

# WEEK-3

Day-2

## PV Components & Economics

# Introduction to PV Components

- PV systems are made up of several key components that enable solar energy conversion, storage, and delivery.
- Each component plays a crucial role in turning sunlight into a reliable power supply.
- In this lecture, we'll focus on inverters, batteries, maximum power point trackers (MPPT), and combiner boxes.
- We'll also delve into financial aspects, payback periods, incentives, and subsidies.
- Proper understanding helps engineers maximize both performance and financial return.
- This forms the basis for designing sustainable, cost-effective solar power systems.

# Inverters — Types and Operations

- An inverter converts DC power from solar modules into AC power for appliances or for injection into the grid.
- There are several types: string inverters, microinverters, and central inverters.
- String inverters connect multiple modules in a series, while microinverters control each panel individually.
- Inverter selection depends on power capacity, shadow effects, cost, and maintenance ease.
- Properly sized inverters enable maximum power delivery while minimizing energy losses.

# Batteries in PV Systems

- Batteries enable energy storage for use during nights or clouds when solar production drops.
- Lead-acid, lithium-ion, and flow batteries are the most commonly used technologies today.
- The battery's depth of discharge, charging rate, and lifecycle determine its performance and cost.
- Proper battery sizing guarantees reliable backup while avoiding over investments.
- Storage converts solar power into a flexible, 24/7 energy resource

# Maximum Power Point Trackers (MPPT)

- An MPPT maximises power delivery by continually matching solar array voltage to its maximum power point.
- This helps extract the maximum available solar energy under changing conditions.
- Without MPPT, solar modules may perform at less than their rated power.
- Some inverters have integrated MPPTs; large solar plants often use separate, specialized ones.
- Implementing MPPT can significantly increase energy harvest and financial payback.



# Junction Boxes and Combiner Boxes

- Junction boxes consolidate solar strings and enable easy maintenance and connection to the rest of the PV system.
- Combiner boxes gather output from multiple strings while adding overcurrent protection and surge arrestors.
- Proper combiner box design safeguards the solar array against overcurrent, surges, and other faults.
- This contributes to a reliable, code-compliance, and safe solar power installation.
- Combiner boxes are especially important in large and rooftop solar installations.

# System Costs — CAPEX and OPEX

## CAPEX

CAPEX (Capital Expenditure) covers the initial investment for solar modules, inverters, structures, and installation.

## OPEX

OPEX (Operating Expenditure) includes maintenance, repairs, cleaning, and eventual component replacements.

- Lower OPEX typically results from choosing high-reliability components and employing proper maintenance routines.
- An accurate financial projection must account for both CAPEX and OPEX over the system's lifespan.
- This guides investors toward realistic payback periods and profits.



# Return on Investment (ROI)

- The Return on Investment measures financial payback — how much money is recovered over time.
- ROI depends on solar energy production, incentives, maintenance, financing, and energy prices.
- Generally, solar payback periods range from 5–10 years.
- After payback, the solar array produces free energy for 15–20 additional years.
- Higher solar incentives and energy prices shorten payback periods and increase profits.



# Levelized Cost of Electricity (LCOE)

- The Levelized Cost of Electricity (LCOE) is the price per kWh of energy over the system's lifespan.
- $LCOE = (\text{Total Costs}) / (\text{Total Energy Produced})$ .
- This metric helps investors compare solar with other energy sources, like natural gas or coal.
- Lower LCOE signals greater financial competitiveness.
- The main contributors to LCOE are the initial installation, maintenance, financing, and incentives.

# Ecology and Sustainability of PV Systems

- PV systems enable clean, renewable energy without emitting greenhouse gases.
- This directly reduces reliance on fossil fuels and helps ease climate change impacts.
- PV modules typically pay back their energy investment within 2–4 years.
- After payback, solar power is practically emissions-free for the rest of its operational lifespan.
- Proper disposal and recycling further aid in conserving resources at the end of a PV system's life.

## Case Study (Example)

- This case study involves a 5kWp rooftop solar PV system in Mumbai.
- The total installed cost was ₹2.5 lakhs, with a subsidy from PM-KUSUM.
- The payback period fell to nearly 6 years due to incentives and energy savings.
- The system produces about 7,000 kWh per year, reducing reliance on grid power.
- This illustrates how policy incentives can make solar energy more accessible and cost-effective.

# Review Questions:

Ques 1: How does the choice between microinverters and string inverters affect system performance, reliability, and cost in a rooftop installation with partial shading?

Ques 2: In what ways can integrating MPPTs and properly sized batteries work together to optimize both energy output and financial returns in a hybrid solar system?

Ques 3: A developer is considering two solar systems: one with high CAPEX but low OPEX, and another with low CAPEX but high OPEX. How should they use LCOE and ROI to make an informed decision?

**Feel free to reach  
out with any  
questions!**

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