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Unit - 2

Energy Supply System

Energy power supply system in a country comprises of generating units that produce electricity, high voltage transmission lines that transport electricity over long distances, distribution lines that ~~produce~~ deliver electricity to consumers, and electricity control station to coordinate the operation of the components

→ A system responsible for the generation, transmission, and distribution of electricity

Fuel → Power Plant → Substation → Transmission → Substation → Power lines → Customers

~~AC Sources~~ Generation: Electricity is produced using energy sources such as coal, oil, natural gas, nuclear energy and hydropower. In India, 70% of power generation is coal based thermal power plants.

Transmission — High voltage transmission lines (220 kV & 400 kV) transport electricity over long distances.

Distribution: Distribution lines deliver electricity to consumers at lower voltages (11 kV / 6.6 kV / 3.3 kV)

Substation: Connect various components and regulate voltage levels

Energy Control Centres: Coordinate the operation of the entire system

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Components of AC Power

Alternating Current (AC) Power is widely used because
- It can be transmitted over long distances with low losses
- Voltage levels can be easily transformed
- Compatible with most electrical appliances

Characteristics—
- Frequency (F) — In India, AC operates at 50 Hz
- Voltage (V) — Domestic supply is 230 V single phase, industries use 400 V three - phase.
- Amplitude — Higher ~~of~~ amplitude indicates greater power capacity.
- Phase — In three phase systems, waveforms are typically 120° apart for efficient power flow

Types —

1. Active Power (P) — Power used to perform work, measured in kilowatts (kW)

$$P = VI \cos \phi$$

V = Voltage, I = current $\cos \phi$ = Power Factor

2. Reactive Power (Q) — Power wasted in inductive loads, measured in kVAR (kilo volt-ampere reactive)

$$Q = VI \sin \phi$$

3. Apparant Power (S) — Total power supplied, measured in kilovolt ampere (kVA)

$$S = VI$$

4. Power factor (PF) — Efficiency of power usage

$$PF = \frac{P}{S} = \cos \phi$$

Power factor close to 1 → efficient system

Low PF → Higher energy loss

Windows

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Sanctioned Load

It refers to the maximum electrical load (kilowatts or Kilovolt amperes) that a utility company agrees to supply to a customer.
This value is determined when a consumer applies for an electricity connection, based on expected power requirements of their premises

Features —

- Agreement Based : It is specified in the agreement b/w the electricity distribution company and the consumer at the time of connection approval.

- Biling Implications : The electricity traiff structure often depends on the sanctioned load. ~~eg~~ Consumers may incur penalties if their actual load exceeds sanctioned load. Fixed charges on electricity bills are usually calculated based on the sanctioned load

Categories of Consumers

- Residential Consumers — Load depends on household appliances
- Commercial Consumers — Load is based on equipments like light, HVAC computer
- Industrial Consumers — Load is much higher & determined by machinery used

Components

- Connected Load : Sum of rated power of all electrical equipment installed at the premises.
- Diversity Factor : Accounts for the fact that not all equipment operates simultaneously

Example

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Appliances	Quantity	Power Rating (kw)	Diversity factor
LED lights	10	0.01	1.0
Ceiling Fans	5	0.07	0.8
AC	2	1.5	0.6

Step 1 - Connected load

$$= (10 \times 0.01) + (5 \times 0.07) + (2 \times 1.5) = 3.85 \text{ kw}$$

Step 2 - Sanctioned load

$$= \frac{\text{Connected load (kw)}}{\text{Diversity Factor Avg.}} = \frac{3.85}{0.8} = 4.8125 \text{ kw}$$

Maximum Demand

It refers to the highest level of electrical power or load that a system building or equipment consumes over a specified period, usually in kilowatts (kW) or kilovolt-amperes (kVA)

- Helps industries optimize energy usage
- Avoids overloading transformers and generators.
- Ensures cost-effective energy planning

$$\underset{(\text{kw})}{\text{MD}} = \frac{\text{Energy used in a fixed Time Period}}{\text{Time Period (hours)}}$$

Application

1. Energy Management - Identifying peak load times to optimize energy consumption and reduce cost.
2. Infrastructure Design - Used to design electrical systems, including transformers, generators & substations ensuring they can handle peak load

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3. Cost Allocation — Utilities use it to calculate demand charges

Measurement Tools

1. Maximum Demand Indicators (MDI) :

Maximum or digital devices installed on electrical panels to measure peak load over a ~~load~~ period.

2. Energy meters with a demand measurement —

Mordern digital energy meters come with built in features to record, maximum demand

3. Power Analyzers —
Portable devices for real time measurement and analysis of electrical load,

4. Supervisory Control and Data Acquisition (SCADA) —
SCADA systems monitor and record maximum demand.

Contract Demand

It refers to the maximum level of electrical power that a customer agrees to draw from the utility provider, as specified in a formal agreement

Contract Demand Charge = Contract Demand(kW) x Rate per kW.

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Contract Demand	Maximum Demand
• The pre-agreed maximum power a consumer commits to drawing from the utility provider	The actual highest power consumed by the consumer during a specific period.
• Based on a formal agreement between consumer and utility provider	• Measured dynamically & represents the peak load during the billing cycle or observation period.
• Fixed value as specified in contract	• Variable & depends on power consumption pattern
• Controlled and chosen by the consumer in agreement	• Determined by the consumer's operational usage and load patterns.
• Helps utilities allocate resources, plan infrastructure & ensure grid reliability	• Helps track and analyze peak energy usage for operational efficiency.
• ~~Customers~~ Consumers can request to revise the contract demand, usually with advance notice and utility approval.	• Cannot be revised but can be managed by controlling load patterns.

AC Machines

• They are electrical devices that operate on AC & are widely used in industrial, commercial and residential ~~operations~~ applications

Types —

1. AC Motors — Convert electrical energy into mechanical energy
   eg - driving machinery, pumps, fans & compressors.
2. AC Generators — Convert mechanical energy into electrical energy
   used in power generation systems to produce electricity.

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Types of AC Motors —

1. <u>Induction Motors</u> — Most commonly used type of AC motor Operates on the principle of electromagnetic induction.
eg - fans, pumps, compressors.

2. <u>Synchronous Motors</u> — Operate at constant speed synchronized with the frequency of the supply voltage. Require an external DC ~~ext.~~ excitation system for operation. eg - power factor connection

3. <u>Specialized AC Motors</u> — Include single-phase motors (household appliances) and universal motors (portable tools).

<u>Working Principle</u> — The stator generates a rotating magnetic field when supplied with AC Power. This field induces a current in the rotor, producing torque that drives the motor

Types of AC Generators

1. <u>Alternators</u> — Produce alternating current by rotating a coil within a magnetic field. Widely used in Power Plants for electricity generation.

2. <u>Brushless Generators</u> — Do not require brushes for excitation, rely on electronic systems for operation eg - Aircraft systems, portable generator

<u>Working Principle</u> — Mechanical energy rotates the rotor within a magnetic field to induce an AC in the stator winding.

<u>Adv.</u> → High efficiency & reliability
→ Easy to control & maintain
→ Suitable for large scale power generation & industrial applications