

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)**Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)**

Semester-III

Course Title: Solar Energy

(Course Code: 1336405)

Diploma program in which this course is offered	Semester in which offered
Renewable Energy	3 rd Semester

1. RATIONALE

The Diploma program of Renewable Energy is multi-disciplinary branch. Any form of energy from renewable sources is finally converted into electrical energy. At various stages of energy transformation, the role of Solar energy is important. Diploma students undertaking this course are expected to understand the fundamentals of Solar energy. Students would be able to apply these concepts to analyze and study energy conversion from solar energy to require from of energy like heat or electricity in renewable energy systems. They will be able to understand solar insolation, geospatial views and other terminologies related to solar energy systems

2. COMPETENCY

The purpose of this course is to help the students to attain the following industry identified competency through various teaching learning experiences:

- **Understanding of solar energy conversion into heat and electricity.**
- **Calculate the energy usage at a location**
- **Design a basic photovoltaic system to meet a specific energy need at a specific location**
- **Prediction of Solar insolation and learning Solar cell technology in grid and standalone systems.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

- a) Acquire knowledge about solar insolation and its measurement in India and globally.
- b) Interpret the working of various solar thermal power plants.
- c) Understand various concepts regarding emerging trends of photovoltaic cell
- d) Understand Technical Standards and Specification, Technical Considerations, metering arrangement and policies of Indian government for solar roof top in India

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				Total Marks
L	T	P		Theory Marks		Practical Marks		
			C	CA(M)	ESE(E)	CA(I)	ESE(V)	
2	0	2	3	*30	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

Legends: L-Lecture; T – Tutorial/Teacher Guided Theory Practice; P - Practical; C – Credit, CA - Continuous Assessment; ESE - End Semester Examination.

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the Course Outcomes (Cos). Some of the PrOs marked '*' are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx.Hrs. Required
1	Identify and measuring the parameter of solar PV module	3	2
2	Verify dark and illuminated VI-Characteristics Solar PV cell	3	2
3	Examine efficiency of Solar PV panel	3	4
4	To measure life time of solar PV cell	3	2
5	To measure global solar irradiation using a solar cell	1	2
6	To create array and module for a required power capacity	4	2
7	To estimate the effect of sun tracking on energy generation of PV system	4	4
8	To measure efficiency of standalone solar PV system	4	4
9	To measure the spectral response of a solar cell	3	2
10	To study about different type of solar collectors	2	2
11	To measure sunshine duration using sunshine recorder	1	2
	Total		28

Note

e) More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.

f) The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare and operate experimental setup	30
2	Follow safe practices	10
3	Record observations correctly	20
4	Interpret the result and conclude	20
5	Quality of Answer related to experiment (Q & A)	20
Total		100

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to use in uniformity of practical's in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrOs No.
1	Solar PV module (monocrystalline and Polycrystalline), 10W	1
2	Multimeter, Rheostate	1-6
3	Quartz halogen lamps	3-4
4	Banana connectors, MC4 connectors, Temperature indicator	1-8
5	Lead acid battery, Li-Po battery	
6	LED bank, CRO	4,11
7	Spectral response meter	9
8	Pyranometer, sunshine recorder	11
9	Inverter (100W)	
10	Pulse generator / function generator 1Mhz with DC offset	4

7. AFFECTIVE DOMAIN OUTCOMES

The following **sample** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs, more could be added to fulfill the development of this course competency.

- a) Work as a leader/a team member (while doing a micro-project).
- b) Follow ethical practices.
- c) Work as a group member (while performing experiments and taking readings).
- d) Practice environmentally friendly methods and processes. (Environment related).

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- I. 'Valuing Level' in 1st year
- II. 'Organization Level' in 2nd year.
- III. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit I: Solar Radiation and its measuring technology	1.a Solar Energy Basics 1.b Sun–Earth Geometric Relationship. 1.c Atmospheric effect on solar radiation 1.d Solar energy measuring instruments- Pyrheliometer, Pyranometer, Photoelectric Detectors 1.e Solar Radiation Data 1.f Solar potential of India	Insolation on earth Solar Time and Angles Sun-Path Diagram Shadow-Angle Protractor Solar Radiation Extraterrestrial Solar Radiation Estimation of Terrestrial Solar Radiation Atmospheric Extinction of Solar Radiation Factors affecting solar radiation Radiation measurement techniques Detectors for Solar Radiation Measurement of Sunshine Duration Measurement of Spectral Solar Radiation Wide Band Spectral Measurements. Solar Radiation Data Solar Radiation Mapping Using Satellite Data.
Unit II Solar Thermal	2.a Solar energy collectors 2.b Radiative Properties and	Radiative Properties and Characteristics of Materials.

Systems	<p>Characteristics of Materials</p> <p>2.c Collector Efficiency Factor</p> <p>2.d Solar thermal power plant</p> <p>2.e Solar Air-Heating Systems</p> <p>2.f Passive solar heating</p> <p>2.g Solar Distillation of Saline Water</p> <p>2.h Application: Cooking, crop drying, water heating</p>	<p>Concentrating type, non concentrating type, parabolic collectors</p> <p>Tubular Solar Energy Collectors</p> <p>Central Receiver Collector</p> <p>Fresnel Reflectors and Lenses .</p> <p>Collector Efficiency Factor</p> <p>Working of solar thermal power plant. Low temperature power plant</p> <p>Medium temperature power plant</p> <p>High temperature power plant</p> <p>Factors considered for solar thermal power plant</p> <p>Solar Distillation of Saline Water</p> <p>Application: Cooking, crop drying, water heating</p>
Unit III Solar PV Cells	<p>3.a Semiconductors</p> <p>3.b Photovoltaic effect</p> <p>3.c Classification of PV cells</p> <p>3.d Crystalline cell Thin film cell</p> <p>3.e Advance solar cell</p> <p>3.f Fabrication of solar cell</p> <p>3.g Solar cell, Solar array and solar Panel</p>	<p>Effect of light on silicon cell</p> <p>V /I Characteristics of PV cells</p> <p>Classifications of solar cells</p> <p>Monocrystal and Polycrystalline Cells Amorphous Silicon and Thin-Film Fabrication</p> <p>Parametric Requirements for Optimum</p> <p>Factors affecting efficiency of solar cells</p> <p>General & Technical requirements for Cell, array and module</p> <p>Module Conversion Efficiency</p>
Unit IV Solar power plant	<p>4.a Classification of solar power plant.</p> <p>4.b Rooftop solar power plant</p> <p>4.c Ground mounted solar power plant</p> <p>4.d Components of solar PV system</p> <p>4.e PV panel arrangement</p> <p>4.f Installing of PV panels, batteries inverters and meters</p> <p>4.g Losses in PV Systems</p> <p>4.h Indian standards and regulations for PV systems</p> <p>4.i Government initiative for solar power plant in India</p>	<ul style="list-style-type: none"> • Type of module mounting structure (MMS) • MMS with tracker • Determining energy needs and sizing a PV system for rooftop installation • Calculation of. Parameters i.e. panel wattage, cable size, inverter, battery capacity. • Principle of Maximum Power point Tracking • Off grid and grid connected systems • Solar panel protection • Losses contributed in PV systems • Maintenance in installed PV systems • Energy storage system- Batteries

SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Solar Radiation and its measuring technology	5	6	6	6	14
II	Solar Thermal Systems	4	6	5	4	15
III	Solar PV Cells	8	6	6	5	17
IV	Solar Roof top system	11	5	8	7	24
	Total	28	23	25	22	70

Legends: R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)

Note: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.

9. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related **co-curricular** activities which can be undertaken to accelerate the attainment of the various outcomes in this course. Students should perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

- a) Visit solar module manufacturing unit.
- b) Field visit to PV site
- c) Solar resume development for placement.
- d) Conduct a seminar on solar energy potential.
- e) Undertake micro-projects in teams.

10. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

- a) Massive open online courses (**MOOCs**) may be used to teach various topics/sub topics.
- b) Guide student(s) in undertaking micro-projects.
- c) '**L**' in **section No. 4** means different types of teaching methods that are to be employed by teachers to develop the outcomes.
- d) Show animation/ video related to course content.
- e) Some of the topics/sub-topics which are relatively simpler or descriptive are to be given to the students for self-learning but to be assessed using different assessment methods.
- f) Correlating the importance of the content of this course with other courses/practical applications.
- g) Guide students for using data manuals.
- h) Guide students on how to address issues on environment and sustainability.

11. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should **not exceed three**.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16 (fourteen to sixteen) student engagement hours** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

- a) Prepare report for System Assembly and Building Integration of given house load.
- b) Undertake market survey for various component use in solar energy conversation.
- c) Make MPPT Charge Controller using Arduino
- d) Measure Solar Radiation using Arduino
- e) Prepare Arduino based Solar Charge Controller
- f) Prepare LED Street Lights using Solar Power
- g) Prepare Li-Po battery charger using Solar Energy
- h) Solar Panel Cleaning Robot and calculate gain on efficiency after cleaning
- i) Prepare impact analysis of solar energy on environment

12. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Principles of Solar Engineering	D Yogi Goswami	CRC Press
2	Solar Electricity Handbook	Michael Boxwell	Green Stream Publishing
3	Solar Cell Technology and Applications	A.R. Jha	CRC Press
4	Photo Voltaic Design System	Suneel Deambi	CRC Press
5	Solar Energy: Principles of Thermal Collection and Storage	S. P. Sukhatme and J. K. Nayak	Tata McGraw Hill, 2006
6	Solar Photovoltaics: Fundamentals, Technologies and Applications	C. S. Solanki	Prentice Hall India, 2nd Edition, 2011
7	Solar Energy: Fundamentals and Applications	H. P. Garg and J. Prakash	Tata McGraw Hill, 1997.

13. SOFTWARE/LEARNING WEBSITES

- (1) <https://ndl.iitkgp.ac.in>
- (2) <https://www.pvsyst.com/>
- (3) [PC1D simulator](#)
- (4) www.vlab.co.in
- (5) https://onlinecourses.nptel.ac.in/noc23_ph40
- (6) https://onlinecourses.nptel.ac.in/noc23_ge41
- (7) <https://lectures.gtu.ac.in/>(related to course content)

14. PO-COMPETENCY-CO MAPPING:

Semester III	Fundamental Of Electrical and Electronics Engineering (Course Code: 1326401)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solution	PO4 Engineering Tools, Experimentation & Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life- long learning
<u>Competency</u>	<ul style="list-style-type: none"> • Maintain electrical systems by applying principles of AC-DC circuits. • Test the different electronic devices. 						
CO1: Acquire knowledge about solar insolation and its measurement	3		2	2	2		1
CO2 Interpret the working of various solar thermal power plants.	3		2	1	2		1
CO3 Understand concepts regarding emerging trends of photovoltaic cell	3	2	2	2	2	2	1
CO4 Apply Technical Standards and specification, metering arrangement and policies of Indian government for solar roof top in India	3	2	3	2	2	2	1

Legend: '3' for high, '2' for medium, '1' for low and '-' for no correlation of each CO with PO.

15. COURSE CURRICULUM DEVELOPMENT COMMITTEE**GTU Resource Persons**

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	B B Chauhan	Government Polytechnic, Jamnagar	99252 10010	bbc.gpjam@gmail.com
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