

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)

V– Semester

Course Title: Distributed Generation Systems

(Course Code: 4356401)

| Diploma programmer in which this course is offered | Semester in which offered |
|--|---------------------------|
| Renewable Energy Department | Five |

1. RATIONALE

A distributed generation system offers several benefits, including enhanced grid reliability and resilience by decentralizing power sources, reducing the risk of widespread outages. It supports renewable energy integration, lowering carbon emissions and promoting sustainability. Distributed systems reduce transmission losses and can provide power to remote or underserved areas, improving energy access. They also offer economic advantages by enabling local generation and consumption, potentially lowering energy costs for consumers. Additionally, distributed generation can enhance energy security by diversifying energy sources and reducing dependence on centralized power plants. Overall, it represents a flexible, sustainable, and efficient approach to modern energy needs.

2. COMPETENCY

The purpose of this course is to help individual to understand their role and responsibilities for depth Understanding of various Distributed generation system and its connection with Grid. Competency For individuals working with Distributed generation system can vary depending on the specific roles and responsibilities, but here are some key competencies and skills often associated with distributed generation system:

- **Proficiency in renewable energy technologies (solar, wind, Fuel Cell).**
- **Sustainability Focus**
- **Grid Connection and Regulations**
- **Innovation and Learning**

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 Explain the fundamental concepts and principles of distributed generation (DG) and micro grids
- b) Able to illustrate the concept of distributed generation.
- c) Understand the control and operation of micro grids.
- d) Able to Understand various tariff structure and advanced metering technology

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 |
| L | T | P | C | CA | ESE | CA | ESE | |
| 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 | Prepare report for scenario of conventional and non-conventional power plants in India | I | 2 |
| 2 | Prepare a working model of districted generation system and grid connection. | I | 2 |
| 3 | Prepare model showing principal and operation of distributed generation. | I | 4 |
| 4 | Prepare chart with detailed comparison among various DG technology | I | 2 |
| 5 | Prepare detailed report showing direct and indirect connection of DG to grid | I | 4 |
| 6 | Use software like MATLAB/Simulink, HOMER, or PSCAD to model a microgrid. | I | 2 |
| 7 | To Identify various PV Module and measure the efficiency and performance of various PV modules | II | 4 |
| 8 | Understand the working of solar PV systems and measure their performance. | II | 4 |
| 9 | Organize a visit to a local renewable energy facility such as a solar farm, wind farm and small hydroelectric plant. | II | 4 |
| 10 | Set up a microgrid with variable loads and distributed generation sources. | III | 2 |
| 11 | Prepare detailed report showing various types of Grid connection method for DG. | III | 2 |
| 12 | Visit to a grid-connected PV system installation to understand grid interconnection and compliance | III | 4 |
| 13 | Collaboration with industry experts and engineers for practical insights and mentorship for Grid operation and protection. | III | 4 |
| 14 | Build a model showing Set up of a microgrid with protective relays and circuit breakers. | III | 4 |
| 15 | Explore the use of smart meters in monitoring and managing energy consumption. | IV | 4 |

| Sr. No. | Practical Outcomes (PrOs) | Unit No. | Approx. Hrs. Required |
|---------|--|----------|-----------------------|
| 16 | Prepare report showing manufacturer of smart meter along with all specification, working and detailed operation of smart meter | IV | 4 |
| 17. | Collect and analyze data on energy consumption patterns. | IV | 2 |
| 18. | Prepare report showing comparison of various tariff structure | IV | 2 |
| | 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 | Simulink software | 6 |
| 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 | 1,2,8 |
| 7 | Wind energy characteristic Kit | 1,2 |
| 8 | Energy meter and Controller/data logger | 15,17 |

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) 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 Distributed Generation and Microgrid | 1a. Introduction to DG system 1b. Distinguish between various DG technology 1c. State merit and demerit of DG system. 1d. Describe concept of microgrid 1e. Explain connection of DG to Grid | 1.1 Definition, features and operation of DG 1.2 1) Fuel based Technology: a) micro turbine b) fuel cell c) diesel generator 2) Technology based on Renewable Energy a) solar cell b) wind turbine c) small hydro plants 1.3 Advantages and disadvantages of DG system. 1.4 General comparison among DGs. 1.5 Comparison among capabilities of DGs 1.6 Formation and working operation of micro grid. 1.7 Key components of microgrid 1.8 Direct connection to Grid via synchronous generator. 1.9 Indirect connection to grid via power electronics converters. |

| Unit | Unit Outcomes (UOs) (4 to 6 UOs at different levels) | Topics and Sub-topics |
|--|--|--|
| <p>Unit-II</p> <p>Distributed Energy Resources (DRE)</p> | <p>2a. Introduction to distributed energy resources</p> <p>2b. Combined heat and power (CHP) generation.</p> <p>2c. Explain Solar photovoltaic (PV) as a DG.</p> <p>2d. Explain Wind energy conversion systems as a DG</p> <p>2e. Explain Small scale hydroelectric power generation</p> | <p>2.1 Definition and Overview of DERs</p> <p>2.2 Types of Distributed Energy Resources.</p> <p>2.3 Benefits of DERs.</p> <p>2.4 Principles of CHP Systems.</p> <p>2.5 Different CHP technologies: reciprocating engines, gas turbines, fuel cells.</p> <p>2.6 Principles of Solar PV Technology.</p> <p>2.7 Components of Solar PV Systems.</p> <p>2.8 Theory of IV characterization.</p> <p>2.9 Types of Solar PV Installations.</p> <p>2.10 Advantages and challenges of Solar PV adoption.</p> <p>2.11 Principles of Wind Energy Conversion.</p> <p>2.12 Components of Wind Energy Systems</p> <p>2.13 Types of Wind Turbines.</p> <p>2.14 Advantages and challenges of Wind energy deployment.</p> <p>2.15 Principles of Hydroelectric Power Generation.</p> <p>2.16 Types of Small-Scale Hydroelectric Systems and its components.</p> <p>2.17 Advantages and challenges of Small-Scale Hydro plant deployment.</p> |
| <p>Unit-III</p> <p>Protection Issues for Microgrids</p> | <p>3a. Overview of protection requirements in microgrids.</p> <p>3b. Describe various Islanding, Different islanding scenarios</p> <p>3c. Explain Major protection issues of standalone Microgrid.</p> <p>3d. Impact of DG integration on electricity market, environment and distribution system.</p> | <p>3.1 Definition and importance of protection systems in microgrids.</p> <p>3.2 Objectives of microgrid protection (e.g., safety, reliability, and stability).</p> <p>3.3 Protection challenges in microgrid.</p> <p>3.4 Definition and types of islanding (intentional and unintentional)</p> <p>3.5 Planned islanding vs unplanned islanding.</p> <p>3.6 Impact of Islanding on Microgrid Operations</p> <p>3.7 Definition and applications of standalone microgrids.</p> <p>3.8 Use of local generation and energy storage for reliability.</p> |

| Unit | Unit Outcomes (UOs) (4 to 6 UOs at different levels) | Topics and Sub-topics |
|--|--|--|
| | | 3.9 Voltage and frequency stability challenges. 3.10 Overcurrent and short-circuit protection. 3.11 Changes in market dynamics due to DG. 3.12 Influence on electricity pricing and tariffs. 3.13 Contribution of renewable DG (e.g., solar, wind) to environmental sustainability. |
| Unit-IV Tariff and smart metering | 4a. Explain various Types of Electricity Tariff method. 4b. Describe various Tariff Structure 4c. Introduction to Smart Metering and its components. 4d. Introduce Functions and Capabilities of Smart Meters | 4.1 Flat rate tariff, block rate tariff, maximum demand tariff, power factor tariff. 4.2 Residential tariffs. Commercial and industrial tariffs. 4.3 Special tariffs for renewable energy and distributed generation. 4.4 Definition and Overview of Smart Meters 4.5 Components and Technology of Smart Meters 4.6 Benefits and Challenges of Smart Metering |

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 | Distributed Generation and Microgrid | 12 | 9 | 8 | 3 | 20 |
| II | Distributed Energy Resources | 12 | 10 | 6 | 4 | 20 |
| III | Protection Issues for Microgrids | 9 | 6 | 5 | 4 | 15 |
| IV | Tariff and smart metering | 9 | 7 | 5 | 3 | 15 |
| 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 various distributed generation system
- c) Conduct a lab experiment to measure and compare the efficiency of different types of solar panels.
- d) Create and present posters on different distributed generation technologies.
- e) Allow students to practice installation procedures, including mounting and wiring of solar Panel and Inverter.
- f) Solve numerical problems regarding course contents.
- g) Assign a research project on wind energy and solar energy policies at local, national, or international levels.
- h) Analyze case studies of successful distributed generation projects.

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 wind farm for getting knowledge of latest trends in it.
- 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 latest distribution generation technology.
- h) Guide students on how to address issues on environment and sustainability.
- i) Organize a visit to a local renewable energy facility such as a solar farm, wind farm, or a microgrid installation.

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) Assemble the components: solar panel, charge controller, battery, and USB charging ports.

- b) Construct a small-scale wind turbine model to generate electricity
- c) Measure the voltage and current output under different wind speeds.
- d) Design a solar water heater using readily available materials (e.g., PVC pipes, black paint, glass or plastic cover).
- e) Prepare Arduino based Solar Charge Controller
- f) Conduct an energy audit of a typical home and suggest optimization techniques.
- g) Simulate a basic microgrid using software tools like MATLAB or HOMER.
- h) Build a solar-powered water pump system.
- i) Design and implement a small battery storage system for a solar PV setup.

13. SUGGESTED LEARNING RESOURCE

| Sr. No. | Title of Book | Author | Publication with place, year and ISBN |
|---------|--|--|--|
| 1 | "Distributed Generation Systems: Design, Operation, and Grid Integration" | Gevork B. Gharehpetian and S. Mohammad Mousavi Agah | Published by book aid International (2017) ISBN: 978-0-12804208-3 |
| 2 | "Distributed Generation: The Power Paradigm for the New Millennium" | Anne-Marie Borbely and Jan F. Kreider | CRC Press (2001) ISBN: 9780849300745 |
| 3 | 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 |
| 4 | Smart Metering (Infrastructure, Methodologies, Applications, and Challenges) | Vijay K. Sood, Monalisa Biswal, saumendra sarangi, Hassan Haes Alhelou | February 26, 2024 ISBN : 9780443155864 |
| 5 | Electricity Metering in Easy Step | Shashikant Bakre | Kindle Edition January 21, 2015 |

13. SOFTWARE/LEARNING WEBSITES

Websites and Online Resources:

- National Renewable Energy Laboratory (NREL) - Distributed Generation
- Electric Power Research Institute (EPRI) - Distributed Energy Resources

Standards and Guidelines:

- IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems
- IEC 61727 - Photovoltaic (PV) systems - Characteristics of the utility interface

Articles and Papers:

- "A Review of Distributed Generation (DG) and Grid Integration" - IEEE Xplore
- "Distributed Generation: A Definition" by Thomas Ackermann, Göran Andersson, Lennart Söder (IEEE Xplore)

Video link:

- [Lecture-1 Introduction | Distributed Generation | DG | Microgrid | Smartgrid | Kaushal Patel | UTC \(youtube.com\)](#)
- [Lecture-3 Renewable Energy Sources \(Part-1\) | Distributed Generation | Smartgrid | Kaushal Patel \(youtube.com\)](#)
- [Lecture-5 Concept of Distributed Generations | Kaushal Patel \(youtube.com\)](#)
- [Lecture-9 Impact of Grid Integration | Kaushal Patel \(youtube.com\)](#)
- [Lecture-11 Basics of Microgrid | Kaushal Patel \(youtube.com\)](#)
- [What is Microgrid, how does it work? \(youtube.com\)](#)

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 |
| <u>Competency</u> | To help individual to understand their role and responsibilities for depth Understanding of Solar Photo Voltaic system | | | | | | |
| <u>Course Outcomes</u> | | | | | | | |
| CO1 Able to Explain the fundamental concepts and principles of distributed generation (DG) and microgrids | 2 | 1 | -- | -- | -- | -- | -- |
| CO2 Able to illustrate the concept of distributed generation. | 2 | -- | -- | -- | 1 | -- | 2 |
| CO3 Understand the control and operation of micro grids. | -- | 1 | -- | 2 | -- | 1 | -- |
| CO4 Able to Understand various tariff structure and advanced metering technology | 2 | -- | 1 | -- | -- | -- | 1 |

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**

| S. No | Name and Designation | Institute | Contact No. | Email |
|-------|---|---------------|-------------|--------------------|
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