

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 power.

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 vs. Off-grid	<i>Grid-connected:</i> feeds excess power to the utility and draws power when needed. <i>Off-grid:</i> operates independently, typically with battery storage.

2. Core Components

Component	Function	Typical Specs / Options
Solar Modules (Panels)	Convert sunlight to DC electricity.	Monocrystalline, polycrystalline, thin-film; 250-600W per panel.
Mounting Structure	Secure panels at optimal tilt/azimuth.	Fixed-tilt, adjustable, tracking (single/dual axis).
Inverter	Converts DC to AC; may also perform MPPT (Maximum Power Point Tracking).	String inverter, micro-inverter, power-optimiser, hybrid inverter.
Combiner Box	Joins strings of modules; houses fuses/MCBs.	Rated for system voltage (e.g., 600VDC).
DC Disconnect	Provides a safe means to isolate the DC side.	Rated for max current & voltage.
AC Disconnect	Isolates the AC side from the building or grid.	Typically 30A-60A, UL-listed.
Charge Controller (off-grid)	Regulates battery charging, prevents over-charge/discharge.	PWM or MPPT; sized to handle array current.

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Battery Bank (off-grid)	Stores excess energy for later use.	Lead-acid, Li-ion, flow; rated in Ah/kWh.
Monitoring System	Tracks performance, alerts faults.	Web-based portal, mobile app, data logger.

3. How a PV System Works – Step-by-Step Flow

1. **Sunlight hits the PV cells** → photons generate electron-hole pairs.
 2. **Electric field in the cell separates charges** → DC current flows through the module.
 3. **Modules are wired in series/parallel** to form strings that meet system voltage & current targets.
 4. **DC power passes through a combiner box** → protected by fuses.
 5. **Inverter performs MPPT** → extracts maximum power from each string, converts DC → AC.
 6. **AC power is dispatched** → either directly to loads, into a battery bank (hybrid), or exported to the grid.
 7. **Monitoring unit records** voltage, current, energy produced, and system health.
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4. Design Fundamentals

4.1 Sizing the Array

1. **Determine daily energy demand (kWh/day).**
2. **Account for system losses** (inverter 5%, wiring 2%, shading 5%, temperature 10% → ~20% total).
3. **Calculate required DC energy:**
$$[\text{DC Energy}] = \frac{[\text{Daily Load}]}{[1 - \text{Losses}]}$$
4. **Select location's solar irradiance (k**