

**A STUDY REPORT ON AUDIT**

**COURSE**

**“SUSTAINABLE ENERGY SYSTEMS”**

Submitted to Savitribai Phule Pune University, Pune



In partial fulfillment for the awards of Degree of Engineering in  
Computer Engineering

**Submitted by**

**Mr. Pratik Madhukar Ugalmugale**

**Roll No: 73**

**Under the Guidance of  
Dr. R. M. Gawande**



**Academic Year 2023-24**

**Department of Computer Engineering**

**Matoshri College of Engineering &**

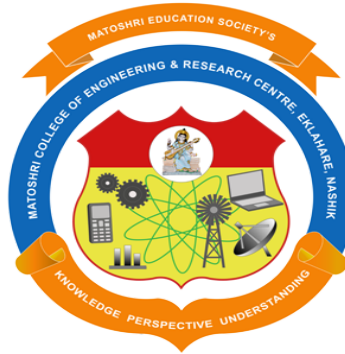
**Research Centre, Nashik**

**Matoshri College of Engineering & Research Centre, Nashik**

**Department of Computer Engineering**

**Academic Year 2023-24**

# **CERTIFICATE**



This is to certify that, **Name of Student**

have successfully completed the Audit Course report entitled “**Sustainable Energy Systems**” under my guidance in partial fulfillment of the requirements for the Third Year of Engineering in Computer Engineering under the Savitribai Phule Pune University during the academic year 2023-2024.

**Date :    /    /2024**

**Place:Nashik**

**Dr. R. M. Gawande**  
**Course Guide**

**Dr. V. H. Patil**  
**Head of Department**

**Dr. G.K. Kharate**  
**Principal**

# “AUDIT COURSE REPORT”

Topic: **Sustainable Energy Systems**

Name: Pratik Madhukar Ugalmugale

Roll No: 73

Class: TE Comp

Year: 2023-24

# Index

<b>Topic: Sustainable Energy Systems</b>	<b>3</b>
<b>1. Wind Energy and Wind Power Plants</b>	<b>4</b>
<b>2. Solar PV and Thermal Systems</b>	<b>8</b>
<b>3. Other Energy Sources</b>	<b>11</b>

# 1. Wind Energy and Wind Power Plants

## **Introduction:**

Wind energy, as a renewable and clean energy source, has gained significant attention in recent years due to its potential to mitigate climate change and reduce reliance on fossil fuels. Wind Power Plants (WPPs) harness the kinetic energy present in the wind and convert it into electrical energy. This study report provides an overview of wind energy, the types of WPPs, their components, working principles, siting considerations, and the grid integration challenges associated with WPPs.





## **1. Power in the Wind:**

Wind energy is a form of solar energy. It is generated by the uneven heating of the Earth's surface, which causes air masses to move, creating wind. The kinetic energy present in the wind can be harnessed using various technologies to generate electricity. The power available in the wind is proportional to the cube of the wind speed, which means that even a small increase in wind speed results in a significant increase in available energy.

## **2. Types of Wind Power Plants (WPPs):**

There are several types of WPPs, including:

- **Onshore Wind Farms:** These are located on land and are the most common type of WPP. Onshore wind farms typically consist of multiple wind turbines connected to a power grid. Onshore wind farms are strategically located in areas with favorable wind conditions, typically in rural or remote regions where there is ample space for the installation of wind turbines. The selection of a suitable site is crucial for maximizing energy production and ensuring the economic viability of the wind farm. Factors such as wind speed, wind consistency, terrain, land availability, environmental impact, and proximity to existing power infrastructure are taken into consideration during site selection.

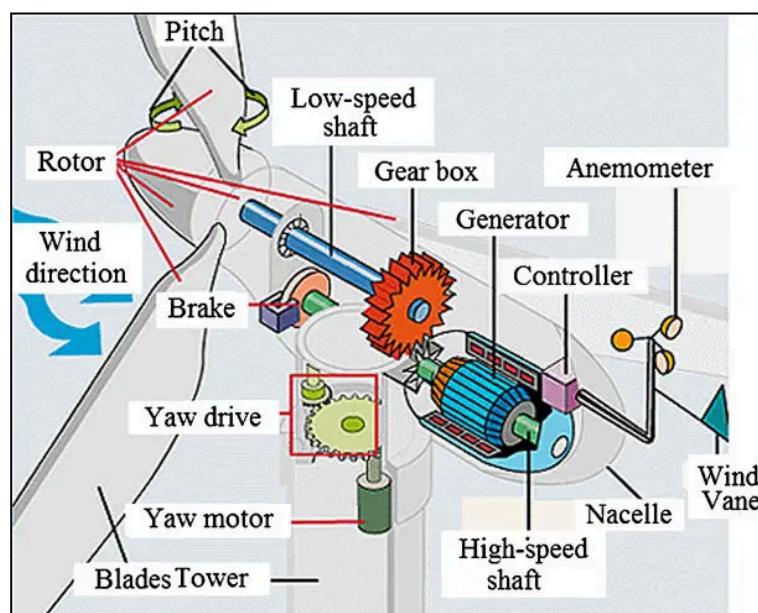
	HAWT	VAWT
Lift Type		
Drag Type		

- **Offshore Wind Farms:** These are located in bodies of water, usually in coastal areas or offshore. Offshore wind farms have the potential to generate larger amounts of electricity due to higher and more consistent wind speeds, but they also pose unique challenges in terms of construction and maintenance.
- **Small-Scale Wind Turbines:** These are used for decentralized power generation, often for residential or small commercial applications. They are smaller in size compared to turbines used in large-scale WPPs.

### 3. Components of WPPs:

The main components of a typical WPP include:

- **Wind Turbines:** These are the primary components that capture wind energy and convert it into mechanical energy through the rotation of blades.



- **Tower:** Wind turbines are mounted on towers, which elevate them to higher altitudes, where wind speeds are typically higher and more consistent.
- **Nacelle:** The nacelle houses the gearbox, generator, and other electronic components necessary for converting mechanical energy into electrical energy.
- **Rotor Blades:** These are aerodynamically designed blades attached to the rotor, which captures the wind's energy.
- **Control System:** This system monitors wind speed and direction and adjusts the orientation of the turbine to maximize energy capture.

#### **4. Working of WPPs:**

The working principle of a WPP involves several steps:

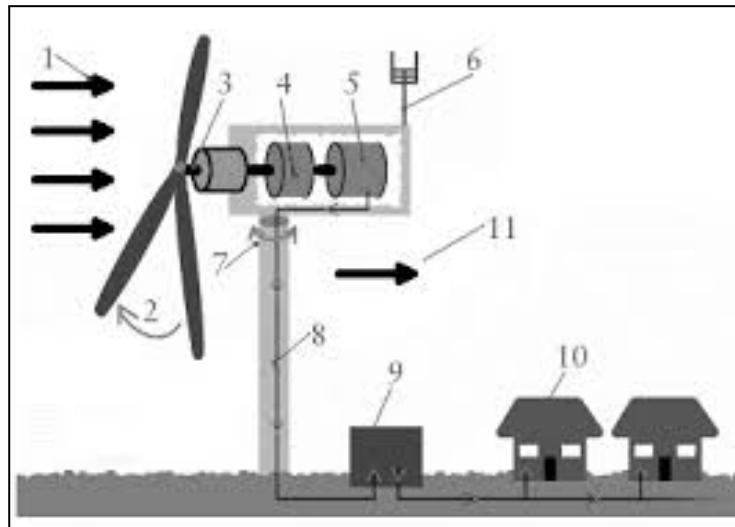
1. Wind energy is captured by the rotor blades of the wind turbine.
2. The rotor blades spin a shaft connected to a gearbox, which increases the rotational speed.
3. The high-speed shaft drives a generator, which converts mechanical energy into electrical energy.
4. The electricity generated is transmitted through power lines to the grid or to local consumers.

#### **5. Siting of WPPs:**

The siting of WPPs is crucial for maximizing energy production and minimizing environmental impacts. Factors to consider include:

- **Wind Resource:** Areas with high and consistent wind speeds are ideal for WPPs. Areas with consistently high wind speeds are highly desirable for onshore wind farms. Higher wind speeds mean more kinetic energy available for the wind turbines to capture, resulting in increased electricity generation. Wind speed is typically measured at various heights above the ground, as wind velocity tends to increase with altitude due to reduced surface friction. In addition to high wind speeds, the consistency of wind patterns is crucial for the reliable operation of onshore wind farms. Wind patterns can vary

significantly based on factors such as geographic location, topography, and seasonal variations.



- Environmental Impact: WPPs should be sited in locations that minimize impacts on wildlife, habitats, and local communities.
- Accessibility: Easy access to transportation infrastructure is essential for construction and maintenance activities.
- Grid Connection: Proximity to existing power infrastructure facilitates grid integration.

## 6. Grid Integration Issues of WPPs:

Grid integration refers to the process of connecting WPPs to the electrical grid. Some challenges associated with grid integration include:

- Intermittency: Wind energy is intermittent and variable, depending on wind speed and direction. This variability can pose challenges for grid stability and reliability.
- Forecasting: Accurate forecasting of wind power output is essential for grid operators to maintain balance between supply and demand.
- Grid Infrastructure: Upgrading and expanding grid infrastructure may be necessary to accommodate large-scale WPPs, especially in remote or offshore locations.



- **Market Integration:** Integrating wind energy into electricity markets requires appropriate regulatory frameworks and market mechanisms to ensure fair compensation for wind power producers.
- 

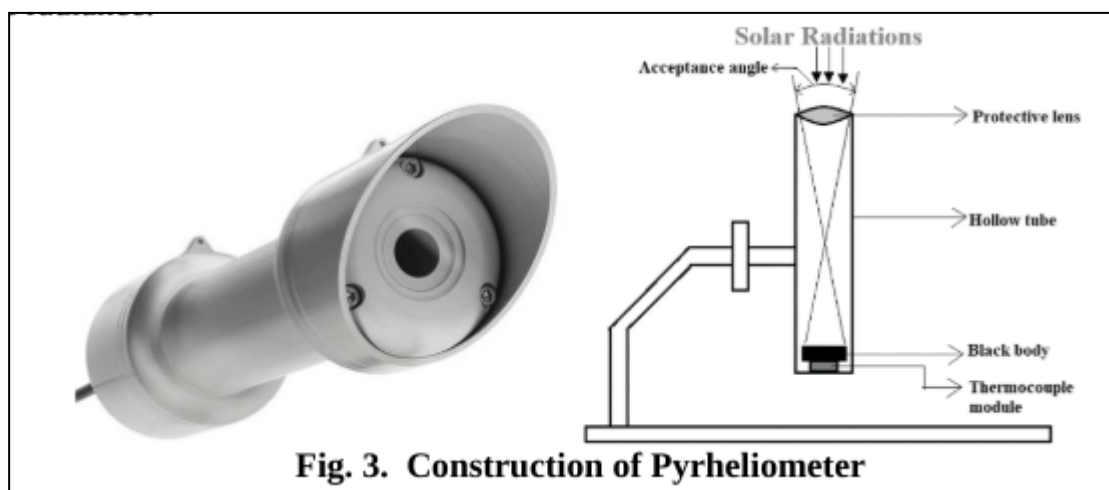
## 2. Solar PV and Thermal Systems

### **Introduction:**

Solar energy, derived from the sun's radiation, is abundant, renewable, and clean. It holds immense potential for addressing energy needs sustainably. This study report delves into Solar Photovoltaic (PV) and Solar Thermal Systems, encompassing solar radiation, measurement techniques, different types of solar power plants, thermal energy storage systems, and the principles, types, and applications of solar photovoltaic systems.

### **1. Solar Radiation and Measurement:**

Solar radiation is the electromagnetic radiation emitted by the sun. It can be measured using instruments such as pyranometers and pyrhelimeters.



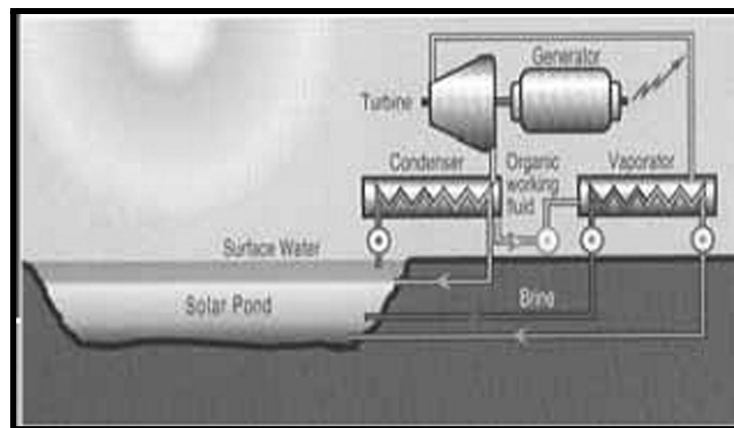
Pyranometers measure global horizontal irradiance, while pyrhelimeters measure direct normal irradiance. Solar radiation data is crucial for assessing the solar energy potential of a particular location and designing solar power systems.

## 2. Solar Thermal Power Plants:

Solar thermal power plants generate electricity by harnessing solar energy to heat a fluid, usually water or molten salt, to produce steam that drives a turbine generator.

Types of solar thermal power plants include:

- **Central Receiver Power Plants:** Also known as concentrated solar power (CSP) plants, these utilize mirrors or lenses to concentrate sunlight onto a receiver mounted atop a tower, where the heat is collected and used to generate steam.
- **Solar Ponds:** Solar ponds are large bodies of saltwater with different layers of salinity. They absorb and store solar energy, which can be used for heating or electricity generation.



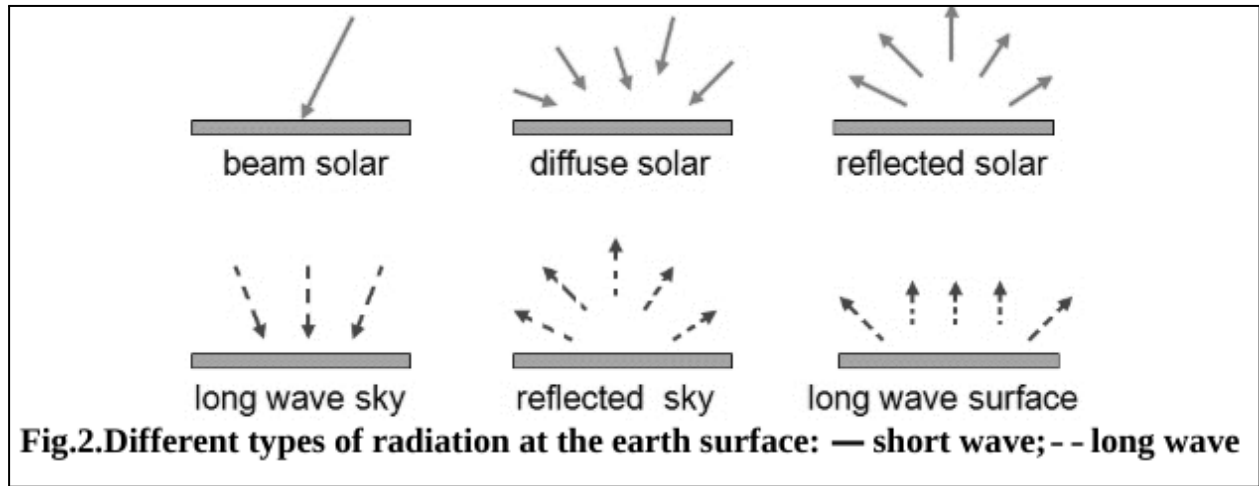
- **Thermal Energy Storage System with PCM:** Phase Change Material (PCM) thermal storage systems store and release heat energy by changing phase (solid to liquid or vice versa) at a constant temperature. They are used to extend the availability of solar thermal energy beyond daylight hours.

## 3. Solar Photovoltaic Systems:

Solar Photovoltaic (PV) systems convert sunlight directly into electricity using semiconductor materials. Key concepts and components include:

- **Basic Principle of SPV Conversion:** Photovoltaic cells, made of semiconductor materials such as silicon, absorb photons from sunlight, generating an electric current through the photovoltaic effect.

- **Types of PV Systems:** PV systems can be categorized into grid-connected systems, off-grid systems, and hybrid systems that combine PV with other renewable energy sources.



- **Types of Solar Cells:** Solar cells can be classified into crystalline silicon, thin-film, and emerging technologies such as perovskite and organic solar cells.
- **Photovoltaic Cell Concepts:** Individual solar cells are connected in series and parallel to form modules, which are further connected to form arrays. PV module characteristics include current-voltage (IV) curves, efficiency, and quality parameters.
- **Maximum PowerPoint Tracking (MPPT):** MPPT algorithms optimize the operating point of a PV system to maximize power output under varying solar conditions.

#### 4. Applications:

Solar PV and thermal systems find applications in various sectors, including:

- **Residential:** Rooftop solar PV systems for electricity generation and solar water heating systems for domestic hot water.
- **Commercial:** Solar PV installations for businesses, industries, and institutions to offset energy costs and reduce carbon footprint.
- **Remote Areas:** Off-grid solar PV systems provide electricity to remote areas without access to the utility grid.

- Agriculture: Solar-powered irrigation systems and water pumping solutions for agricultural applications.
- Transportation: Solar-powered vehicles, including electric cars and solar-powered boats, harness solar energy for propulsion.

### 3. Other Energy Sources

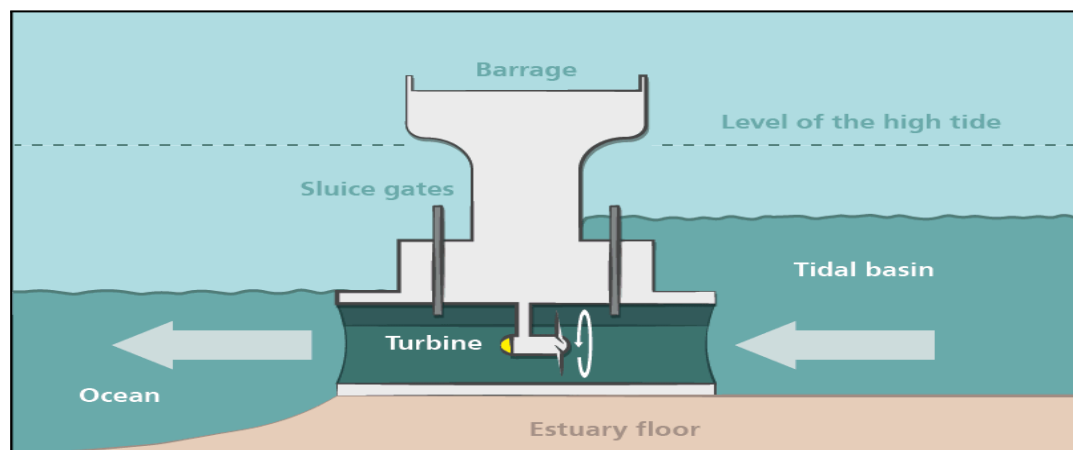
#### **Introduction:**

In addition to solar and wind energy, there exist other promising sources of renewable energy that hold significant potential for sustainable power generation. This study report explores tidal energy, wave energy, ocean thermal energy conversion (OTEC), hydrogen production and storage, fuel cells, energy storage systems, and hybrid energy systems, providing insights into their principles, technologies, and applications.

#### **1. Tidal Energy:**

Tidal energy is derived from the gravitational forces of the moon and sun, which cause the periodic rise and fall of sea levels, known as tides. Tidal power systems harness this energy using two main approaches:

- Barrage Tidal Power Systems: Barrages are built across estuaries or tidal rivers to capture tidal energy. They consist of sluice gates and turbines that generate electricity as water flows in and out of the estuary.



- **Non-Barrage Tidal Power Systems:** These systems utilize tidal currents to drive underwater turbines, similar to wind turbines, placed on the seabed. They have less environmental impact compared to barrages but require suitable underwater topography.

## **2. Wave Energy:**

Wave energy is generated by the movement of waves on the ocean surface. Wave power devices capture this energy using various technologies, including oscillating water columns, point absorbers, and attenuators. These devices convert the kinetic energy of waves into electricity through the movement of buoys, floats, or other mechanical components.

## **3. Ocean Thermal Energy Conversion (OTEC):**

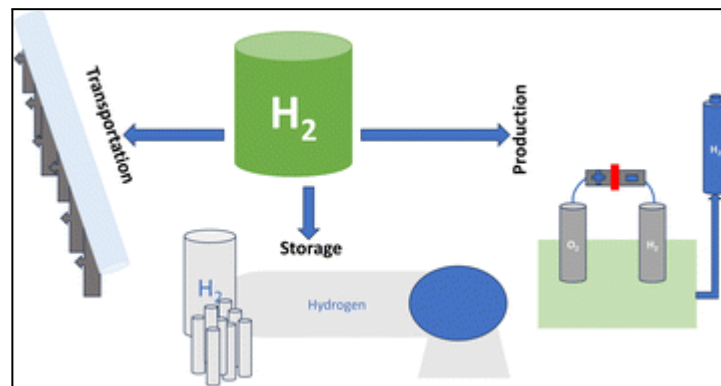
OTEC utilizes the temperature difference between warm surface water and cold deep water to generate electricity. This temperature gradient drives a heat engine, typically a Rankine cycle or a closed-cycle gas turbine, to produce power. OTEC has the potential to provide continuous baseload power with minimal environmental impact. OTEC systems rely on the natural temperature gradient that exists in oceans. Near the surface, seawater is heated by the sun, reaching relatively high temperatures, typically around 25-30°C in tropical regions. At greater depths, seawater remains colder, with temperatures ranging from 5-10°C or even lower.

## **4. Hydrogen Production and Storage:**

Hydrogen is considered a versatile and clean energy carrier. It can be produced through electrolysis of water using renewable electricity or from fossil fuels with carbon capture and storage. Hydrogen has a low volumetric energy density, which means that it requires a large volume to store a significant amount of energy. Additionally, hydrogen has low density as a gas, making storage challenging. Several methods of hydrogen storage are being explored:

- Compressed Hydrogen:** Hydrogen gas can be compressed and stored in high-pressure tanks. The gas is typically compressed to pressures of 350-700 bar (5,000-10,000 psi) to achieve adequate energy density for transportation and other applications. Compressed

hydrogen storage is relatively mature and has been used in various hydrogen fuel cell vehicles and stationary applications



Hydrogen can be stored and transported as a gas or converted into other forms such as ammonia or synthetic fuels for various applications, including transportation, heating, and industrial processes.

## 5. Fuel Cells:

Fuel cells are electrochemical devices that convert chemical energy directly into electrical energy through the reaction of hydrogen with oxygen. Key types of fuel cells include proton exchange membrane fuel cells (PEMFC), solid oxide fuel cells (SOFC), and alkaline fuel cells (AFC). They find applications in stationary power generation, transportation, and portable electronics due to their high efficiency and low emissions.

### Types of Fuel Cells:

- Proton Exchange Membrane Fuel Cells (PEMFC): These use a solid polymer electrolyte membrane, such as Nafion, to conduct protons. PEMFCs operate at relatively low temperatures (typically around 80°C) and are commonly used in transportation applications like cars and buses.
- Solid Oxide Fuel Cells (SOFC): SOFCs use a solid ceramic electrolyte, typically made of zirconia or ceria, which operates at high temperatures (typically between 500-1000 °C). This high temperature allows SOFCs to directly use various fuels like hydrogen, natural gas, and even biogas.

- Alkaline Fuel Cells (AFC): AFC's use a liquid alkaline electrolyte, typically potassium hydroxide (KOH) or sodium hydroxide (NaOH). They were one of the first types of fuel cells developed and were used in the Apollo space missions. AFC's operate at relatively low temperatures and have high efficiency, but are sensitive to CO<sub>2</sub> and other impurities in the hydrogen fuel.

## **6. Energy Storage Systems:**

Energy storage systems play a crucial role in balancing supply and demand in electricity grids and enhancing the integration of renewable energy sources. Technologies such as batteries, pumped hydro storage, and thermal energy storage enable the storage of surplus energy during periods of low demand for later use during peak demand or when renewable resources are unavailable.

## **7. Hybrid Energy Systems:**

Hybrid energy systems combine multiple renewable energy sources and energy storage technologies to maximize reliability, efficiency, and cost-effectiveness. Examples include solar-wind hybrids, wind-hydro hybrids, and solar-diesel hybrids, which leverage complementary characteristics of different energy sources to meet varying energy demand profiles. By integrating multiple sources, these systems can capitalize on the strengths of each source while mitigating their individual limitations. For example:

- Solar energy systems generate power during daylight hours when the sun is shining.
- Wind energy systems produce electricity when wind speeds are sufficient.
- Hydroelectric systems generate power using the gravitational force of flowing water.
- Biomass energy systems utilize organic materials to produce bioenergy.
- Geothermal energy systems harness heat from the Earth's interior.