

Introduction to Power Generation Systems

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Key concepts, main technologies, and fundamental principles

1. What Is Power Generation?

Aspect	Description
Definition	Conversion of primary energy (fuel, heat, wind, solar radiation, etc.) into electrical energy.
Purpose	Supply electricity to residential, commercial, industrial, and transportation loads. 1. Prime mover – converts primary energy into mechanical work. 2. Prime mover drive – gearbox, couplings, or direct coupling to the generator.
Components of a Power Generation System	3. Electrical generator – transforms mechanical rotation into AC or DC electricity. 4. Control & protection – governors, exciters, relays, and monitoring systems. 5. Auxiliary systems – cooling, lubrication, fuel handling, emissions control, and waste heat recovery.

2. Core Energy Conversion Principles

Principle	Formula / Key Idea	Example
Conservation of Energy	Input energy = Output energy + Losses	Fuel LHV → heat → steam → turbine → electricity
Thermodynamic Cycles	Efficiency = (Work output) / (Heat input)	Rankine, Brayton, Combined Cycle
Electromagnetic Induction	$e = -N \frac{d\Phi}{dt}$	Rotating magnetic field in a synchronous generator
Power Factor	$\text{PF} = \cos\phi = \frac{P}{S}$	Determines real vs. apparent power in AC systems

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3. Major Types of Power Generation Technologies

Category	Typical Prime Mover	Typical Cycle	Typical Applications
Thermal (Fossil fuel) Plants	Steam turbine (coal, natural gas, oil)	Rankine (or combined Rankine ? Brayton)	Base?load utility generation
Gas Turbine (Combustion) Plants	Gas turbine	Brayton	Peaking, cogeneration, combined cycle
Nuclear Power Plants	Steam turbine driven by nuclear?heated water/steam	Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR) – Rankine	Large, low?carbon base?load
Hydropower	Water turbine (Francis, Pelton, Kaplan)	Direct mechanical ? generator	Run?of?river, reservoir, pumped storage
Wind Power	Wind turbine rotor	Direct drive or gearbox ? generator (usually synchronous or permanent?magnet)	Distributed & utility? scale
Solar Photovoltaic (PV)	Photons ? electrons	Semiconductor p?n junction ? DC ? inverter	Rooftop, utility? scale
Solar Thermal (CSP)	Sun?heated fluid ? steam turbine	Rankine (or Brayton)	Concentrated solar power plants
Geothermal	Steam/ hot water from earth	Direct steam turbine or binary cycle (Rankine)	Baseline power in volcanic regions
Biomass / Waste?to?Energy	Combustion of organic material	Rankine	Small?to?medium utility plants

4. Key Performance Metrics

Metric	Definition	Typical Target
Net Electrical Efficiency	$\eta = \frac{P_{el}}{Q_{in}}$	30?38?% (simple coal) ? 60?%+ (