

Overview of Solar PV Systems

Overview of Solar Photovoltaic (PV) Systems
(Designed as concise, easy-to-read study notes)

1. What Is a Solar PV System?

- **Definition:** A collection of components that convert sunlight directly into electricity using the photovoltaic effect.
- **Primary Purpose:** Generate clean, renewable electricity for residential, commercial, or utility-scale applications.

2. Core Components

Component	Function	Typical Characteristics
Solar Modules (Panels)	Convert solar irradiance into DC electricity.	Made of silicon cells (monocrystalline, polycrystalline, or thin-film). Power rating: 250-600W per panel.
Inverter	Converts DC from the modules to AC for grid or load use.	Types: String (central), micro-inverters, power-optimizers. Efficiency 95-99%.
Mounting Structure	Secures modules at optimal tilt/azimuth. All auxiliary hardware.	Fixed-tilt, adjustable tilt, or tracking (single-axis, dual-axis).
Balance-of-System (BOS)	Includes: • Cabling & connectors • Combiner boxes • Disconnects • Fuses & surge protectors • Monitoring equipment	
Energy Storage (optional)	Stores excess energy for later use.	Batteries (Li-ion, lead-acid, flow). Paired with charge controller if off-grid.

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Component	Function	Typical Characteristics
Grid-tied Equipment (for grid-tied)	Enables safe interaction with utility network.	Net-metering meter, anti-islanding relay, protective relays.

3. System Configurations

Configuration	Typical Use	Key Features
Off-grid	Remote sites, islands, cabins	No utility connection; includes battery bank and charge controller.
Grid-tied (without storage)	Residential/commercial rooftops	Supplies power to the grid; excess electricity exported (net metering).
Hybrid (grid-tied with storage)	Sites needing backup power or load shifting	Combines inverter, battery, and grid connection; can operate in island mode during outages.
Utility-scale	Large solar farms (MW-GW)	Central inverters, high-voltage collection, extensive tracking systems.

4. Design Basics

1. Site Assessment

- Solar resource (irradiance, shading analysis).
- Roof/ground orientation, tilt, and structural capacity.
- Local climate (temperature coefficients affect performance).

2. Sizing the Array

- Determine daily energy demand (kWh).
- Apply a performance factor (typically 0.75-0.85) to account for losses.
- **Formula:**
$$[\text{Required DC Capacity (kW)}] = \frac{\text{Annual Energy Demand (kWh)}}{\text{Annual Peak Sun Hours (h)}} \times \text{Performance Factor}$$

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3. Inverter Selection

- Match inverter AC rating to expected AC output (usually 80?100?% of DC capacity).
- Consider MPPT (Maximum Power Point Tracking) voltage range.

4. Electrical Layout

- Series strings ? voltage increase, current stays low.
- Parallel strings ? current increase, voltage stays constant.
- Keep string voltage below inverter maximum input and above minimum for MPPT efficiency