GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
IV – Semester

Course Title: Solar Photovoltaic
(Course Code: 4346401)

Diploma programmer in which this course is offered		Semester in
Renewable Energy Department		Fo

1. RATIONALE

The rationale for solar photovoltaic (PV) technology is based on a multitude of environmental, economic, and social factors. Solar PV has gained popularity and widespread adoption due to its many advantages, including:

1. Renewable Energy Source: Solar energy is a renewable resource, which means it can be harnessed as long as the sun shines, making it an almost inexhaustible source of power. This stands in contrast to finite fossil fuels.

2. Environmental Benefits:

a. Reduced Greenhouse Gas Emissions: Solar PV systems produce electricity without emitting greenhouse gases, helping to mitigate climate change.

b. Reduced Air Pollution: Solar PV systems produce no air pollutants, making them a clean energy source that improves air quality and public health.

c. Lower Water Usage: Solar PV requires minimal to no water for operation, unlike many traditional power generation methods, which are water-intensive.

3.Energy Independence: Solar PV reduces dependence on fossil fuels, which are often imported. This enhances energy security and reduces exposure to volatile fuel prices.

4. Economic Benefits:

a. Job Creation: The solar industry generates jobs in manufacturing, installation, maintenance, and research and development.

b. Lower Electricity Bills: Solar PV can lead to reduced electricity bills, especially in regions with high solar exposure, helping consumers save money.

5. Energy Access: Solar PV can be deployed in remote areas, providing electricity to communities that are not connected to the grid, thus improving quality of life and supporting economic development.

6. Incentives and Policies: Many governments provide incentives and subsidies for the installation of solar PV systems, making it more financially viable for individuals, businesses, and utilities.

In summary, the rationale for solar photovoltaic technology is multifaceted, combining environmental concerns, economic advantages, energy security, and technological progress. Its use continues to expand as it becomes more cost-effective and environmentally friendly, making it a key player in the transition to a sustainable energy future.

2. COMPETENCY

The purpose of this course is to help individual to understand their role and responsibilities for depth Understanding of Solar Photo Voltaic system. Competency For individuals working with solar photovoltaic (PV) technology can vary depending on the specific roles and responsibilities, but here are some key competencies and skills often associated with different positions within the solar PV industry:

- **Technical Knowledge**
- **System Design and Engineering**
- **Energy Storage Integration**
- **Grid Connection and Regulations**
- **Performance Monitoring and Analysis**

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) Able to demonstrate a fundamental understanding of solar photovoltaic technology, including the photovoltaic effect, types of solar cells, and their working principles.
b) Able to Understand Role of each component in solar PV systems, including site layout, configuration, and sizing, considering load requirements.
c) Proficiency in the safe installation of solar PV systems, electrical connections, and basic maintenance procedures for optimal system performance.
d) Analyzing incentives, subsidies, and return on investment for PV projects.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	4	5	30*	70	50	50	200

(*): 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	Demonstrate VI-Characteristics of Solar PV cell	I	4
2	Demonstrate PV-Characteristics of Solar PV cell	I	2
3	To create array and module for a required power capacity	II	4

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
4	To measure efficiency of standalone solar PV system	I	4
5	To estimate the effect of sun tracking on energy generation of PV system.	I	4
6	To Identify various PV Module and measure the efficiency and performance of various PV modules	II	4
7	To Prepare detailed Comparative report of various Solar Panel available in market	I	4
8	Site visits to assess a real-world location for PV system installation	IV	4
9	Use of simulation software to optimize system design based on location-specific data.	III	2
10	Set up a PV system with monitoring equipment to track energy production and performance	III	4
11	Visit to a grid-connected PV system installation to understand grid interconnection and compliance	III	4
12	Collaboration with industry experts, solar installers, and engineers for practical insights and mentorship.	I	4
13	Practical exercises in designing PV systems for various applications, such as residential, commercial, and off-grid.	II	4
14	Prepare Summaries sheet for various Government Incentive Schemes & Policies to promote renewable energy	IV	4
15	Hands-on experience with solar radiation measurement tools, such as pyranometers and pyrheliometers	I	4
	Minimum 10 Practical Exercises		56

Note

i. *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.*

ii. *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	Understanding of concepts	20
2	Explanation of conclusion	20
3	Student attitude towards learning	20
4	Quality of term work	20
5	Timely completion of term work	20
Total		**100**

5. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Pyranometer, pyrheliometers, sunshine recorder	15
2	PV cell ,6V,100 Mah	1,2,3
3	Solar PV module (monocrystalline and Polycrystalline), 10W	2,4
4	Ammeter, Voltmeter	1 to 4
5	Lead acid battery, Li-Po battery	8,10
6	Solar PV characteristic Kit	1,2,6,7
7	Multimeter, Rheostat	1,2,3

6. 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 safety practices while using Electrical supply and electrical equipment.
c) Follow ethical practices.
d) Adhere to safety protocols to ensure the safe installation and maintenance of system.
e) Practice environmental 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 Energy Fundamentals**	**1a**. Introduction to Photovoltaics and its basics. **1b**. Distinguish between Photovoltaic Materials and Characteristics of PV Cell **1c**. State Types of Solar Cells & It's Efficiency **1d**. Describe various Solar radiation measuring instrument **1e**. Solar photo Voltaic Power generating System	**1.1** Overview of semiconductor materials used in solar cells (e.g., silicon). **1.2** VI (current-voltage) characteristics of Solar Photo voltaic. **1.3** Detailed discussion of various types of solar cells, such as: a) Crystalline silicon b) Thin-film technologies c) Emerging technologies like perovskite solar cells. **1.4** Understanding key electrical parameters: short-circuit current, open-circuit voltage, fill factor, and maximum power point. **1.5** solar radiation measuring instrument: Pyranometer & Pyrheliometer. **1.6** Solar power Curve and Types of Solar PV generating system. **1.7** Advantages and disadvantages of solar PV system.
Unit-II **PV System Components**	**2a**. Explain various PV System Components **2b**. describe function of PV Panels and Modules, Batteries as Energy Storage, Inverter, Charge Controllers. **2c**. Explain Mounting and Tracking Systems. **2d**. Describe Wiring, Connectors, and Junction Boxes **2e**. Explain Solar farm	**2.1** Introduction to key components that make up a PV system. **2.2** Battery & Inverter selection, sizing, and design. **2.3** Role of charge controllers in managing battery charging. **2.4** Electrical connections in a PV system. **2.5** Arrangement and orientation of PV panels. **2.6** Mitigating environmental challenges like dust and extreme weather. **2.7** Sizing PV components to match energy demand. **2.8** introduction and Case study of Production of Power based on available land size

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit-III Solar PV Installation-Maintenance	**3a**. Explain Safety Protocols for PV Installation and Maintenance. **3b**. Describe various Tools and Equipment **3c**. State Installation Best Practices and Electrical connection **3d**. Explain Installation of Mounting and Tracking Systems. **3e**. Describe steps for Testing and Commissioning **3f**. Explain Maintenance Guidelines Troubleshooting Common Issues	**3.1** Safety standards and guidelines for working with electrical systems. **3.2** Tools required for the installation and maintenance of PV systems. **3.3** Step-by-step guide to safely install solar panels, inverters, and balance of system components. **3.4** Wiring solar panels, inverters, and charge controllers. Ensuring proper electrical connections and adherence to electrical codes. **3.5** Installation of mounting structures and tracking systems. **3.6** Routine maintenance tasks to ensure system longevity and performance. Cleaning, inspection, and upkeep of system components. **3.7** Case studies of common problems and their solutions.
Unit-IV Environmental Benefits & Policies	**4a**. Describe various Government Incentive Schemes & Policies to promote renewable energy	**4.1** Grid connected solar roof top solar program, objectives, CFA for different sectors **4.2** Grid connected solar power projects **4.3** PM KUSUM Scheme, incentives, Feeder level solarization scheme

9. 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 Energy Fundamentals	14	8	8	6	22
II	PV System Components	09	4	8	4	16
III	Solar PV Installation-Maintenance	12	4	8	6	20
IV	Environmental Benefits & Policies	07	6	4	4	12
Total		42	22	28	20	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.*

10. 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) Present seminar on various topics from course content.
b) Present seminar on recent technologies used for power generation and transmission
c) Conduct a lab experiment to measure and compare the efficiency of different types of solar panels.
d) Allow students to practice installation procedures, including mounting and wiring of solar Panel and Inverter.
e) Solve numerical problems regarding course contents.
f) Assign a research project on solar energy policies at local, national, or international levels.

The student should be encouraged to get their work assessed by the concerned teacher progressively during the term and at the end of the term the whole work should be submitted to the concerned teacher.

11. 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) Visit to a nearby Solat power plant.
f) Co-relating the importance of content of this course with other courses and practical applications.
g) Discuss the impact of policies on the adoption of solar technologies.
h) Create informational materials, host workshops, or design a small solar-powered exhibit.
i) Guide students on how to address issues on environment and sustainability.

12. 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) Develop a small solar charger for electronic devices.

b) Create a mechanism to automatically clean solar panels.

c) Investigate the impact of dust and dirt on panel efficiency.

d) Use a small solar panel, charge controller, and rechargeable battery.

e) Prepare Arduino based Solar Charge Controller

f) Measure and analyze the impact of tilt angle on energy production.

g) Develop a solar-powered LED lighting system.

h) Build a solar-powered water pump system.

i) Develop a data logging system for a solar panel.

j) Obtain small samples of different types of solar panels.

13. SUGGESTED LEARNING RESOURCE

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Solar Photovoltaics - Fundamentals, Technologies and Applications	Chetan Singh Solanki	Published by Prentice Hall (2015) ISBN 10: 8120351118
2	Solar Electricity Handbook - 2021 Edition: A simple, practical guide to solar energy - designing and installing solar photovoltaic systems	Michael Boxwell	Greenstreet Publishing (2021) ISBN-10: 1907670742
3	Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers	Chetan Singh Solanki	Published by Prentice Hall (2013) ISBN 10: 8120347110
4	Solar Photovoltaic Power Systems: Principles, Design and Applications	Dr. Sundaravadivelu S (Author), Mr. Suresh R. Norman (Author)	Published by Notion Press (2018) ISBN 10: 1642497096 ISBN 13: 978-1642497090

13. SOFTWARE/LEARNING WEBSITES

- www.youtube.com/@studentenergy
- http://ocw.mit.edu/2-627F11 (Fundamentals of Photovoltaics complete course)
- https://lectures.gtu.ac.in/(related to course content)
- How do Solar cells work? - YouTube
- How Solar Panel Work | Monocrystalline & Polycrystalline | One Sun One Grid | Layers of Solar Panel - YouTube
- Solar Panels Explained - Unravel the Mysteries of How Solar Panels Work! - YouTube
- 5 kilowatt solar system AC module installation solar panel in Delhi - YouTube
- PVsyst – Photovoltaic software
- Solmetric - Home of the SunEye, PV Analyzer, and other solar test and measurement equipment.

15. PO-COMPETENCY-CO MAPPING:

Semester IV	Solar Photovoltaic (Course Code: 1346401)						
	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
Competency	To help individual to understand their role and responsibilities for depth Understanding of Solar Photo Voltaic system						
Course Outcomes CO1 Able to demonstrate a fundamental understanding of solar photovoltaic technology, including the photovoltaic effect, types of solar cells, and their working principles.	2	--	--	--	--	--	--
CO2 Able to Understand Role of each component in solar PV systems, including site layout, configuration, and sizing, considering load requirements.	2	1	2	--	--	--	2
CO3 To get Proficiency in the safe installation of solar PV systems, electrical connections, and basic maintenance procedures for optimal system performance.	--	1	1	2	--	1	--
CO4 Analyzing incentives, subsidies, and return on investment for PV projects.	2	--	2	--	2	--	--

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

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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