

Introduction to Solar PV Systems

Introduction to Solar Photovoltaic (PV) Systems

Designed as a quick-reference guide for students, technicians, and anyone new to solar energy.

1. What Is a Solar PV System?

Term	Definition
Photovoltaic (PV)	Direct conversion of sunlight into electricity using semiconductor materials.
Solar PV System	A collection of components that capture solar energy, convert it to DC electricity, and deliver usable power to a load or the grid.
Grid-connected	System feeds excess electricity to the utility and draws power when solar output is insufficient.
Off-grid (stand-alone)	System supplies power to an isolated load, typically with battery storage.
Hybrid	Combines grid connection, battery storage, and sometimes a diesel generator for backup.

2. Core Components & Their Functions

Component	Primary Function	Typical Specs / Options
Solar Modules (Panels)	Convert sunlight to DC electricity.	- Crystalline silicon (mono or poly) - Thin-film (CdTe, CIGS) - Power 250-600W per panel
Mounting Structure	Secure panels at optimal tilt & orientation.	Fixed-tilt, adjustable tilt, tracking (single/dual axis)
Combiner Box	Parallel-connect strings, provide over-current protection.	Fuses or MCBs, surge protection devices (SPDs)
Inverter (DC-AC)	Turns DC from modules into grid-compatible AC.	- String inverter, central inverter, micro-inverter, power-optimiser - Efficiency 96-99%

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Component	Primary Function	Typical Specs / Options
DC Disconnect	Manual isolation of the PV array for safety.	• Rated for system voltage & current
AC Disconnect	Isolates inverter output from the grid or load.	• Must meet local code (e.g., NEC 690.13)
Battery Bank (optional)	Stores excess energy for later use.	• Lead-acid, Li-ion, flow; rated in Ah or kWh
Charge Controller (for battery systems)	Regulates charging voltage/current, protects batteries.	• PWM or MPPT (Maximum Power Point Tracking)
Monitoring System	Tracks performance, alerts faults.	• Web portal, smartphone app, data logger
Safety Devices	Protect people & equipment.	• Ground-fault circuit interrupters (GFCI), arc-fault circuit interrupters (AFCI), lightning arrestors

3. Basic System Design Steps

1. Assess Energy Demand

- Gather monthly/annual load data (kWh).
- Determine peak demand (kW) and load profile (day/night).

2. Select Solar Resource

- Use solar irradiance maps or tools (e.g., PVGIS, NREL's SAM).
- Typical values: 4–6 kWh/m²·day (depends on location).

3. Size the PV Array

$$[\text{Array Power (kW)}] = \frac{\text{Annual Energy (kWh)}}{\text{Peak Sun Hours (h)}} \times \text{System Efficiency}]$$

- System efficiency ? 0.75–0.85 (covers losses: wiring, inverter, temperature, soiling).

4. Determine Number of Modules & Strings

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- Choose module wattage ? calculate total modules.
- Group modules into strings respecting inverter input voltage range and