

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)**Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)**
Semester-III**Course Title: Renewable Energy Instrumentation Applications**
(Course Code:1336403)

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

1. RATIONALE

Instrumentation plays a crucial role in the renewable energy sector. It enables efficient and reliable operation, monitoring, control, and optimization of renewable energy systems. This course will enable the students to understand the need and carry out accurate measurement and monitoring of various parameters in solar and wind energy systems. The knowledge of measurement and instrumentation is very much necessary as it contributes to improved performance, increased safety and enhanced integration with the electrical grid, ultimately supporting the growth and sustainability of renewable energy technologies.

2. COMPETENCY

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

- **Use relevant measuring instruments in wind and solar energy applications**

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:

- Understand various terminologies related to measurement and instruments.
- Understand working of various transducers and measurement of different physical quantities.
- Carry out different measurements required for installation of renewable energy systems.
- Carry out operations of measuring instruments and instrumentation systems in renewable energy systems.
- Carry out trouble shooting and up gradation of measurement and instrumentation systems in renewable energy systems.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
L	T	P		Theory Marks		Practical Marks		Total Marks
			C	CA(M)	ESE(E)	CA(I)	ESE(V)	
3	0	2	4	*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 measuring instruments on the basis of symbols on dial, type, accuracy, class, position and scale.	I	2
2	Study of different types of errors.	I	2
3	To plot the characteristics of LVDT	II	2
4	Use of Thermocouple, RTD and Thermistor for temperature of a measurement.	II	2
5	To measure the stress & strain using strain gauges mounted on beams	II	2
6	To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic or photoelectric).	II	2
7	Characteristic curves of a solar cell	III	2
8	To measure temperature of solar cell with thermography.	III	2
9	Demonstration of Study of solar radiation measurement using Pyranometer – Pyrheliometer – Pyrgeometer	III	2

10	Demonstration of Anemometer, Wind Vane and Wave Sock for different wind speed measurement.	IV	2
11	To simulate solar PV model with MATLAB.	III	2
12	Simulation study on Wind Energy Generator.	IV	2
13	Case study based on instrumentation system in solar thermal and solar PV systems	III	2
14	Case study based on instrumentation system in wind energy systems	IV	2
15	Case study on advanced monitoring and control systems using AI application in renewable energy systems	V	2
16	Study of Intelligent Controllers for Hybrid (Solar-Wind) Systems.	V	2

Note

- f) 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.
- g) 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 user in uniformity of practical's in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrOs No.
1	LVDT Kit, Digital Multimeter	1-3
2	Trainer Kit for temperature measurement (RTD, Thermistor and Thermocouple)	1,2,4
3	Strain Guage trainer Kit, Weights(100gm x 10), Digital Multi meter	1,2,5
4	Speed measurement experimental setup and analog tachometer	1,10
5	Solar Cell, voltmeter(0 to 2/4)volt, ammeter(0-to 250mA/2.5mA), load resistance 50 ohm, 100 W lamp	1,8
6	Solar PV Module, Thermal Imaging Camera	1,11,13
7	Demonstration of Pyranometer, Pyrheliometer and Pyrgeometer	1,9
8	Demonstration of Anemometer, Wind Vane and Wave Sock for different wind speed measurement.	1,10

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 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 Fundamentals of measurement & instrumentation	1a. Differentiate between direct and indirect measurement 1b. Discriminate between Indicating, integrating and recording, absolute and secondary instrument 1c. Explain different terms related to static characteristics of instruments. 1d. Explain different terms related to dynamic characteristics of instruments	1.1 Methods of measurement -Direct and indirect methods 1.2 Types of Instruments - Indicating, integrating and recording, absolute and secondary instrument 1.3 Static characteristics of instruments - Accuracy, Sensitivity, Reproducibility, Precision, Precision Error, Drift, Static Error, Dead Zone, Hysteresis, Resolution. 1.4 Dynamic characteristics of instruments - Dynamic Error, Response Speed, Fidelity, Lag Retardation Lag, Time Delay Lag
Unit – II Transducers	2a. Explain the Types of Transducers and classification. 2b. Explain the Characteristics and applications of transducer. 2c. Describe working principle of different types of electrical transducers. 2d. Describe working principle of Piezo Electric and Opto Electric Transducers	2.1 Types of Transducers - Active Transducers, Passive Transducers 2.2 Characteristics, Classification, Applications 2.3 Variable Resistance Transducer - Variable Capacitance Transducer - Variable Inductance Transducer. 2.4 Piezo electric transducers, Opto Electric Transducers

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	2e. Explain the measurements of Non electrical quantities using different transducers.	2.5 Measurement of Non-electrical quantities such as strain, pressure, displacement, temperature, torque, velocity, speed & humidity.
Unit – III Instruments for Solar Thermal & PV Systems	3a. List various sensors for heat flow measurements. 3b. Explain various instrument for analyzing flat plate collectors. 3c. Explain working of different instruments for Solar radiation measurements. 3d. Illustration of PV roof top design and performance using Solar pathfinder/ sun eye, 3e. Study various methods and Instruments for analysing battery performance	3.1 Sensors for heat flow measurements, Heat flux meters 3.2 Instruments for analysing Flat plate collectors. 3.3 Instruments for Solar radiation measurements : Pyranometer – Pyrheliometer – Pyrgeometer, Sunshine recorder 3.4 Solar pathfinder/ sun eye, Instruments for analysing PV performance, Solar Simulators, 3.5 Methods and Instruments for analysing battery performance.
Unit– IV Instruments for Wind Energy Systems	4a. List various instruments for wind speed and wind direction measurement 4b. Explain methods of measuring power output of wind energy systems. 4c. Study methods of Torque and Speed Measurement 4d. Study methods of measurement of Temperature and Humidity in wind energy systems. 4e. Study methods of Measurement of Vibration and Noise Monitoring 4f. Understand Control Systems, Communication and SCADA in Wind energy systems	4.1 Anemometer, Wind Direction Measurement, 4.2 Power Output Measurement, 4.3 Torque and Speed Measurement, 4.4 Temperature and Humidity 4.5 Measurement, Vibration and Noise Monitoring, 4.6 Control Systems, Communication and SCADA

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – V Recent Trends in Instrumentation	5a. State advanced monitoring and control systems and remote sensing technologies used in wind energy systems. 5b. Study condition monitoring and predictive maintenance in wind energy conversion systems 5c. Explain grid integration and predictive maintenance in wind energy systems. 5d. Explain the need of Cybersecurity and data management, 5e. Study the possibility of Integration of energy storage, Enhanced operational and performance optimization	5.1 Advanced monitoring and control systems, Remote sensing technologies, 5.2 Condition monitoring and predictive maintenance, 5.3 Grid integration and power quality monitoring, 5.4 Cybersecurity and data management, 5.5 Integration of energy storage, Enhanced operational and performance optimization

SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Overview of Instruments and Measuring Systems	08	4	4	4	12
II	Sensor and Transducers	10	5	4	7	16
III	Instruments for Solar Thermal & PV Systems	10	4	6	8	18
IV	Instruments for Wind Energy Systems	08	4	5	5	14
V	Recent Trends in Instrumentation	06	3	3	4	10
	Total	42	20	22	28	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) Present seminar on various topics from course content.
- b) Prepare specification of various transducers.
- c) Test different instruments for Solar Thermal & PV Systems
- d) Undertake market survey for different Solar Thermal & PV Systems
- e) Undertake market survey for different Wind Energy Systems
- f) 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 a basic model to demonstrate working of transducers for temperature measurement.
- b) Build a simple electrical model to demonstrate transducers for distance measurement.
- c) Build a simple electrical model to demonstrate Speed measurement experimental setup and analog tachometer
- d) Build a simple electrical model to demonstrate Solar PV Module, Thermal Imaging Camera
- e) Prepare a model chart describing various types instruments for solar radiation measurements like Pyranometer, Pyrheliometer and Pyrgeometer with specifications.
- f) Build model to demonstrate Anemometer, Wind Vane and Wave Sock for different wind speed measurement.

12. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	"Instrumentation Devices and Systems",	Raman .C.S, Sharma .G.R, Mani .V.S.V,	Tata McGraw-Hill, New Delhi, 2010
2	"Principles of Measurements and Instrumentation",	Morris .A.S,	Prentice Hall of India, 2009
3	A Course in Electrical and Electronics Measurements and Instrumentation,	Sawhney A. K. (2011);	Dhanpat Rai
4	Solar Energy,	S P Sukhatme,	Tata McGraw Hill, 2008
5	Principles of Measurement Systems,	Bentley J. P.	Fourth Edition, Pearson Prentice Hall(2005);

6	Thermal Engineering System,	Tiwari G.N., Suneja S., Solar	Narosa Publishing House, New Delhi, 1997.
7	Solar Photo Voltaics: fundamentals, technologies and applications.	Solanki, Chetan Singh.	Phi learning Pvt. Ltd., 2015.
8	Solar photovoltaic technology and systems: a manual for technicians, trainers and engineers.	Solanki, Chetan Singh	PHI Learning Pvt. Ltd., 2013.
9	Wind Energy Systems (Electronic Edition),	Johnson G. L. (2006);	Prentice Hall
10	Wind Energy: Fundamentals, Resource Analysis and Economics,	Mathew S. (2006);	Springer
11	Wind Power Technology, Third Edition	Earnest, Joshua, Rachel, Sthuthi	PHI Learning Pvt. Ltd., 01-Jul-2019 - Third Edition.
12	Battery Systems Engineering,	Rahn C. D. and Wang C. (2013);	First Edition, Wiley

13. SOFTWARE/LEARNING WEBSITES

- (1) www.nptel.iitm.ac.in
- (2) <https://ndl.iitkgp.ac.in>
- (3) www.electrical4u.com
- (4) www.vlab.co.in
- (5) <https://nptel.ac.in/courses/108/105/108105112/>
- (6) <https://lectures.gtu.ac.in/>(related to course content)
- (7) <https://www.electricaltechnology.org/>
- (8) <https://circuitmaker.com/>
- (9) <https://www.allaboutcircuits.com/>
- (10) <https://youtu.be/pCMHV92KMmg>
- (11) <https://nptel.ac.in/courses/117/108/117108141/>
- (12) <https://nptel.ac.in/courses/112/105/112105051/>
- (13) <http://ocw.mit.edu/courses/energy-courses/>
- (14) <http://vlab.amrita.edu/>

6. 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. 						
<u>Course Outcomes</u> CO-1 Understand various terminologies related to measurement and instruments.	3	2	2	2	-	-	1
CO-2 Understand working of various transducers and measurement of different physical quantities.	3	2	2	2	-	1	1
CO-3 Carry out different measurements	3	2	2	2	-	1	1

required for installation of renewable energy systems.							
CO-4 Carry out operations of measuring instruments and instrumentation systems in renewable energy systems.	3	2	2	2	1	1	1
CO-5 Carry out trouble shooting and up gradation of measurement and instrumentation systems in renewable energy systems.	3	2	2	2	2	1	1

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

7. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	J K Rathod. HOD Electrical Engg.	Tolani F G Polytechnic, Adipur	9909606658	jkathod1272@gmail.com
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