Practice”By *V. V. N. Kishore (TERI Publication)*
5. “Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications”By *Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad*

**Reference Books:**

1. “Wind Energy Systems for Electric Power Generation”By *Manfred Stiebler*
2. “Integration of Distributed Generation in the Power System”By *Math H. J. Bollen and Fainan Hassan*



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<b>II Semester</b>	<b>ENERGY SYSTEMS SIMULATION LABORATORY-II</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>0</b>	<b>1</b>	<b>2</b>	<b>2</b>

**List of Experiments:**

1. Review of Renewable Energy softwares.
2. Develop a model for monitoring, modelling and simulation of a DC Surface solar PV pump system.
3. Construction of a wind rose using spread sheet for a particular given interval.
4. Construction of a wind rose using hydrognomon software tool for a particular given interval.
5. Simulate a small PV system designed for a residential rooftop, with a power of 50 kWp. The details of the PV system are as follows:
  - i. PV generator: formed by 200 modules of 250 Wp, series connection in a string 10, parallel strings 9. The PV modules are formed by 60 solar cells, and the module characteristics are the following: MPP:  $I_{mp} = 3.4A$ ,  $V_{mp} = 16.2V$ . Short circuit current  $I_{scr} 3.7A$  and open circuit voltage  $V_{oc} 20.5V$ . Inverter parameters: nominal power 4.00 kW, one output line: AC voltage 220 V rms, efficiency 0:85. Minimum input DC voltage is 30 V. AC loads are also connected to the inverter output. Select any daily power load demand but maintain a total energy demand of 75MWh/year.
  - ii. Evaluate the simulation of this PV system over a year. Temperature and irradiance profiles may e ascertained for Ka location.
  - iii. Ascertain/assume data not given.
6. Develop a model for a Wind turbine generator and simulate performance curves ( $C_p V_s \lambda$ ) and ( $T_m V_s N$ ) using Doubly fed induction generator
7. Develop a model for a Wind turbine generator and simulate performance curves ( $C_p V_s \lambda$ ) and ( $T_m V_s N$ ) using synchronous generator
8. Develop a model for a Wind turbine generator, PV array and a PV-Wind hybrid system to analyze the performance of the hybrid system connected to a pump load under various wind and irradiance conditions at geographical location Kakinada. . Assume PV array capacity of 480 Wp and Wind turbine rating of 700 Watts. Assume data not given.
9. Design model using any design software.
10. Load Forecasting using Artificial Intelligent techniques.

**Reference Text:**

1. *Modeling Photovoltaic Systems using PSpice*, LuisCastaner and Santiago Silvestre John Wiley & Sons Ltd, West Sussex, England, 2002.



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<b>II Semester</b>	<b>RENEWABLE ENERGY LABORATORY-II</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
		<b>0</b>	<b>1</b>	<b>2</b>	<b>2</b>

**List of Experiments:**

1. Estimating the effect of sun tracking on the energy generation by PV modules.
2. Efficiency measurement of a standalone PV System.
3. Testing of MPPT System at various tilt angles under series and shunt configuration.
4. Photovoltaic System sizing exercise.
5. Measurement of global solar irradiation using a solar cell.
6. Dark and illuminated current-voltage characteristics of solar cell.
7. Dynamic Response test of MPPT using Buck converter based solar pv emulator
8. Dynamic Response test of MPPT using Boost converter based solar pv emulator
9. Dynamic Response test of MPPT using Buck- Boost converter based solar pv emulator
10. Estimation of average wind speed over a protracted period of time with the help of an anemometer and data logger.
11. Water efficiency measurement of a Solar PV Water Pumping System. Also generation of Head-Discharge, Efficiency-Discharge and Input power-Discharge performance curves.
12. Testing of Charge Controllers (Series and Shunt type).

**Reference Books (Practical)**

1. ***Solar Photovoltaics: A Lab Training Manual***, Chetan S. Solanki et al, IIT Bombay, Cambridge University Press India Pvt. Ltd, 2013.
2. **System Technician Training Manual Part II, Solar Photovoltaic Training Programme**  
CEC, IIT Madras, (under IREDA/World Bank/Siemens/IITM programme).