# Model Curriculum for Minor Degree Course in Sustainable Energy Engineering (SEE)

**2022**


ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

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# MESSAGE

With a view to enhance the employability skills and impart deep knowledge in emerging areas which are usually not being covered in Undergraduate Degree credit framework, AICTE has come up with the concept of '**Minor Degree**' in emerging areas. The concept of Minor Degree is discussed in the Approval Process Handbook (APH) for the academic session 2021-22 issued by AICTE. Minor Degree will carry 18 to 20 credits in addition to the credits essential for obtaining the Under Graduate Degree in Major Discipline (i.e. 163 credits usually).

Keeping in mind the need of manpower in emerging areas, AICTE with the help of industry-academia experts, has framed the curriculum for Minor Degree in -

- Sustainable Energy Engineering (SEE)

Courses have been designed after rigorous brainstorming and considering the inputs from the experts of corresponding domain. I am hopeful that knowledge of these emerging areas will help students in capturing the plethora of employment opportunities available in these domains.

I gratefully acknowledge the time and efforts of all those who were involved in preparation of this curriculum especially, the contributions of the members of the Working Group: Prof. Chetan Singh Solanki from IIT Bombay, Prof. P. Bansod from SGSITS Indore, Prof P. Ghosh from IIT Bombay, Prof. S Mishra from IIT Delhi, Prof. V. Saraswat from B.R. Ambedkar University, Khadari campus, Agra

The well timed initiative to have this model curriculum addressing the need by Prof. M.P Poonia, Vice Chairman, Prof. Rajive Kumar, Member Secretary, AICTE is highly appreciated. I also appreciate the continuous effort put in coordinating the complete process of development of this curriculum by members of the Policy and Academic Planning Bureau of AICTE namely, Col. A Shreenath, Director; Dr. Pradeep Bhaskar, Assistant Director, Mr. Rakesh Kumar Pandit, Young Professionals and others.

**(Prof. Anil D. Sahasrabudhe)**
Chairman
All India Council for Technical Education

## Working Group for this Model Curriculum of Minor Degree for UG Degree Courses in Engineering & Technology

| S.No | Name & Role | Institute/Address |
|---|---|---|
| 1 | Prof. Chetan Singh Solanki (Chairman) | Professor ,Department of Energy Science and Engineering, IIT Bombay |
| 2 | Prof. Sukumar Mishra (Member) | Professor, Dept. of Electrical Engg, IIT Delhi |
| 3 | Prof. Prakash Ghosh (Member) | Professor ,Dept. of Energy Science and Engg., IIT Bombay |
| 4 | Prof. V. K. Saraswat (Member) | Professor and Head,Dept. of Electrical Engg,Dr B.R. Ambedkar University, Khadari campus, Agra |
| 5 | Prof. Prashant Bansod (Member) | Professor, Electronics and Instrumentation, SGSITS, Indore |

# GENERAL COURSE STRUCTURE & THEME

**A. Definition of Credit:**

| | |
|---|---|
| 1 Hr. Lecture (L) per week | 1 Credit |
| 1 Hr. Social (T) per week | 1 Credit |
| 1 Hr. Practical (P) per week | 0.5 Credit |
| 2 Hours Practical (P) per week | 1 Credit |

**B. Range of Credits:** 18-20 credits needs to be covered by a student to be eligible to get a Minor Degree in "Sustainable Energy Engineering (SEE)".

**C. Course Level Coding Scheme:** Three-digit number (odd numbers are for the odd semester courses and even numbers are for even semester courses) used as suffix with the Course Code for identifying the level of the course e.g.

101, 102 … etc. for first year

201, 202 …. Etc. for second year

301, 302 … for third year

**D. Total Courses = 06**
**Total Credits=18**
**Following courses are included:**

| Year | Course title and numbering | |
|---|---|---|
| | Sem-1 | Sem-2 |
| 2nd | SEE-201: Energy and its Resources | SEE-202: Climate Change Understanding and Observations |
| 3rd | SEE-301: Energy Storage for Renewables | SEE-302: Electronics for Renewables |
| 4th | SEE-401: Solar Energy Technologies and System Design | SEE-402: Solar Energy System Installations and Maintenance |

# Minor Degree in "Sustainable Energy Engineering (SEE)"

| Course Structure | | | | | | | From Page No. | To Page No |
|---|---|---|---|---|---|---|---|---|
| **S. No.** | **Course Code** | **Title** | **L** | **S** | **P** | **Credits** | | |
| 1 | SEE-201 | Energy and its resources | 1 | 1 | 2 | 3 | 6 | 11 |
| 2 | SEE-202 | Climate Change Understanding & Observations | 1 | 1 | 2 | 3 | 12 | 17 |
| 3 | SEE-301 | Energy storage systems for renewables | 1 | 1 | 2 | 3 | 18 | 21 |
| 4 | SEE-302 | Electronics for Renewables | 1 | 1 | 2 | 3 | 22 | 25 |
| 5 | SEE-401 | Solar Energy Technologies and System Design | 1 | 1 | 2 | 3 | 26 | 31 |
| 6 | SEE-402 | Solar Energy System Installations and Maintenance | 1 | 1 | 2 | 3 | 32 | 37 |
| **TOTAL** | | | **6** | **6** | **12** | **18** | | |

Course Coding Nomenclature:

- SEE denotes that Minor Degree related to "Sustainable Energy Engineering".
- 01, 02, 03, 04, 05 are course in order they have to be taken, if taken in different semesters.

## Detailed Syllabus

# Energy and its Resources

(Sustainable Energy Engineering)

| | |
|---|---|
| Course Code | SEE-201 |
| Course Title | Energy and its resources |
| Number of credits | 03 [ Lecture (15 hours):1 ,Practical (15 hours) :2,Social (15 hours) :1 ] |
| Course category | SEE |
| Pre-requisite | None |

### Course Objective:

This course will offer

- Understanding of energy units, unit conversion, unit magnitudes
- Description and quantification of various energy resources – renewable and non-renewable
- Understanding energy needs of self, institution, country and world, energy consumption by sector
- Debate on advantages and disadvantages of energy sources
- Energy resources of India and World, Sankey diagrams
- Wind, biomass and solar energy resources
- Per capita energy consumption and impact on social and economic parameters
- Future scenarios of energy requirements

### Course Content

#### A. Theoretical Learning

Each lecture is assumed to be of one hour. In content column, if possible breakdown the content of 1 hour in sub-topics

| Lecture No. | Contents |
|---|---|
| 1 | **Energy and its units:** discussion on role of energy in our lives, various sources of energy that we use, units of energy, small and large units of energy, magnitude of energy units, units for energy consumption of individual, institution and country |
| 2 | **Renewable and Non-renewable energy:** difference, characteristics of resources, advantages and disadvantages, discussion in class on which type of resources to be used by individual, by a country, reason out why? |

| | |
|---|---|
| 3 | **Understanding individual energy requirements:** take a case of any student, discuss what energy resources he/she uses, differentiate between energy and power, estimating electrical energy needs, estimating fuel energy needs (petrol/diesel), estimating cooking energy needs, convert all energy sources in single energy units, estimate total energy needs of a person, discussion on possible growth on energy demand, should it grow or not? |
| 4 | **Energy requirements of a country:** evolution of energy consumption, population of country, number of demands for energy, per demand energy, estimating energy consumption of country, discussion on possible growth on energy demand, should it grow or not? |
| 5 | **World energy scenario- consumption:** energy consumption of world, by resources, by sector, per capita electricity and total energy consumption, comparison among countries and between continents, relationship between Human Development Index (HDI) and energy consumption, discussion in the class on disparity in energy consumption |
| 6 | **World's energy resources – non-renewable:** fossil fuels like coal, oil gas as energy resources, difference between reserves and resource, current production and consumption rates of fossil fuels, peak oil, first and second oil shock, discussion on limited nature of the fossil fuels, whether peak oil would ever come? |
| 7 | **World energy flows:** world energy consumption, total primary energy supply (TPES), total final consumption (TFC), Sankey diagram for depicting energy flow, draw Sankey diagram for world energy flow and few selected countries, |
| 8 | **India's energy scenario – non-renewable:** India's energy consumption from all resources, consumption of oil, coal, gas, import of fossil resources, foreign exchange requirements, discussion on energy security of country and imports dependency |
| 9 | **Renewable energy sources:** what are renewable energy sources? Why they are renewable?, summary of all RE resources, global scenario of these resources |
| 10 | **Wind and Biomass resources in India**: discussion on origin of these resources, potential of these resources in India, how these resources are converted into useful energy, |
| 11 | **Solar energy resources:** Sun as source of energy, solar energy reaching the Earth's surface, solar spectrum, photons of different energy, solar irradiation and solar radiation/insolation, extra-terrestrial solar radiation, global, direct and diffuse solar radiation |
| 12 | **Quantifying solar energy resources**: units of solar energy, air mass, AM1.5 and standard test conditions; hourly, daily, monthly and yearly solar radiation, solar radiation maps of India and world, variation of solar radiation at a given location within a day, over a season and reason behind it, significance of summer and winter solstice |

| | |
|---|---|
| 12 | **Finding solar radiation data**: measuring solar radiation data, meteorological stations, sources of solar radiation data for various cities of India |
| 13 | **Optimal collection of solar radiation:** apparent motion of sun and earth, apparent position of sun for an observer, optimal angle of solar collectors for maximum solar radiation collection, optimum angle for summer and winter |
| 14 | **Hydrogen energy:** source and storage medium, generation of hydrogen, storage of hydrogen, conversion of hydrogen into useful energy, future of hydrogen |
| 15 | **Future energy scenarios:** summary of the class, students to summarize their experiences in the form of poster on any one topic, discussion on what are possible scenarios? |

## B. Practical Learning

In contents please provide as detailed titled of the experiments as possible, also break down experiments in sub experiments to give clear indication on what are the concepts/observations students are expected to learn in each experiments.

| Experiment No. | Contents |
|---|---|
| Note | Conduct any of the five experiments listed below |
| 1 | Measure instantaneous solar irradiation (W/m2) inside a classroom, under cloudy condition (if possible), and under clear sunny sky and compare.<br><br>Measure 8 to 10 readings of instantaneous solar irradiation over couple of hours and based on readings estimate the solar insolation (kWh/$m^2$) falling over duration of experiment day of experiment |
| 2 | On the day of experiment, take a solar panel out under the sunlight and measure its short circuit current under various orientation of solar panel with respect to the Sun. Note down reading, compare the variation in measured current values and compare and comment on variation in the values. |
| 3 | Measure energy consumption of a light and a fan (or any other appliance) in your lab using power meter / energy meter over the duration of experiment. Also do the theoretical estimation of possible energy consumption by the appliances over the same time. Compare both and comments. |
| 4 | Figure out from which point electricity is entering your campus, how it is being measured (visit the site), check if you can take any reading, discuss the electrical supervisor on daily, monthly electricity consumption of the campus, discuss the variation of electricity consumption with season and reason behind it. Make summary of your observations. |

| | |
|---|---|
| 6 | Visit canteen of your campus, make a list of all appliances used in campus, note down the hours of usage and estimate daily and monthly electricity consumption of canteen.<br><br>Also estimate how much energy is consumed in canteen through other fuels like LPG or coal or any other sources. |
| 7 | Debate on which energy sources to be promoted, students are to be divided in 4 or 5 groups, each group representing different source, each group presents their idea why that particular source should be promoted, the task of the whole class is to come to a conclusion on use of a particular soruce |

## C. Social Learning

This activity would be most crucial and needs careful design. This includes activities outside the classroom and outside the laboratory. Students must do something to apply their knowledge. This can also be exercise to apply the knowledge learned in classroom and laboratory and gather more information/data from society on a topic.

| **Social experiment No.** | **Contents** |
|---|---|
| Note | Conduct any of the three experiments / exercises |
| 1 | Estimate the monthly energy consumption of your own family, include energy consumption from electricity, petrol, diesel, LPG, public transportation, etc. Make a brief report on it. |
| 2 | Make a brief report on energy consumed for food production and consumption, collect the data on energy consumed on per meal basis |
| 3 | Estimate the energy consumption of an industry / start-up /institution in your area, include energy consumption from electricity, petrol, diesel, LPG, public transportation, etc. Make a brief report on it. |
| 4 | Write a brief 2-page report on total annual energy consumption of any country, other than India. Include energy consumed from all resources, and draw its Sankey diagram. |
| 5 | Write a brief 2-page report on annual renewably energy consumption of any country, other than India. Include energy consumed from all resources, and draw its Sankey diagram. |
| 6 | Measure instantaneous solar radiation at your location, collect reading every hour from 10am to 4pm. Use a pyranometer or solar cell. Prepare a report on it. Assuming similar radiation falling on entire city. How much total solar energy would be falling on your city/village over those three days? |

**Tools requirement:**

- Pyranometer or calibrated solar cell for measuring solar radiation
- Solar panel of 20 or 50 or 100 or any power rating

**Text books and other references**

- Energy flow of a country is presented using Sankey diagram. This link offers you to draw Sankey diagram for energy country, it also offers you to select a particularly timeline, a country, a region, etc.
  https://www.iea.org/sankey/
- World Energy report
  https://www.iea.org/reports/world-energy-outlook-2021
- Report- Statistical Review of World Energy -2021, 70th edition;
  https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
- Knowledge Centre, Ministry of New & Renewable Energy - Government of India
  https://mnre.gov.in/
- Ch. Pavan Kalyan and M. Pavan Das, Future Energy Scenario: A Better Planet with Renewable Energy, 2020
- O.P. Gupta, Energy Technology, Khanna Publishing House, New Delhi, 2020.
- Chandra & Chandra, Non-Conventional Energy Resources, Khanna Book Publishing, Delhi 2022.
- Chapter 01 and 09, S. P. Sukhatme and J. K. Nayak, Solar Energy – Principles of Thermal Collection and Storage, Tata McGraw Hill, 2008
- Chapter 01 and 12, C. S. Solanki, Solar Photovoltaics – Fundamentals, Technologies and Applications, 3rd Ed. Prentice Hall of India, 2016
- Ankur Mathur, Non-Conventional Sources of Energy, Laxmi Publications Pvt. Ltd., 2015
- John Twidell, Tony Weir, Renewable Energy Resources, Taylor & Francis, 2005
- Andrew L. Simon, Energy Resources, Elsevier Science, 2013

**Expected outcome of course:**

Possible outcome of course is ability to:

- Quantify energy usage at various levels (individual, country, world)
- Debate on use of renewable and non-renewable energy sources
- Correlate energy consumption with social and economic parameters
- Understand availability of renewable energy resources in a given region
- Comment on possible future energy scenario

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# Climate Change: Understanding & Observation

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|---|---|
| Course Code | SEE-202 |
| Course Title | Climate Change Understanding & Observations |
| Number of credits | 3 [Lecture (14 hours) :1, Practical (10 hours) :2, Social (15 hours) :1 ] |
| Course category | SEE |
| Prerequisite | None |

**Course Description:**

Climate Change poses an increasing threat to the stability of Earth's systems. If we want to protect our planet from dangerous and unprecedented change, first we must understand the science behind climate change. This course will help in looking back across understanding the dynamics of climate change, its causes, and consequences, and learning the difference between 'natural' from 'human' induced climate change; looking to the present to see how the impacts of climate change are already being felt; finally looking to the future to see what it might hold for our planet.

**Course Objective:**

This course will offer

- Understanding of climate change, the difference between climate and weather
- Understanding the causes, consequences of climate change
- Evidence of the climate change - frequency and intensity of the erratic climatic events
- Comprehending the future of fossil fuels in a carbon-constrained world
- Understanding the past climate agreements
- Understanding the pledges of COP26
- Future scenarios of climate action
- Up-scaling renewable energy

**Course Content**

### A. Theoretical Learning

Each lecture is assumed to be for one hour. In the content column, if possible breakdown the content of 1 hour in sub-topics

| Lecture No. | Contents |
|---|---|
| 1 | **Understanding the climate and weather:** discussion on what is climate, weather, the difference between the two, and defining climate change, understanding the relevance of 1.5 degrees and 2-degree Celsius warming. |
| 2 | **Science of climate change:** In-depth understanding of the causes climate change, human contribution to climate change, anthropogenic drivers of climate change, |

| | |
|---|---|
| 3 | **Understanding the depletion of natural elements:** What would be the impacts of these changes in climate for human well-being and the natural world? Understanding the consequences of climate change on the depletion of the two natural resources - **water and soil changes,** amount of changes, reasons behind, what are future trends |
| 5 | **Understanding the depletion of natural elements: change:** An understanding and analysis of the consequences of the climate change of two parameters - **temperature and precipitation change,** amount of changes, reasons behind, what are future trends |
| 6 | **Understanding the depletion of natural elements:** An understanding and analysis of the consequences of the climate change of two parameters **- droughts & heatwaves and hurricanes,** amount of changes, reasons behind, what are future trends |
| 7 | **Understanding the depletion of natural elements:** An understanding and analysis of the consequences of the climate change of two parameters - **sea levels and glacier melting,** amount of changes, reasons behind, what are future trends |
| 8 | **The future of fossil fuels in a carbon-constrained world:** Understanding the fossil fuels and how they will be earmarked in the future of the energy generation and consumption, how we can move towards the decarbonized world |
| 9 | **Climate Change Agreements:** Understanding the evolution of the climate agreements, UNFCCC, kyoto protocol, the defining agreements of Paris and COP |
| 10 | **The pledges of COP26:** What is COP26?, participating organizations, Understanding the synopsis of the current climate agreement of COP26 and how the countries have committed to marking their progress with the initial commitment |
| 11 | **Future scenarios of climate action:** In-depth study of two scenarios - one with the world wherein the consumption of fossil fuels remain the same, then what will happen to our ecosystems and the second scenario, wherein we move towards a decarbonized world, what will be the impact on our ecosystems |
| 12 | **Mitigation and Adaptation Strategies (Part -1):** Understanding the what are roles of individuals, countries, and the global community in adapting to climate change and policies for upscaling renewable energy |
| 13 | **Mitigation and Adaptation Strategies (Part-2):** Understanding the what are roles of individuals, countries, and the global community in adapting to climate change and policies for upscaling renewable energy |
| 14 | **Case Study -1: Climate change mitigation and adaptation** |
| 15 | **Case Study -2: Climate change mitigation and adaptation** |

## B. Practical Learning

Each experiment can be for 4 to 6 hours. In contents please provide as detailed a title of the experiments as possible, also break down experiments in sub experiments to give a clear indication on what are the concepts/observations students are expected to learn in each experiment.

| Experiment No. | Contents |
|---|---|
| Note | Conduct any of the five experiments listed below |
| 1 | Find out the records (measurements from meteorology stations) of average temperature changes of the past 20-30 years in your region. Observe the patterns of temperature change and make critical comments on patterns and reasons behind. |
| 2 | Find out the records (measurements from meteorology stations) of average precipitation of the past 20-30 years in your region. Observe the patterns of temperature change and make critical comments on patterns and reasons behind. |
| 3 | Prepare a report on the possible role of your institutions in the mitigation of climate change. Do this based on discussion with people in society. Frame a set of 5 to 6 questions, interview people and based on the interview prepare a report. |
| 4 | Estimate the carbon footprint of your institute based on energy consumption of the institute. Also make an estimate of carbon emission of your institute (even if it is very approximate) that includes travelling by students and staff, carbon footprint due to residents, etc. |

## C. Social Learning

This activity would be most crucial and needs careful design. This includes activities outside the classroom and outside the laboratory. Students must do something to apply their knowledge. This can also be exercised to apply the knowledge learned in the classroom and laboratory and gather more information/data from society on a topic.

| Social experiment No. | Contents |
|---|---|
| Note | Conduct any of the three experiments/exercises |
| 1 | Prepare a report on the possible role of individuals in the mitigation of climate change. Prepare this report based on discussion with people in society. Frame a set of 5 to 6 questions, interview people and based on the interview prepare a report. |

| | |
|---|---|
| 2 | Visit a nearby river / pond /forest, discuss with people living around it and figure out the changes people have observed since the last 20-30 years. Prepare a report. |
| 3 | Prepare a report on what is your and your family's possible role in contribution to climate change and its mitigation. As far as possible quantify the contributions. |
| 4 | Prepare a report on newspaper coverage of climate change and related happenings of your region and country since last one year. Make your remarks on newspaper coverage. |

**Textbooks and other references**


1. University of Cambridge (2013). Climate Change: Action, Trends and Implications for Business. Available at: https://www.cisl.cam.ac.uk/system/files/documents/Science_Report_Briefing_WEB_EN.pdf
2. IISD, UNITAR & UNEP (2009). IEA Training Material: Vulnerability and Climate Change Impact Assessment for Adaptation. Available at: https://www.iisd.org/system/files/publications/iea_training_vol_2_via.pdf
3. IPCC (2021). Climate Change 2021. The Physical Science Basis - Summary for Policymakers Available at https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf
4. OECD (2009): Guidance on Integrating Climate Change Adaptation into Development Co-operation. Available at: https://www.oecd.org/env/cc/44887764.pdf
5. UNEP (2009). Climate Change Science Compendium. Available at: https://www.unep.org/resources/report/climate-change-science-compendium-2009
6. UNEP (2009). Climate in Peril, a Popular Guide to the Latest IPCC Report. Available at https://www.unep.org/resources/report/climate-peril-popular-guide-latest-ipcc-reports
7. UNEP & UNDP (2011). Mainstreaming Climate Change Adaptation into Development Planning: A Guide for Practitioners. Available at https://www.undp.org/sites/g/files/zskgke326/files/publications/Guide%20Mainstreaming%20Climate%20Change%20Adaptation%202011.pdf
8. UNFCCC. CGE Climate Change Training Materials. Available at https://unfccc.int/process-and-meetings/bodies/constituted-bodies/consultative-group-of-experts/cge-training-materials/cge-training-materials-for-the-preparation-of-national-communications
9. UNFCCC (2008). Compendium on Methods and Tools to Evaluate Impacts of, and Vulnerability and Adaptation to, Climate Change. Available at https://unfccc.int/files/adaptation/nairobi_workprogramme/compendium_on_methods_tools/application/pdf/20080307_compendium_m_t_complete.pdf
10. UNFCCC (2006). UNFCCC Handbook. Available at

https://unfccc.int/resource/docs/publications/handbook.pdf
11. UNFCCC & UNEP (2002). Climate Change Information Kit. Available at https://unfccc.int/resource/iuckit/cckit2001en.pdf
12. World Bank Report (2012). Turn Down the Heat. Available at https://documents1.worldbank.org/curated/en/865571468149107611/pdf/NonAsciiFileName0.pdf
13. World Meteorological Organization (2012). Greenhouse Gas Bulletins. Available at https://library.wmo.int/doc_num.php?explnum_id=10100
14. O.P. Gupta, Elements of Environmental Pollution Control, Khanna Book Publishing.
15. O.P. Gupta, Energy Technology, Khanna Publishing House, New Delhi, 2020.
16. Khandelwal, K. C. and Mahdi, Biogas Technology - A Practical Hand Book, Tata McGraw.
17. A. Chakrabarti, Energy Engineering and Management, PHI.

**The expected outcome of course:**

The possible outcomes of course are:

- Ability to describe the key principles of climate change
- Ability to identify the causes and consequences of climate change
- Ability to identify signs of climate change
- Understand the impacts on the current ecosystems
- Understanding the future projections and what the future may hold for Earth

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## Energy Storage for Renewables

| | |
|---|---|
| Course Code | SEE-301 |
| Course Title | Energy storage systems for renewables |
| Number of credits | 03 (L:1; P;2 S:1) |
| Course category | SEE |
| Pre-requisites | SEE-201 |

**Course Objective:**

This course will offer

- An overview of the storage system suitable for offering reliable energy solutions.
- Energy storage types based on energy form
- Sustainable storage solutions for renewable energy systems will be identified based on reliability and affordability.
- Life cycle cost, energy and environmental analysis of conventional storage systems
- Study of the characteristics of conventional energy storage systems

**Course Content**

### A. Theoretical Learning

| Lecture No. | Contents |
|---|---|
| 1 | **Demand-supply mismatch and role of energy storage:** Discussion on types and variation in different load demands such as residential load, office, agricultural load; Variation in renewable energy resources, Understanding the mismatch between load profile and generation profile; introduction to the mismatch time scale |
| 2 | **Overview of different energy storage options:** Introduction to the Ragone plot; Introduction of demand-supply mismatch time scale on Ragone plot; C-rating |
| 3 | **Mechanical Energy Storage-Compressed Air:** Basic thermodynamics; working principle; general consideration; power extraction system-diabatic, adiabatic and isothermal method |
| 4 | **Mechanical Energy Storage-Flywheel:** Introduction to the moment of inertia, angular momentum and kinetic energy of rotating object; working principle; components; characteristics; applications |
| 5 | **Mechanical Energy Storage-Pumped Hydro:** Introduction; working principle; components and complete system; open-loop and closed-loop pumped hydro storage; turbines types and applications |

| | |
|---|---|
| 6 | **Thermal Energy Storage:** Introduction to the fluid flow and heat transfer; latent and sensible heat storage; phase change materials (PCM) for thermal energy storage; different geometries for PCM based thermal storage |
| 7 | **Overview of Electrochemical Energy Storage:** Electrochemical cells and batteries; primary cell; secondary cell, Faradic and Non-faradic process, charging and discharging of electrochemical cells and polarity, efficiencies |
| 8 | **Open circuit voltage for electrochemical storage:** Standard pressure and temperature, standard electrode potential, concentration cell |
| 9 | **Current-voltage behaviour of electrochemical storage:** Types of electrode-electrolyte interfaces, double layer capacitance, mechanism of electron transfer at the interface, oxidation and reduction and polarity, anode and cathode, cell polarisation behaviour-activation polarisation, ohmic polarisation, concentration polarisation |
| 10 | **Supercapacitor as energy storage:** Introduction, working principle, basic design, types, charging-discharging characteristics and efficiencies, applications |
| 11 | **Batteries storage:** Introduction to Primary battery, reserve batteries and secondary batteries, Lead-acid batteries-working principle, components and characteristics, Li-ion batteries- working principle, components and characteristics |
| 12 | **Hydrogen storage:** Introduction to water electrolysis, alkaline electrolyser, PEM electrolyser, current-voltage characteristics, materials for electrolyser, engineering configurations |
| 13 | **Hybrid energy storage:** Introduction to hybrid energy storage, C-rating of a storage system, Life of energy storage, studying the demand-supply mismatch and selection of storage system |
| 14 | **Flow batteries:** Working principle, Types of flow battery, components and configurations, current-voltage characteristics, efficiencies, lifetime |
| 15 | **Life cycle analysis:** Depth of discharge and state of charge, cycle life of a battery as a function of depth of discharge, full effective cycle, shelf life, life cycle cost analysis, environmental impact and recycling, |

## B. Practical Learning

The duration of each experiment is for 3 hours.

| Experiment No. | Contents |
|---|---|
| 1 | Study the characteristics of a lead-acid battery, note down the parameters on charging and discharging cycles |

| | |
|---|---|
| 2 | Study the characteristics of a flywheel<br>Reference link:<br>https://vlab.amrita.edu/?sub=1&brch=74&sim=571&cnt=3 |
| 3 | Study the behaviour of different electrodes for electrochemical energy storage |
| 4 | Study the thermal behaviour of different phase change material |

## C. Social Learning

| Social experiment No. | Contents |
|---|---|
| 1 | Visit an office / industry / any other place (it may be there in your own institution) where battery based storage is installed. Observe the kind of batteries installed, their configuration, ratings of individual battery and that of combined storage, back-up that battery storage is performing. |
| 2 | Prepare a report on Lead-acid battery recycling. If possible, visit a factory premises where batteries are manufactured or recycled. Identify aspects of battery manufacturing and recycling that would environmental impact. |
| 3 | Prepare brief report on any one of the following energy storage (more than 100 kWh) mechanisms based on actual installations: pump storage / $H_2$ storage / battery storage |

**Text books and other references**


1. O.P. Gupta, Energy Technology, Khanna Publishing House, New Delhi (ISBN – 978-93-86173- 683), 2020.
2. A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4), 2011
3. Robert A. Huggins, "Energy Storage", Springer Science (ISBN - 978 -1-4419-1023-3), 2010
4. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN - 13:9789380090122), 2011
5. A. Chakrabarti, Energy Engineering and Management, PHI.


**Expected outcome of course:**

- Understanding about the different types of demand supply mismatches in a renewable system
- Understanding of basic operating principle of different storage systems
- Ability to analyse the life cycle energy cost of different energy storage system
- Knowledge of characteristics behaviour of different storage systems

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## Electronics for Renewables

| | |
|---|---|
| Course Code | SEE-302 |
| Course Title | Electronics for Renewables |
| Number of credits | 03 (L:1; P:2; S:1) |
| Course category | SEE |
| Pre-requisites | Basic Electronics, Energy resources |

**Course Objective:**

This course will offer

- An understanding of basic components used in electronics application in renewable energy
- Operation of rectifiers
- Description and design of DC to DC convertors and their role in renewable energy technologies
- Description and design of DC to AC convertors and their role in renewable energy technologies
- Understanding and functionality of simple, PWM and MPPT charge controllers, their input and output parameters
- Understanding and functionality of off-grid, grid-tied and hybrid solar inverters
- Details of the efficient solar products available commercially for domestic and commercial applications

**Course Content**

### A. Theoretical Learning

| Lecture No. | Contents |
|---|---|
| 1 | **Electronic components-1**: Components of electronic circuits used in renewable energy like diode, MOSFETs, IGBTs, etc. their functionalities and I-V characteristics |
| 2 | **Electronic components-2**: Components of electronic circuits used in renewable energy like diode, MOSFETs, IGBTs, etc. their functionalities and I-V characteristics |
| 3 | **Rectifier**: Half bridge and full-bridge converters, Power circuit and steady state analysis |

| Lecture No. | Contents |
|---|---|
| 1 | **Electronic components-1**: Components of electronic circuits used in renewable energy like diode, MOSFETs, IGBTs, etc. their functionalities and I-V characteristics |
| 4 | **DC – DC controller -1**: Need of DC-DC conversion in renewable energy technologies, basics of DC-DC conversion, design of circuits, input and output parameters |
| 5 | **DC – DC controller -2**: Need of DC-DC conversion in renewable energy technologies, basics of DC-DC conversion, design of circuits, input and output parameters |
| 6 | **DC – AC conversion-1**: Need of DC-AC conversion in renewable energy technologies, basics of DC-AC conversion, design of circuits, input and output parameters |
| 7 | **DC – AC conversion-2**: Need of DC-AC conversion in renewable energy technologies, basics of DC-AC conversion, design of circuits, input and output parameters |
| 8 | **Application of DC-DC controllers to solar energy-1**: functionality and design of simple charge controller, input and output parameters |
| 9 | **Application of DC-DC controllers to solar energy-2**: functionality and design of PWM charge controller, input and output parameters |
| 10 | **Application of DC-DC controllers to solar energy-3**: functionality and design of MPPT charge controller |
| 11 | **Application of DC-AC inverter to solar energy-1**: functionality and design of off-grid inverter, input and output parameters |
| 12 | **Application of DC-AC inverter to solar energy-2**: functionality and design of grid-connected inverter, input and output parameters |
| 13 | **Application of DC-AC inverter to solar energy-3**: functionality and design of hybrid inverter, input and output parameters |
| 14 | **Efficient solar operated products-1**: Solar based DC products for domestic and industrial appliances |
| 15 | **Efficient solar operated products-2**: Solar based DC products for domestic and industrial appliances |

## B. Practical Learning

In contents please provide as detailed titled of the experiments as possible, also break down experiments in sub experiments to give clear indication on what are the concepts/observations students are expected to learn in each experiments.

| Experiment No. | Contents |
|---|---|
| 1 | Learn to make a PCB, design of PCB, fabrication of PCB |
| 2 | Experiment with an Half Bridge & Full bridge rectifiers & observer their characterisation, note down input and output parameters |
| 3 | Various firing circuits for IGBTs & their characterisation |
| 4 | Open up a hybrid / MPPT solar inverter, look at each and every block inside the inverter, write down the function of each block and match it with the theory that you have learned, note down the input and output parameters, using oscilloscope observe the shape of output waveform. |
| 5 | Make a PCB with DC-DC conversion ICs and create a DC-DC converter |
| 6 | Make a simple inverter on a PCB, observe the input and output parameters, observe the output waveform shape |

## C. Social Learning

This activity would be most crucial and needs careful design. This includes activities outside the classroom and outside the laboratory. Students must do something to apply their knowledge. This can also be exercise to apply the knowledge learned in classroom and laboratory and gather more information/data from society on a topic.

| Social experiment No. | Contents |
|---|---|
| 1 | Use the DC-DC charge controller that you have made and installed it for someone or some shop (like Paan shop, or any other shop) as device for their mobile charging. Make a brief report on it, possibly with photo of installation and small interview. |
| 2 | Use DC-DC charge controller that you have made, couple it with battery and solar panel to run a 2 W LED light, install the light at someone's place who may need such light e.g. vegetable / fruit vendor, a hut, etc. Make a brief report on it possibly with photo of installation and small interview. |
| 3 | Based on your understanding of electronics used for solar energy applications, give one or two talks to junior classes or in a school |
| 4 | Visit a solar system installation in institution or any other location, small or big, observe the electronics used in the installation, prepare a report on it. |

**Text books and other references**


- Power Electronics, P.S. Bimbhra, Khanna Book Publishing Co., New Delhi.
- Electrical Machines – I & II, P.S. Bimbhra, Khanna Book Publishing Co., New Delhi.
- Rashid.M. H "power electronics Hand book", Academic press, 2001.
- Mohan, Undeland and Robins, "Power Electronics – Concepts, applications and Design, John Wiley and Sons, Singapore.

- Ned Mohan, T.M. Undeland and William P.Robbins, Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009.
- Industrial Electronics and control /Biswanath Paul.
- Renewable Energy Technologies /Ramesh & Kumar /Narosa
- Electrical power systems quality-Roger C.Dugan- McGraw- Hills
- Energy Technology, O.P. Gupta, Khanna Publishing House, New Delhi, 2020.
- Khandelwal, K. C. and Mahdi, Biogas Technology - A Practical Hand Book, Tata McGraw.
- A. Chakrabarti, Energy Engineering and Management, PHI.


**Expected outcome of course:**

- Ability to understand the role of various electronic components in renewable energy technologies
- Ability to theoretically design DC to DC and DC to AC converters
- Ability to describe various charge controller and inverters used in solar energy technologies
- Ability to understand various solar DC efficient products available in the market
- Ability to fabricate simple DC to DC converters using ICs and deploy in the field

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## Solar Energy Technologies and System Design

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| Course Code | SEE-401 |
| Course Title | Solar Energy Technologies and System Design |
| Number of credits | 3 [ Lecture (15 hours):1 ,Practical (15 hours) :2,Social (15 hours) :1 ] |
| Course category | SEE |
| Pre-requisite | None |

**Course Objective:**

This course will offer

- An introduction to various solar PV and solar thermal technologies
- Basic parameters of solar PV panels and systems
- Standard test conditions under which the parameters are measured
- Design of solar PV system for electrical energy requirements, sizing of PV modules, battery, electronics, etc.
- Design of solar thermal system for given thermal energy requirements

**Course Content**

### D. Theoretical Learning

Each lecture is assumed to be of one hour. In content column, if possible breakdown the content of 1 hour in sub-topics

| Lecture No. | Contents |
|---|---|
| 1 | **Materials for solar energy conversion:** discussion on what are different material categorization, use of semiconductors for converting sunlight into electricity and use of metals for converting sunlight into heat, basic properties of semiconductors and metal required for conversion, e.g. bandgap, absorption coefficient, solar spectrum and energy of photons |
| 2 | **Material parameters:** important material parameters of semiconductors, band gap, absorption coefficient, absorption length, mobility, carrier drift, diffusion coefficient, carrier diffusion, Light absorption and recombination in semiconductors, |
| 3 | **I-V characterises of P-N junction diode :** forward and reverse biasing of P-N junction, forward biased current, reverse bias current, total current of P-N junction, I-V equation and curve |
| 4 | **Illuminated P-N Junction as solar cells:** discussion on why P-N junction diode requires power, but solar cell generates power, different quadrant of operations for P-N junction, dark and illuminated behaviour of P-N junction, demonstration through shift in I-V curve, discussion on photovoltaic effect |

| | |
|---|---|
| 5 | **I-V characteristic of solar cells:** I-V characteristics of a P-N junction diode under dark (write expression), light illuminated current component, I-V characteristics of a P-N junction diode under illumination, fourth quadrant operation, explain solar cell parameters Voc, Isc, FF, Efficiency using I-V curve, write down expressions |
| 6 | **Standard Test Condition and PV module parameters:** discussion on why there is need of STC, Converting solar cells to modules for obtaining required current, voltage and power, STC for solar energy technologies, PV modules parameters, effect of temperature and radiation on output parameters, reasons for variation in actual output of solar PV modules in real life conditions |
| 7 | **Solar PV technologies (part-I):** discussion on what students have seen in market or real life installations, various material and corresponding PV technologies, thin-film and crystalline Si technologies, commercially available technologies, best efficiencies of solar modules in labs and commercial market |
| 8 | **Solar PV technologies (part-II):** discussion on what students have seen in market or real life installations, various material and corresponding PV technologies, thin-film and crystalline Si technologies, commercially available technologies, best efficiencies of solar modules in labs and commercial market |
| 9 | **Typical parameters of c-Si solar cells:** Parameters of commercially produced solar cells and modules, typical values of voltage, current, FF and Efficiency, typical power ratings |
| 10 | **Solar thermal technologies:** various solar thermal technologies like solar hot water heater, solar cooker, discussion on need of concentration of light for higher temperatures, methods of sun light concentrations, solar concentration for power generation |
| 11 | **Design of solar hot water system:** discussion on what should be the solar thermal system components, use of thermosyphon effect, drawing of solar hot water system, estimate the energy required for heating water, estimation of collector area required for delivering required energy, considering typical losses in conversion, efficiency equation of solar thermal system |
| 12 | **Design of solar PV system (Part-I):** discussion on what should be the solar PV system components, block diagram of simple (no storage, no electronics) and complicated systems (grid tied with diesel and wind generators), estimating user's electrical energy requirements, sizing solar PV, battery and power conditioning units required in solar system, configuration of battery and panels, fixing input and output parameters of all system components |
| 13 | **Design of solar PV system (Part-II):** discussion on what should be the solar PV system components, block diagram of simple (no storage, no electronics) and complicated systems (grid tied with diesel and wind generators), estimating user's electrical energy requirements, sizing solar PV, battery and power conditioning units required in solar system, configuration of battery and panels, fixing input and output parameters of all system components |

| | |
|---|---|
| 14 | **Costing of solar PV system :** costing of solar components, per unit costing of panels, batteries, structure, wires, electronics, total system costing |
| 15 | **Misconception of solar energy generation and Costing of solar system:** discussion on what possible misconception people have in mind, generation in rainy season, need of maintenance, high costing of solar PV system, clarifying with data why these are misconception as per current status of technologies, typical costing of solar PV system components on per Watt basis as per current norms, estimating overall system costing, costing of solar thermal systems |

## E. Practical Learning

Each experiments can be of 2.5 to 3 hours. In contents please provide as detailed titled of the experiments as possible, also break down experiments in sub experiments to give clear indication on what are the concepts/observations students are expected to learn in each experiments.

| Experiment No. | Contents |
|---|---|
| Note | Conduct any of the five experiments listed below |
| 1 | Take a solar panel and look at it carefully, at looking at it comment and write down various aspects of panel, what materials you see are used, how many solar cells are connected, how they are connected, what is the material used in making solar cells (mono or multi-crystalline or any other), what would be per cell parameters, look at name plate rating, does the name plate rating matches with expected outcome based on solar cell configurations |
| 2 | Take a solar panel (any wattage, 10, 20, 50, 100, 250, 300 Watt, etc.) and measure its parameters in real conditions, Voc, Isc, FF, Efficiency, repeat the experiments several times. What are your observation on variation in these parameters when you repeat the experiment at 30 min, interval (take at least 5 readings). |
| 3 | Measure the effect of sun tracking on output generation by a solar PV module, measure when module is fixed and when it is following the Sun (adjust the orientation of the panel manually), measure power output at every 30 min interval (take at least 5 readings), estimate the energy generated in two conductions and figure out the difference in energy generated when fixed and when tracking the sun. |
| 4 | Measure the energy consumed by few loads in the laboratory like lights, fans on the day of your experiments, use power meter and mustimeter, perform the experiments for at least two hour duration |

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| 5 | Estimate the energy consumed by all appliances used in a lab on monthly basis, design a solar PV system and size various system components for the same, cross-check if your designed system would generate the required energy |

## F. Social Learning

This activity would be most crucial and needs careful design. This includes activities outside the classroom and outside the laboratory. Students must do something to apply their knowledge. This can also be exercise to apply the knowledge learned in classroom and laboratory and gather more information/data from society on a topic.

| Social experiment No. | Contents |
|---|---|
| Note | Conduct any of the three experiments / exercises |
| 1 | Visit any installation of solar PV system or solar thermal system in your institution or any nearby area. Take note of interconnection of various components of system, make a comment on how system is designed |
| 2 | Measure energy consumed by some loads in your home, use power meter and energy meter to carry out measurements, check if the measured energy consumption is as per your expectations. |
| 3 | Make an energy consumption estimation of all the electrical loads in your house, is your estimation matched with the electricity bill that you are paying? |
| 4 | Based on your monthly electricity requirement of your home, design a solar PV system to fulfil your monthly electricity needs, write a design report on the same. |
| 5 | Visit a nearby school, college or any other institution, estimate their load or use their electricity bill for energy requirement, and design a solar system for institution. |

**Tools requirement:**

- Pyranometer or calibrated solar cell for measuring solar radiation
- Solar panel of 20 or 50 or 100 or any power rating
- Power meter, energy meter and multi-meters (two)

**Text books and other references**

- PV system design Software
  - ➢ https://www.pvsyst.com/
  - ➢ https://www.homerenergy.com/homer/software
  - ➢ https://solargis.com/
- Solar radiation data of any place across the world https://globalsolaratlas.info/map
- Knowledge Centre, Ministry of New & Renewable Energy - Government of India

https://mnre.gov.in/

- O.P. Jakhar, Energy Conservations in Buildings, Khanna Publishing House, New Delhi, 2019.
- Chapter 2-4, S. P. Sukhatme and J. K. Nayak, Solar Energy – Principles of Thermal Collection and Storage, Tata McGraw Hill, 2008
- J. K. Nayak and J. A. Prajapati, Handbook On Energy Conscious Buildings, 2006
- Central Solar Hot Water Systems Design Guide, U.S. Army Corps of Engineer Headquarters,

https://www.wbdg.org/ffc/army-coe/design-guides/

- Chapter 02, 04, 6-11, C. S. Solanki, Solar Photovoltaics – Fundamentals, Technologies and Applications, 3rd Ed. Prentice Hall of India, 2016
- C. S. Solanki, Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers, Prentice Hall of India, 2013
- Photovoltaics: Design and Installation Manual, Solar Energy International (SEI), USA

https://www.solarenergy.org/

**Expected outcome of course:**

Possible outcomes of course are ability to:

- Understand various solar energy technologies, how sun light can be converted in electrical and heat energy
- Discuss the efficiency of technologies measured under STC
- Size various components of solar PV system to fulfil given electricity requirements
- Size solar thermal system to fulfil given thermal energy requirements

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## Solar Energy System Installations and Maintenance

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| Course Code | SEE-402 |
| Course Title | Solar Energy System Installations and Maintenance |
| Number of credits | 03 [ Lecture (15 hours):1 ,Practical (15 hours) :2,Social (15 hours) :1 ] |
| Course category | SEE |
| Pre-requisite | SEE-401 |

**Course Objective:**

This course will offer

- Understanding the site survey, feasibility study, site access, clearance and identifying component mounting location.
- Estimating the Solar PV plant capacity based on site active area and electricity bill consumption.
- Making Project SLD and Performance report using simulation software.
- Project scheduling, making BOM, material procurement and logistics at site.
- Understanding of installation tools, safety equipment, and risks involved.
- Project execution strategy and understanding best installation practices.
- Understanding civil work and types of module mounting structures.
- Understanding Earthing and Lightening protection system.
- Hands-On installation, testing & commissioning of a 1 kWp Off-Grid and 1 kWp On-Grid Solar PV plant.
- Understanding net metering, gross metering procedures and other important authority policies and approvals.
- Identify common factors that result in deviations from expected system performance.
- Understanding typical maintenance requirements for PV systems.
- Identify the safety requirements for operating and maintaining different types of PV systems.

**Course Content**

### G. Theoretical Learning

Each lecture is assumed to be of one hour. In content column, if possible breakdown the content of 1 hour in sub-topics

| Lecture No. | Contents |
|---|---|
| 1 | **Site survey and assessment:** Introduction to Solar Radiation, how to measure the solar radiation at site, Optimum orientation of Solar PV modules, Impact of environmental parameters on module performance, Visit and evaluate the site for installation, Points to check when selecting the installation location |

| | |
|---|---|
| 2 | **PV Capacity Estimation:**<br>Understanding the electricity consumption of the customer, case study of any user electricity bills and understanding various parameters essential for estimating the solar capacity, comparing the electricity consumption vs the area available at the site and propose the best capacity that can, In this case as both the inputs are not available, the BATTERY as storage medium |
| 3 | **System SLD and Performance Ratio using Simulation Software:**<br>Read and Interpret the Single Line Diagram, Layout Diagrams Solar Panels Sizing, String combination, Inverter selection, Inverter rating, AJB rating, ACDB rating, How to make the SLD, System designing in Simulation software for calculating the plant performance ratio. |
| 4 | **Understanding PV Components and their Datasheets:**<br>Identify the different components of a Solar PV system and its basic operation; Identify and understand the working of different types of Solar PV systems, Understand and acquire know-how of different Types, sizes and specifications of , Modules, Solar Inverters, Charge Controllers, Cables, Conduits, Junction Boxes, Solar Batteries and allied accessories, Read and Interpret the manufacturing data specification sheets |
| 5 | **Importance of Civil work and type of Solar Structures:**<br>Understand and acquire know-how of different Types, sizes and specifications of foundations/footings, Select the right footing/foundation as per site location including suitability of roof condition or suitability of soil, What is a module mounting structure (MMS), why a mounting structure, What are the typical components of a MMS, design criteria |
| 6 | **Understanding BoS:**<br>The key balance of system components, selection criteria, installation process, Do's and Don'ts while installation.<br>The balance of system equipment must be selected and installed correctly. If appropriate design procedures are not followed through, the system could have performance and reliability problems, premature faults and even failure. |
| 7 | **Plant and array Layout:**<br>How to make a plant layout, Maintenance walkways, safety lifeline, access to solar panels, Shadow impact mitigation, Stringing – as per inverter specifications, temperature, Inter-row gap w.r.t. latitude of site, Landscape or portrait orientation |
| 8 | **AC and DC Cables and its sizing:**<br>What is a conductor, Aluminium and Copper conductor difference, Power cable, Properties of cable insulation, Points to check before wiring, Types of |

| | |
|---|---|
| | wires, Different sizes of wires, Selection parameters of wires, Select the correct cable type, color, and gauge, Sizing of wires as per the plant design, Case study on cable sizing for different distances between Inverter and LT panel. |
| 9 | **Understanding Distribution Boards and LT Panels**<br>Identifying the grid LT panels at the site, What is a DCDB/AJB, what are the protections used in a AJB, types of AJB, Connection between Solar panel and AJB, Voltage and current rating of AJB, IP ratings of AJB and ACDB, ACDB types and protections, ACDB ratings and connection with LT panels |
| 10 | **Installation tools and Safety at Site**<br>Introduction to measuring Instruments and types of tools, Marking Tools and hardware required for solar installation such as fasteners, nut bolts, lugs, etc, Plant Safety, inventory management and Assembly, Safe practices against harsh weather, Potential electrical hazards, Potential chemical hazards, Common steps to begin with a safe work practices, How a First aid kit for solar is different |
| 11 | **Project Execution Strategy**:<br>The installer's responsibilities in SPV installation, System Design plan, Procurement plan, Site preparation plan, Material delivery plan, Installation plan, Civil work, Structure erection, Module mounting, Cable laying, Battery connection, Inverter mounting, meter connection and testing commissioning, Testing and commissioning plan, Operation and maintenance plan |
| 12 | **Net and Gross Metering concepts:**<br>Comparison of Net metering and Gross metering, understanding the state policies for net metering, benefits and drawbacks of the net metering, procedure, charges and energy tariff.<br>Eligibility criteria for net metering, various government approvals as per state energy regulation commission. Case study of an electricity bill before meter metering and after solar net meter. |
| 13 | **Grid Synchronization**<br>Protection at the AC side, AC side connection topology, Grid Integration, Integration challenges, Anti Islanding process, What is a micro grid system, Synchronization with DG |
| 14 | **Typical operation and maintenance(O&M) of a PV Plant**<br>What is O&M, approaches or types of O&M, parts of O&M, challenges to O&M, factors that affect the cost of O&M, Health and safety during O&M, Performance indicators in O&M, Warranty Management & its objectives, What should be the general steps in O&M activity?, How you will come to know that |

| | |
|---|---|
| | O&M is needed & how you will initiate? How you will find the fault & trouble shoot it? |
| 15 | **PV Plant protections**<br>Lightning, Surge, faults, earthing and protection, Lightning and Earthing EN standards, IEEE standards, What does a lightening arrestor do, Type of lightening arrestor, Surge arrestors, Earthing procedure and types of earthing, determining the number of earthing in a Solar PV plant. |

## H. Practical Learning

Each experiments can be of 1.5 to 3 hours. In contents please provide as detailed titled of the experiments as possible, also break down experiments in sub experiments to give clear indication on what are the concepts/observations students are expected to learn in each experiments.

| Experiment No. | Contents |
|---|---|
| Note | Hands On Installation in group of 4-5 students |
| 1 | Site assessment, Finalizing the shadow free area facing to the south direction, Foundation Marking using line, dori and measuring tape, Casting Civil Blocks (or using ready-made) with the mentioned grade and steel enforcement and Anchoring the fasteners for MMS |
| 2 | Module Mounting Structure installation for a 1 kWp Solar Plant, Safety at heights and work health |
| 3 | Solar Panel Installation for a 1 kWp Solar Plant, Testing of solar array, Earthing and wiring test |
| 4 | Making string connection as per the plant layout and cable laying to the DCDB/Inverter through conduits, Dismantling cable and crimping termination |
| 5 | Battery connection for Off grid system, Inverter and ACDB erection on the wall, terminating the AC Cables from Inverter to ACDB and ACDB to LT Panel, Testing of batteries and charge controller |

## I. Social Learning

This activity would be most crucial and needs careful design. This includes activities outside the classroom and outside the laboratory. Students must do something to apply their knowledge. This can also be exercise to apply the knowledge learned in classroom and laboratory and gather more information/data from society on a topic.

| Social experiment No. | Contents |
|---|---|
| Note | These experiments are to be done as team work, entire batch can make one or two teams<br><br>Teams may choose the installation of any other renewable energy technology based system like hot water system, biogas plant, wind turbine, etc. |
| 1 | Make a project plan to install solar system in a school / college / NGO, estimate the cost and raise funds. Plan may include installation of solar power system, street light, water pump or any other requirement |
| 2 | Conduct the site survey and estimate the solar PV capacity using his electricity bills, Finalize the design and SLD, make the BOM list |
| 3 | Material procurement and transportation, Installation of the solar, commissioning of solar power plant |

**Tools required:**

- Solar system components (panels, battery, structure, wires) for a given design
- Cement and concrete
- Measuring tape, installation tools (angle meter, screw driver, spanner, level meter, etc.)

**Text books and other references**


- PV system design Software
  - ✓ https://www.pvsyst.com/
  - ✓ https://www.homerenergy.com/homer/software
  - ✓ https://solargis.com/
- Solar radiation data of any place across the world https://globalsolaratlas.info/map
- Knowledge Centre, Ministry of New & Renewable Energy - Government of India https://mnre.gov.in/
- Chapter 03, S. P. Sukhatme and J. K. Nayak, Solar Energy – Principles of Thermal Collection and Storage, Tata McGraw Hill, 2008
- Chapter 01, J. K. Nayak and J. A. Prajapati, Handbook On Energy Conscious Buildings, 2006
- C. S. Solanki, Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers, Prentice Hall of India, 2013
- PV Installation Professional Resource Guide – NABCEP http://www.nabcep.org/wp-content/uploads/2016/10/NABCEP-PV-Resource-Guide-10-4-16-W.pdf
- Photovoltaics: Design and Installation Manual, Solar Energy International (SEI), USA https://www.solarenergy.org/

- Guide to the Installation of Photovoltaic Systems, Microgeneration certification scheme (MCS) (Author), Electrical Contractors' Association (ECA), UK, 2012

https://mcscertified.com/standards-tools-library/

**Expected outcome of course:**

Possible outcomes of course are ability to:

- Estimate the PV plant capacity for any end user by comparing active site area and annual consumption.
- Design plant SLD and simulate the plant performance ratio in simulation software.
- Understand datasheet of major solar components for selection of efficient, optimized, cost effective component from market.
- Identify, handle and operate various installation tools and tackles.
- Install an On grid and Off Grid Solar PV system.
- Monitor and maintain a solar plant for better energy generation and performance.
- Perform visual inspection, analyze the possible dust formation & requirement of cleaning & its frequency.
- Perform continuity tests and Polarity test & Recognize the danger of leaking current
- Identify & Troubleshoot the faults in the system
- Reading & interpretation of Data Sheets, O&M manual & Prepare a maintenance plan

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