

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 PV modules, balance-of-system (BOS) components, and optional storage that delivers usable electric power.
Grid-connected	System feeds excess electricity to the utility grid and draws power when solar output is insufficient.
Off-grid (stand-alone)	System supplies all loads independently, usually with battery storage and a backup generator.

2. Core Components

Component	Function	Typical Specs / Options
PV Modules (Panels)	Convert solar irradiance to DC electricity.	Crystalline silicon (mono or poly), thin film (CdTe, CIGS). Power 250-600W per panel.
Mounting Structure	Secures modules at a fixed tilt or allows tracking.	Roof-mount, ground-mount, single-axis, dual-axis trackers.
Inverter	Converts DC to AC, synchronizes with grid, provides MPPT.	String inverter, central inverter, micro-inverter, power optimiser.
Combiner Box	Merges strings of modules; houses fuses or DC breakers.	Rated for system voltage (e.g., 600VDC).
DC Disconnect	Safety isolation for maintenance.	Manual or motorized, rated for system voltage/current.
AC Disconnect	Isolates inverter from the utility side.	Required by most codes.

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Component	Function	Typical Specs / Options
Monitoring System	Tracks performance, alerts faults.	Web-based dashboards, SCADA, mobile apps.
Battery Storage (optional)	Stores excess energy for later use.	Lithium-ion, lead-acid, flow; rated in kWh.
Charge Controller (off-grid)	Regulates battery charging, prevents over-charge.	PWM or MPPT types.

3. Basic System Design Steps

1. Assess Site & Load

- Solar resource (kWh/m²/day) ? use NASA, PVGIS, or local data.
- Roof/ground orientation, shading analysis (SunEye, LiDAR, or manual Sun-path diagram).
- Determine daily/annual energy demand (kWh) and critical loads.

2. Select Module Type & Size

- Choose based on efficiency, temperature coefficient, warranty, cost.
- Calculate number of modules:
[$N_{\text{modules}} = \frac{\text{Desired kW}_{\text{DC}}}{\text{Module Power (W)}}$]

3. Configure Strings & Voltage

- Keep string voltage < inverter maximum V_{mppt} (typically 600-1000V).
- Ensure current per string ? inverter input current rating.

4. Pick Inverter(s)

- Match inverter AC rating to expected AC output (usually 80-90% of DC rating).
- Consider MPPT count, efficiency (>96%), and grid code compliance.

5. Design BOS & Safety

- Size conductors per NEC/IEC current-carrying capacity.
- Include over-current protection (fuses, breakers).

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- Provide grounding and surge protection.

6. **Optional