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RENEWABLE ENERGY TECHNOLOGY **Course Code : 315337**

Programme Name/s	**: Electrical Engineering/ Electrical and Electronics Engineering/ Electrical Power System**
Programme Code	**: EE/ EK/ EP**
Semester	**: Fifth**
Course Title	**: RENEWABLE ENERGY TECHNOLOGY**
Course Code	**: 315337**

I. RATIONALE

Renewable energy technology has a huge potential in mitigating climate change as well as the gap between power supply and demand and also creating job opportunities. Therefore, Government of India is focusing on the generation of electrical energy through renewable energy sources. This course is designed for diploma students to acquire skills in operating and maintaining the renewable energy technologies for its proper utilization.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help the student to attain the following industry/employer expected outcome through various teaching learning experiences: "Maintain basic electrical components of various renewable energy systems".

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Test the performance of the solar panels.
- CO2 - Maintain working of small wind turbines.
- CO3 - Utilize small-capacity hydrogen fuel cell systems for various applications.
- CO4 - Maintain basic components of biogas plant.
- CO5 - Identify major components of the geothermal, ocean and small hydro power plants.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
315337	RENEWABLE ENERGY TECHNOLOGY	RET	DSE	4	-	2	-	6	2	3	30	70	100	40	25	10	25#	10	-	-	150

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Total IKS Hrs for Sem. : 0 Hrs
Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment
Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination
Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 10 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Define the given terminology related to solar radiation. TLO 1.2 Calculate the given parameter related to solar radiation geometry. TLO 1.3 Explain working principle of the given instrument used for solar radiation measurement. TLO 1.4 Illustrate the working principle of solar cell using equivalent circuit. TLO 1.5 Explain the concept of maximum power point using current intensity verses output voltage graph. TLO 1.6 Calculate the electrical parameters of the given solar array arrangement. TLO 1.7 Describe basic photovoltaic system using block diagram. TLO 1.8 Explain working principle of given solar collector.	**Unit - I Solar Power Technology** 1.1 Solar radiation: Beam radiation or direct radiation, diffused radiation, insolation, absorption. 1.2 Solar radiation Geometry: Declination, hour Angle, altitude angle, incident angle, zenith angle, solar azimuth angle, surface azimuth angle, day length, local solar time. 1.3 Instruments for measuring solar radiation: Pyrheliometer, Pyranometer, Sunshine recorder; Working principle, types. 1.4 Principle of conversion of solar radiation into: electricity and heat 1.5 Solar Cell: Working Principle, Equivalent Circuit, Current intensity verses output voltage graph 1.6 Solar Cell modules and arrays: Solar cell connecting arrangements 1.7 Basic Photovoltaic system for power generation: Concept and Block Diagram 1.8 Flat plate collectors: Typical liquid collector, Solar Air Heaters; Construction, Working Principle and applications and advantages. 1.9 Solar concentrating collectors: Focusing Type, Non-Focusing Type; Working Principle and applications	Lecture Using Chalk-Board Presentations Video Demonstrations Flipped Classroom Site/Industry Visit

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
2	TLO 2.1 Define the given terms related to wind power. TLO 2.2 Explain the principles applicable in the wind turbine rotation. TLO 2.3 Derive expression for governing wind power. TLO 2.4 State the criteria for site selection of wind energy conversion system. TLO 2.5 Describe wind energy conversion system using block diagram. TLO 2.6 Describe the given type of wind mill system. TLO 2.7 Explain wind electric conversion system block diagram. TLO 2.8 Explain working principle of variable speed and constant frequency scheme. TLO 2.9 Explain pitch control and yaw control.	**Unit - II Wind Power Technology** 2.1 Basic terminologies: Cut-in, cut-out and survival wind speeds, Threshold wind speeds, Power in wind, Power coefficient, Maximum power and Betz Limit 2.2 Wind Turbine Rotation Principles: Forces on the blades, lift and drag, thrust and torque on wind turbine rotor 2.3 Mathematical Expression Governing Wind Power 2.4 Site selection consideration 2.5 Wind energy conversion system (WECS): Concept, Block diagram, Working principle 2.6 Wind mill: Horizontal axial, Vertical axial, small and large wind turbine. 2.7 Wind power generators: Permanent Magnet DC Generator, Synchronous Generator, Squirrel-Cage rotor Induction Generator (SCIG), Doubly-Fed Induction Generator (DFIG); working principle 2.8 Gearbox arrangement 2.9 Variable speed and constant frequency scheme - Concept and working principle 2.10 Pitch system: Pitch Control and Yaw control	Lecture Using Chalk-Board Presentations Video Demonstrations Flipped Classroom Site/Industry Visit
3	TLO 3.1 Describe the given hydrogen production method. TLO 3.2 Describe the hydrogen storage and transportation method. TLO 3.3 Compare hydrogen with the other given fuel source(s). TLO 3.4 Explain the hazards and its preventive measures related to hydrogen storage and transportation. TLO 3.5 Define the given terminology related to fuel cell. TLO 3.6 Describe the fuel cell system. TLO 3.7 Explain the resistance polarization in fuel cell.	**Unit - III Hydrogen Energy and Fuel cell** 3.1 Hydrogen Production: Electrolyser, Thermochemical Method, Coal Gasification, Photo-electrolysis; Working principle 3.2 Hydrogen Storage and transportation: Need, methods, limitations 3.3 Hydrogen as an alternative fuel for motor vehicle 3.4 Comparison of hydrogen over other fuels 3.5 Handling of Hydrogen: Hazard and its Preventive measures 3.6 Fuel cell: Terminology, working principle, types, main components of fuel cell system, advantages, disadvantages and applications 3.7 Polarization in fuel cell: Concept, Resistance polarization	Lecture Using Chalk-Board Video Demonstrations Presentations Flipped Classroom
4	TLO 4.1 Explain the given biomass conversion process. TLO 4.2 State the materials used for biomass generation. TLO 4.3 Explain the factors affecting the biomass generation. TLO 4.4 Describe the given biogas plant using schematic diagram. TLO 4.5 State the criteria for selection of site for the biogas plant.	**Unit - IV Biomass Energy** 4.1 Biomass conversion Process: Anaerobic digestion, Ethanol Fermentation, Pyrolysis, Digestion, Gasification, Hydrolysis 4.2 Materials used for Biogas generation 4.3 Factors affecting Biomass generation 4.4 Classification of Biogas Plant: Continuous and Batch type; Dome and Drum type 4.5 Biogas Plants: KVIC digester; Schematic diagram, construction; Chinese Digester; Concept; Pragati Biogas plant; Schematic diagram, working Principle 4.6 Selection of site for Biogas plant	Lecture Using Chalk-Board Video Demonstrations Presentations Flipped Classroom

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
5	TLO 5.1 Describe the general arrangement of the given type of geothermal power plant. TLO 5.2 Explain the working principle of the given type of geothermal power plant. TLO 5.3 State the types of ocean energy power plant. TLO 5.4 Describe the general arrangement of the given type of ocean energy power plant. TLO 5.5 Explain the working principle of the given type of ocean energy power plant. TLO 5.6 Describe the general arrangement of the given type of small hydroelectric power plant. TLO 5.7 Explain the working principle of the given type of small hydroelectric power plant. TLO 5.8 State the site selection criteria for the small hydroelectric power plant.	**Unit - V Other Renewable Sources of Energy** 5.1 Geothermal power plant: General arrangements, types (Dry type, Wet Type and Binary type), working principle, advantages and limitations 5.2 Ocean Energy: Ocean Thermal Electric Conversion, Tidal energy, wave energy, marine current; General arrangement and working principle, Prospects in India 5.3 Small Hydroelectric Power Plant (SHP): Classification; Mini and Micro, General arrangement and working principle, Prospects in India 5.4 Site selection for the Small Hydroelectric Power Plant	Lecture Using Chalk-Board Video Demonstrations Presentations Flipped Classroom Case Study

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Measure current, voltage and power output of the solar cells/panel. LLO 1.2 Measure current, voltage and power output of the solar panel for shadow effect.	1	*Measurement of electrical parameters of the solar cells/panel.	2	CO1
LLO 2.1 Measure the current, voltage and power output of the solar panel connected to variable resistive/inductive load. LLO 2.2 Locate the maximum power generation point by analysing the graph of power verses load resistance. LLO 2.3 Measure power output of the solar panel at different inclination angles. LLO 2.4 Locate the maximum power generation point by analysing the graph of power verses inclination angle.	2	*Effect of load and inclination angle on solar panel output.	2	CO1
LLO 3.1 Connect solar panels in series and parallel combination. LLO 3.2 Measure voltage and current of the solar array by connecting solar panels in series and parallel.	3	*Series parallel connection of solar panels.	2	CO1
LLO 4.1 Design solar panel for the residential unit based on annual consumption. LLO 4.2 Prepare layout for the installation of solar panels.	4	Sizing of Solar panels required for a residential house having 500 W electrical load.	2	CO1

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Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 5.1 Measure wind speed using given meters at different heights and locations.	5	*Measurement of windspeed at different heights and locations.	2	CO2
LLO 6.1 Dismantle small wind turbine. LLO 6.2 Identify different parts of small wind turbine.	6	Components of small wind turbine (Horizontal axis / Vertical axis).	2	CO2
LLO 7.1 Measure output voltage and current of given type of induction generator for different wind speeds.	7	*Performance of Induction Generator.	2	CO2
LLO 8.1 Identify different components of fuel cell by dismantling experimental kit. LLO 8.2 Assemble the fuel cell kit and operate fuel cell on load.	8	*Demonstration of hydrogen fuel cell.	2	CO3
LLO 9.1 Identify different components of biogas operated plant. LLO 9.2 Observe the output of biogas plant OR Prepare a report on biogas operated Plant	9	*Demonstration of biogas operated plant. OR Visit to biogas operated Plant.	2	CO4
LLO 10.1 Identify different components of geothermal power plant.	10	Demonstration of geothermal power plant using video/animation.	2	CO5
LLO 11.1 Prepare a report on tidal and wave power plant.	11	Demonstration of tidal and wave power plant using video/animation.	2	CO5
LLO 12.1 Prepare a report on marine power plant and ocean thermal energy conversion (OTEC) plant.	12	Demonstration of marine power plant and ocean thermal energy conversion (OTEC) plant using video/animation.	2	CO5
LLO 13.1 Identify different components of small hydro power. OR Prepare a report on small hydro power.	13	*Demonstration of small hydro power plant using video/animation. OR Visit to hydro power plant.	2	CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Suggested Activities

- Numerical based on governing of wind power.
- Prepare a report on potential of hydrogen as a fuel for vehicles.
- Prepare a report on effect of shadow on output parameters of solar panel.
- Numerical based on parameter related to solar radiation geometry.
- Design the solar system for a small residential premises.
- Prepare a report on cleaning and maintenance of solar panel system installed on a small residential premises.

Note:

- Self learning activity (SLA) is not given in this course. However, it is recommended that student continue to learn in the advancements in renewable energy technology area on their own.

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Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Solar cell: Maximum Power (Pmax)-7.33 W, Voltage at Maximum Power Point (Vmpp)-0.605 V, Current at Maximum Power Point (Impp)- 12.12 A, Open Circuit Voltage (Voc)-0.683 V, Short Circuit Current (Isc)- 13.35 A	1
2	Energy Sensor, Source Input Potential Range: ± 30 V Source Input Current Range: ± 1000 mA	1,2,3
3	Solar Panel: 75 Watt 12 Volt polycrystalline or monocrystalline solar panel OR 100 Watt 12 Volt polycrystalline or monocrystalline solar panel.	1,2,3,4
4	AC and DC Voltmeter: 0 to 300V, Sensitivity = 1V/div. TRIAC: It = 4A, IGT = 10mA, Vt = 600V.	1,2,3,4,7
5	AC and DC Ammeter: Range = 0 to 20A, Sensitivity = 0.5A/div.	1,2,3,4,7
6	Multimeter: 2000 count digital display, 1000V DC/750 V AC ranges, 10 A AC/DC ranges	1,2,3,4,7
7	Biogas experimental kit, Plant Capacity-0.8 Cubic Meter, Waste Input 25 kg	10
8	Rheostat: Nicrome wire, 300ohm, 10A, 400V	2
9	Anemometer, Wind Speed Measuring Range 0.3~30m/s Accuracy of Temperature ±5% ±0.1dgt	5
10	Small wind turbine (Horizontal/Vertical axis) experimental kit, Output-20W/50W/75W/100W/ whichever is available in small size	6,7,8
11	Fuel cell experimental kit. Power in Hydrogen and Oxygen Mode: 900 mW Power in Hydrogen and Air Mode: 300 mW Generated Voltage: 0.45 - 0.96 V DC	9

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Solar Power Technology	CO1	12	4	6	10	20
2	II	Wind Power Technology	CO2	8	2	6	8	16
3	III	Hydrogen Energy and Fuel cell	CO3	7	2	6	4	12
4	IV	Biomass Energy	CO4	7	2	6	4	12
5	V	Other Renewable Sources of Energy	CO5	6	0	6	4	10
Grand Total				**40**	**10**	**30**	**30**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

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- 30 Marks of Theory FA shall be obtained from an average mark of two unit tests (each of 30 marks) held in the semester. At least 2 COS should be covered in each unit test.
- Continuous assessment shall be based on process and product related performance indicators and laboratory experiences. Each practical shall be assessed for 25 marks considering 60% weightage to process and 40% weightage to product.
- Rubrics of continuous assessment of practical, including performance indicators, shall be designed by concerned course teacher.

Summative Assessment (Assessment of Learning)

- End semester, practical summative assessment of 25 marks shall be based on student's performance in end semester practical performance exam.
- End semester, theory summative assessment of 70 marks shall be based on offline mode of written examination.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	3	1	2	3	3	1	2			
CO2	3	1	1	3	3	1	2			
CO3	3	-	-	1	3	1	2			
CO4	3	-	-	1	3	-	2			
CO5	3	-	-	-	3	-	2			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	Chetan Singh Solanki	Renewable Energy Technologies- A Practical guide for beginners	PHI Learning Pvt. Ltd. ISBN:9788120334342
2	S.P. Sukhatme, Nayak J. K	Solar Energy: Principles of Thermal Collection and Storage	McGraw-Hill Education (India) ISBN:978-0074519462
3	Chetan Singh Solanki	Solar Photovoltaic: Fundamentals, Technologies and Application	PHI Learning Pvt. Ltd. ISBN : 9788120351110, eBook ISBN : 9789390544448
4	Joshua Earnest, Tore Wizelius	Wind Power Plants and Project Development	PHI Learning Pvt. Ltd. ISBN: 978-81-203-5127-1
5	D.P.Kothari, K.C.Singal, Rakesh Ranjan	Renewable Energy Sources and Emerging Technologies	PHI Learning Pvt. Ltd. ISBN: 978-81-203-4470-9
6	Chetan Singh Solanki	Solar Photovoltaic Technology and System: A Manual for Technicians, Trainers and Engineers	PHI Learning Pvt. Ltd. ISBN: 978-81-203-4711-3
7	G.D.Rai	Non Conventional Energy Sources	Khanna Publishers, ISBN:978-8174090737

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://www.youtube.com/watch?v=jswDvFzGoO4	50 MW Solar Power Plant for NTPC at Rajgarh, Madhya Pradesh
2	https://archive.nptel.ac.in/courses/108/108/108108078/	Non-Conventional Energy Systems by Prof. L. Umanand (IISc Bangalore)
3	https://archive.nptel.ac.in/courses/103/103/103103206/	Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems by Prof. R. Anandalakshmi and Prof. Vaibhav Vasant Goud (IIT Guwahati)
4	https://archive.nptel.ac.in/courses/103/107/103107157/	Technologies For Clean And Renewable Energy Production by Prof. P. Mondal (IIT Roorkee)
5	https://archive.nptel.ac.in/courses/121/106/121106014/	Non-Conventional Energy Resources by Dr. Prathap Haridoss (IIT Madras)
6	https://www.lccc.edu/science-in-motion/labs-equipment/renewable-energy-lab-experiments/	Renewable Energy Lab Experiments

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students