

Introduction to Solar PV Systems

Introduction to Solar Photovoltaic (PV) Systems

Key concepts, components, and basic design considerations

1. What Is a Solar PV System?

- **Definition:** A collection of solar cells, modules, and balance-of-system (BOS) equipment that converts sunlight directly into usable electricity.
 - **Primary purpose:** Generate clean, renewable electricity for residential, commercial, or utility-scale applications.
 - **Typical outputs:** Direct Current (DC) from the panels ? Inverter converts to Alternating Current (AC) for the grid or local loads.
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2. Core Components

Component	Function	Typical Characteristics
Solar Cells	Convert photons into DC electricity (photovoltaic effect)	Silicon (monocrystalline, polycrystalline), thin-film (CdTe, CIGS)
Solar Modules (Panels)	Group of cells encapsulated in a weather-proof frame	250-600W per panel, voltage ~30-40V (Vmp)
Mounting Structure	Secures panels to roof, ground, or tracking system	Fixed tilt, adjustable tilt, single-axis/dual-axis trackers
Inverter	DC-to-AC conversion; may provide MPPT, grid-support functions	String inverter, central inverter, micro-inverter, power-optimiser
Combiner Box	Merges strings of panels; houses fuses and surge protectors	Rated for system voltage and current
Disconnects & Switchgear	Provide safe isolation for maintenance and emergencies	DC disconnect (pre-inverter), AC disconnect (post-inverter)
Monitoring System	Tracks performance, alerts for faults	Data logger, web/phone interface

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Component	Function	Typical Characteristics
Balance of System (BOS) Wiring	Conductors, conduit, grounding, lightning protection	Copper/Aluminum, sized per NEC/IEC standards
Energy Storage (optional)	Stores excess energy for later use	Lithium-ion, lead-acid, flow batteries

3. Basic Operating Principles

1. **Photon absorption** ? electrons excited in the semiconductor.
 2. **Electric field** in the p-n junction separates charge carriers.
 3. **Current flow** produces DC power proportional to irradiance and temperature.
 4. **Maximum Power Point Tracking (MPPT)** continuously adjusts the load to keep the system at its highest power output.
 5. **Inverter** synchronizes output voltage/frequency with the grid (or supplies an isolated AC load).
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4. System Configurations

Configuration	Description	Typical Use
Grid-connected (grid-tied)	PV feeds the utility grid; excess energy exported, deficits drawn from grid	Residential, commercial
Off-grid (stand-alone)	No grid connection; requires battery bank and charge controller	Remote cabins, islands
Hybrid (grid-tied with storage)	Grid connection plus battery backup; can operate during outages	Critical facilities, residential with backup
Distributed Generation (DG)	Multiple small installations feeding the same distribution network	Rooftop solar, community solar

5. Design Basics

5.1. Sizing the Array

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1. **Determine energy demand** (kWh/day) from load analysis.
2. **Account for system losses** (inverter, wiring, temperature, soiling) – typically 15?20?%.
3. **Calculate required DC capacity:**

[\text{DC size (kW)}] =