

Introduction to Solar PV Systems

Introduction to Solar Photovoltaic (PV) Systems

Key concepts, components, and design fundamentals

1. What Is a Solar PV System?

- **Definition:** A solar photovoltaic (PV) system converts sunlight directly into electricity using semiconductor devices (solar cells) that exhibit the photovoltaic effect.
- **Typical Applications**
 - Residential rooftop installations
 - Commercial and industrial rooftop/ground-mount systems
 - Utility-scale solar farms
 - Off-grid power for remote sites, telecom towers, RVs, and marine vessels

2. Core Components & Their Functions

Component	Primary Role	Typical Technologies / Specs
Solar Modules (Panels)	Capture solar irradiance and generate DC electricity.	Crystalline silicon (mono or poly-Si), thin-film (CdTe, CIGS, a-Si). Typical power: 250W–600W per panel.
Mounting Structure	Secure panels at optimal tilt/azimuth; withstand wind & snow loads.	Roof-integrated, ground-mount, pole-mount; adjustable or fixed tilt.
Inverter (DC-AC Converter)	Convert DC from modules to AC for loads or grid.	String inverter, central inverter, micro-inverter, power-optimiser-based inverter.
Balance-of-System (BOS)	Electrical safety, protection, and monitoring.	Combiner boxes, DC disconnects, AC disconnects, fuses, breakers, surge protectors, wiring, grounding.
Energy Storage (optional)	Store excess energy for later use; enable off-grid or backup operation.	Lithium-ion, lead-acid, flow batteries; rated in kWh.
Monitoring & Control	Track performance, detect faults, optimize output.	Data loggers, SCADA, cloud-based dashboards, smart meters.

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Component	Primary Role	Typical Technologies / Specs
Grid Connection Equipment (grid-tied only)	Safely feed power into the utility network.	Anti-islanding relays, utility-approved inverter, net-metering interface.

3. Basic System Configurations

1. Grid-Tied (On-Grid) System

- No storage; power exported to grid when generation exceeds load.
- Requires anti-islanding protection.

2. Hybrid System

- Grid-tied + battery backup.
- Provides backup during outages and can perform load-shifting.

3. Off-Grid System

- No grid connection; relies on batteries + possibly a generator.
 - Must be sized for worst-case load and autonomy days.
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4. Design Fundamentals

4.1 Sizing the PV Array

1. Determine Energy Demand

- Calculate average daily consumption (kWh/day) from utility bills or load inventory.

2. Account for System Losses

- Typical derating factor: 0.75–0.85 (covers inverter efficiency, wiring, temperature, shading).

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3. Compute Required DC Capacity

$$[\text{Required DC (kW)} = \frac{\text{Daily Energy (kWh)}}{\text{Peak Sun Hours (PSH)}} \times \text{Derating Factor}]$$

- *Peak Sun Hours*: average solar irradiance (kW/m²) integrated over a day for the site (e.g., 4.5h for many U.S. locations).

4. Select Number of Modules

$$[\text{Modules} = \frac{\text{Required DC (kW)}}{\text{Module Power (kW)}}$$