

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?

Element	Definition
Solar PV (Photovoltaic) System	A set of components that convert sunlight directly into electricity using semiconductor devices (solar cells).
Key Purpose	Generate clean, renewable electricity for residential, commercial, or utility-scale applications. • Stand-alone (off-grid)
Typical Configurations	• Grid-connected (with net metering) • Hybrid (grid-plus-battery storage)

2. Core Components

Component	Function	Typical Specs
Solar Modules (Panels)	Convert solar irradiance into DC electricity.	250–600W per panel; 15–22% efficiency; series/parallel strings.
Inverter	Converts DC to AC, synchronizes with grid, provides MPPT (Maximum Power Point Tracking).	String, micro-inverter, or central; 95%+ efficiency.
Mounting Structure	Secures panels at optimal tilt & orientation.	Fixed-tilt, adjustable, or tracking (single/dual axis).
Combiner Box	Merges multiple string currents, includes fuses & surge protection.	Rated for system voltage (e.g., 600V DC).
DC Disconnect	Safety switch to isolate the DC side for maintenance.	Must meet local code (e.g., UL 1083).
AC Disconnect & Breaker Panel	Isolates inverter output; protects downstream circuits.	Typically 30A–60A for residential.

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Monitoring System	Tracks performance (energy production, faults).	Web/app-based dashboards; optional data loggers.
Battery Storage (optional)	Stores excess energy for later use; enables backup power.	Li-ion, lead-acid, flow; rated in kWh.

3. How Solar PV Generates Power

1. **Photon Absorption** – Sunlight photons strike the semiconductor (usually silicon), freeing electrons.
 2. **Electric Field Separation** – Built-in p-n junction creates an electric field that drives electrons toward the front contact, creating a DC current.
 3. **Module Wiring** – Cells are connected in series (increase voltage) and parallel (increase current) to form a module.
 4. **String Formation** – Multiple modules are wired together to achieve the desired system voltage (e.g., 400V_{DC}).
 5. **Inversion** – The inverter tracks the maximum power point of each string, converts DC to AC, and feeds it to the load or grid.
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4. System Design Basics

Design Step	Key Considerations
Site Assessment	Solar resource (kWh/m ² /day), shading analysis, roof orientation, structural integrity.
Energy Requirement	Monthly/annual kWh consumption → determine system size (kW).
Sizing Modules	$\left(\frac{\text{Required kW}}{\text{Peak Sun Hours}} \right) \times \text{Derate Factor}$ Typical derate factor: 0.75–0.85.
Inverter Selection	Match DC-to-AC ratio (often 1.