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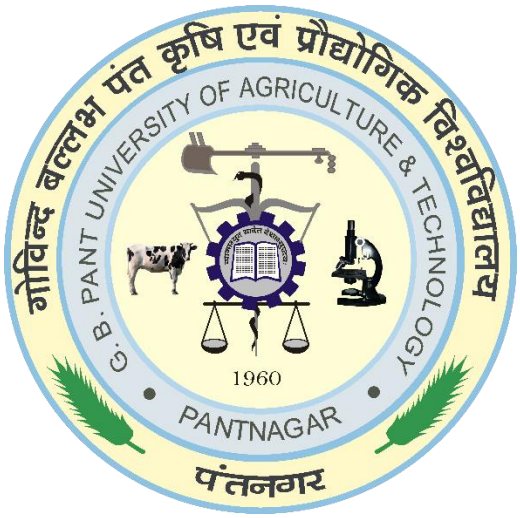

CONCEPTS OF ELECTRICAL POWER SYSTEM

(TEE- 404)

Session: 2024-25

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1.) DOMESTIC LOAD

Domestic load refers to the electrical power consumption in residential buildings for lighting, heating, cooling, and operation of household appliances. In India, domestic electricity supply is provided at 230V, 50Hz, single-phase AC, while large homes with higher power demand may receive a three-phase (415V) supply. The total domestic power consumption varies depending on the number and type of electrical devices used in a household.

Classification of Domestic Load: Domestic loads can be categorized based on their function and nature of power consumption.

- **Lighting Load**- Lighting load includes electrical appliances used for illumination, such as LED bulbs, tube lights, and CFLs. LEDs are highly energy-efficient, consuming 5W to 15W, compared to older incandescent bulbs that consume 60W to 100W. In India, energy-efficient LED lighting has been promoted under government schemes like UJALA (Unnat Jyoti by Affordable LEDs for All).
- **Heating Load-** Heating appliances include electric geysers, room heaters, induction cooktops, and irons. These devices operate on resistive heating principles and consume high power. For example, an electric geyser typically consumes 1.5 kW to 3 kW per hour, contributing significantly to electricity bills.
- **Cooling and Ventilation Load**- Cooling load comprises fans, air conditioners, refrigerators, air coolers, and exhaust fans. These devices either operate on motors or compressors or have varying energy requirements. A ceiling fan consumes 50W to 90W, while a 1.5-ton air conditioner consumes 1.5 kW to 2 kW per hour, depending on usage and efficiency ratings.
- **Motor-Driven Load-** Motor-driven appliances include washing machines, vacuum cleaners, water pumps, mixers, and grinders. Most of these appliances use single-phase induction motors and consume moderate to high power. A domestic water pump of 0.5 HP typically consumes 373W, while a fully automatic washing machine consumes 500W to 1500W per wash cycle.
- **Electronic Load**- This category includes televisions, laptops, mobile chargers, Wi-Fi routers, and home entertainment systems. These devices generally have low power consumption but contribute significantly to total electricity use due to continuous operation. A laptop charger typically consumes 60W to 90W, while a LED TV (32-inch) consumes around 50W to 80W.

Load Characteristics: Domestic loads have several key characteristics that impact power demand and supply efficiency.

- **Variable Demand**- Domestic power consumption fluctuates throughout the day, with peak demand in the morning (6–9 AM) and evening (6–10 PM) due to simultaneous use of lights, fans, TVs, and cooking appliances.
- **Power Factor**- Most domestic appliances have a power factor between 0.8 and 1.0. Resistive loads like geysers and ovens have a power factor of 1.0, while inductive loads like motors and refrigerators have a power factor of 0.6 to 0.8.

- **Load Factor**-The Load Factor (LF), which represents the ratio of average load to peak load, typically ranges between 0.2 and 0.5 for Indian households, meaning that peak demand is significantly higher than the average demand.
- **Seasonal Variation-** Electricity consumption is higher in summer due to air conditioners and coolers, whereas in winter, heating loads like geysers and room heaters increase consumption.

Appliance	Power Consumption (W)	Voltage (V)
LED Bulb	5W – 15W	230V
Ceiling Fan	50W – 90W	230V
Refrigerator	100W – 400W	230V
Air Conditioner	1500W – 5000W	230V
Washing Machine	500W – 1500W	230V
Induction Cooktop	1200W – 2200W	230V
Water Pump (Domestic)	373W (0.5 HP) – 750W (1 HP)	230V

Table 1. Power Ratings of Common Household Appliances in India

Domestic Electricity Supply in India: In India, residential electricity supply is provided by various state and private Distribution Companies (DISCOMs). Most households receive a single-phase 230V supply, while larger homes (with connected loads above 5 kW) may get a three-phase 415V supply.

Connected Load	Recommended Supply	Common Appliances
≤ 2 kW	230V Single-phase	Basic lighting, fans, TV, small fridge
2 – 5 kW	230V Single-phase	AC, geyser, washing machine, large fridge
5 – 10 kW	230V/415V Three-phase	Multiple ACs, high-power kitchen appliances

Table 2. Load Capacity Based on Connected Load

2.) COMMERCIAL LOAD

Commercial load refers to the electricity consumption in business establishments such as shops, offices, malls, hotels, restaurants, educational institutions, and hospitals. Unlike domestic load, which is characterized by individual household usage, commercial load is typically higher, more continuous, and includes a mix of lighting, heating, cooling, and motor-driven equipment. In India, most commercial establishments receive a three-phase (415V, 50Hz) AC supply, though small shops and offices may operate on a single-phase (230V) supply. Electricity tariffs for commercial consumers are higher than domestic consumers due to higher demand and peak-hour usage.

Classification of Commercial Load: Commercial load can be divided into the following categories based on its function:

- **Lighting Load-** Lighting load in commercial establishments includes LED panel lights, CFLs, fluorescent tube lights, decorative lighting, and emergency lighting systems. Since businesses require longer operational hours, energy-efficient lighting is widely used. For example: LED Tube Light (20W–40W) is commonly used in office spaces, Commercial floodlights (100W–300W) are used in showrooms and malls.
- **Heating Load-** Heating load includes electric water heaters, commercial kitchen equipment, ovens, and space heaters. These appliances have high power consumption. For example: Commercial water geysers (3 kW – 6 kW) are commonly used in hotels and hospitals, Industrial microwave ovens (3 kW – 10 kW) are used in restaurants and catering businesses.
- **Cooling and Ventilation Load-** Cooling load in commercial spaces consists of air conditioners, centralized HVAC systems, ceiling fans, and ventilation fans. Since commercial buildings operate for extended hours, cooling demand is significant. For example: Ceiling fans (50W–100W) are used in small offices, Split ACs (1.5–3 tons, 1.5 kW–3 kW) are used in shops and restaurants, HVAC systems (50 kW – 500 kW) are used in malls, hotels, and IT offices.
- **Motor-Driven Load-** This category includes lifts, escalators, pumps, air compressors, and industrial kitchen appliances. Examples: Water pumps (1 HP – 10 HP, 750W – 7.5 kW) are used in buildings for water supply, Lifts & escalators (5 kW – 20 kW per unit) are common in commercial buildings.
- **IT and Office Equipment Load-** Office buildings and IT parks have a large number of computers, printers, servers, networking devices, and UPS systems, which contribute to energy consumption. Examples: Desktop computer (150W – 300W per unit), Server room UPS (5 kVA – 500 kVA).

Load Characteristics:

- **Peak Demand and Load Factor-** Commercial establishments experience peak demand during working hours (typically 9 AM – 8 PM). The load factor (ratio of average load to peak load) for commercial consumers is generally between 0.5 and 0.8, higher than domestic consumers due to continuous operation.

- **Power Factor Considerations**- Many commercial loads, such as motors, air conditioners, and UPS systems, introduce inductive loads, leading to a low power factor (0.6 – 0.9). To avoid penalties from electricity providers, businesses install power factor correction (PFC) devices such as capacitor banks to maintain the power factor close to 1.0.
- **Energy Efficiency Measures**- To reduce electricity consumption, commercial establishments implement:
    - LED lighting instead of CFLs or incandescent bulbs.
    - Energy-efficient HVAC systems with inverter technology.
    - Automatic power factor correction (APFC) panels to reduce reactive power losses.
    - Solar panels for backup power in offices and hotels.
    -

Appliance/Equipment	Power Consumption (W)	Voltage (V)
LED Panel Light	20W – 40W	230V
Split Air Conditioner	1.5 kW – 3 kW	230V/415V
Centralized HVAC System	50 kW – 500 kW	415V
Water Pump	750W – 7.5 kW	230V/415V
Escalator Motor	5 kW – 20 kW	415V
Commercial Oven	3 kW – 10 kW	230V/415V
Desktop Computer	150W – 300W	230V
Office Server	500W – 2 kW	230V

Table 3. Power Ratings of Common Commercial Appliances in India

Commercial Electricity Supply in India:

- Single-phase 230V supply for small businesses (<5 kW load).
- Three-phase 415V supply for large shops, offices, hotels, and malls (>5 kW load).
- High Tension (HT) supply (11 kV and above) for large industries, IT parks, and hospitals.

3.) INDUSTRIAL LOAD

Industrial load refers to the electricity consumption in factories, manufacturing units, processing plants, and other industrial facilities. Unlike domestic and commercial loads, industrial loads are highly power-intensive, operate continuously, and often require high-tension (HT) power supply. These loads include large motors, heavy machinery, furnaces, compressors, and automated production lines.

In India, industries are classified into:

1. Small-Scale Industries (SSI): Load requirement up to 50 kW, often operating on a three-phase (415V) supply.

2. Medium-Scale Industries: Load between 50 kW and 1 MW, requiring a high-tension (11 kV) supply.

3. Large-Scale Industries: Load exceeding 1 MW, requiring 33 kV, 66 kV, or even 132 kV supply.

Classification of Industrial Load:

- **Lighting Load**- Factories and industrial buildings require high-intensity lighting for proper working conditions. These include: LED High Bay Lights (100W – 500W) used in large production halls, Fluorescent Tube Lights (40W – 80W) for small-scale units, Halogen Lamps (500W – 2000W) used in large open industrial areas.
- **Heating Load-** Industries use heavy-duty heating equipment for melting, drying, welding, and chemical processing. Some examples include: Industrial Electric Furnaces (50 kW – 500 kW) for steel and aluminium melting, Industrial Boilers (10 kW – 1000 kW) used in textile, paper, and food industries, Electroplating Units (5 kW – 50 kW) used for coating metals.
- **Motor-Driven Load-** Electric motors form a major portion of industrial load, as they drive conveyors, pumps, fans, and heavy machinery. Examples: Induction Motors (5 HP – 5000 HP) are widely used for industrial automation, CNC Machines (5 kW – 50 kW) in manufacturing and automobile industries, Compressors (10 HP – 500 HP) used in refineries and chemical plants.
- **Cooling and Ventilation Load-** Industrial cooling systems are necessary for maintaining equipment temperature and worker comfort. These include: Industrial Chillers (10 kW – 500 kW) used in pharmaceutical and food processing industries, Cooling Towers (50 kW – 5 MW) in steel plants and power stations, Ventilation Fans (500W – 10 kW) in large-scale industries.
- **Automation and IT Load-** Modern industries use PLC systems, robotics, and IT-based automation, which require continuous power. Examples: Industrial Servers (2 kW – 20 kW) for process monitoring and data management, SCADA Systems (5 kW – 100 Kw) for remote control of industrial operations.

Load Characteristics:

- **High Demand and Load Factor**- Industrial power demand is generally high and stable, with continuous operation in many factories. The load factor (LF), which is the ratio of average load to peak load, is typically between 0.6 and 0.9, much higher than domestic and commercial loads.
- **Power Factor Considerations**- Industries use large inductive loads (motors, transformers, welding equipment), which result in a low power factor (0.6 – 0.9). To avoid penalties and improve efficiency, industries install capacitor banks and Automatic Power Factor Correction (APFC) panels to maintain the power factor close to 1.0.
- **Energy Efficiency Measures-** To reduce industrial electricity costs, industries use:
    - Energy-efficient motors (IE3 and IE4-rated) to reduce power wastage.
    - Variable Frequency Drives (VFDs) to optimize motor speed and reduce energy consumption.
    - Cogeneration (CHP) Systems to generate both electricity and heat from a single energy source.
    - Solar and wind power integration for captive industrial use.

Equipment	Power Consumption (W/kW)	Voltage (V/kV)
LED High Bay Light	100W – 500W	230V/415V
Induction Motor (Industrial)	5 kW – 5 MW	415V – 11 kV
Industrial Furnace	50 kW – 500 kW	415V – 33 kV
CNC Machine	5 kW – 50 kW	415V
Industrial Boiler	10 kW – 1000 kW	415V – 11 kV
Chiller System	10 kW – 500 kW	415V – 11 kV
Air Compressor	10 HP – 500 HP	415V – 11 kV
Cooling Tower	50 kW – 5 MW	11 kV – 33 kV

Table 4. Power Ratings of Common Industrial Equipment

Industrial Electricity Supply in India: Most industries are supplied power based on their demand: Small Industries (<50 kW load): Three-phase 415V supply, Medium Industries (50 kW – 1 MW load): 11 kV HT supply, Large Industries (>1 MW load): 33 kV, 66 kV, or 132 kV HT supply, Heavy Industries (>10 MW load): 132 kV, 220 kV, or 400 kV EHT (Extra High Tension) supply.

4.) AGRICULTURAL LOAD

Agricultural load refers to the electric power consumption in farming activities, including irrigation, harvesting, processing, and storage. In India, agriculture is a major sector, consuming about 18-20% of the total electricity generated. The demand for agricultural power is largely seasonal, rural-based, and heavily dependent on groundwater extraction through electric pumps.

Most agricultural consumers receive low-tension (LT) power supply at 230V (single-phase) or 415V (three-phase), while large farms and agro-industries may require high-tension (HT) supply at 11 kV.

Classification of Agricultural Load:

- **Irrigation Load**- Irrigation is the most power-consuming agricultural activity. Electric pumps and bore wells extract groundwater to irrigate fields. Examples: Submersible Pumps (2 HP – 50 HP) used for deep groundwater irrigation, Centrifugal Pumps (1 HP – 30 HP) used for surface water irrigation, Drip and Sprinkler Systems (1 kW – 10 kW) for water-efficient farming.
- **Agricultural Processing Load-** Farms with storage and processing facilities require power for: Threshers (3 kW – 20 kW) for separating grains from crops, Milling Machines (10 kW – 50 kW) for rice, wheat, and maize processing, Cold Storage Units (5 kW – 500 kW) for preserving perishable produce.
- **Lighting and Farm Electrification Load-** Electricity is needed for barns, cattle sheds, storage facilities, and security lighting. Examples: LED Tube Lights (20W – 40W) for farm lighting, High-Intensity Discharge (HID) Lamps (150W – 500W) for large farmyards.
- **Livestock and Dairy Load-** Farms with poultry, dairy, and cattle require power for: Milking Machines (2 kW – 15 kW) for automated dairy farming, Ventilation Fans (500W – 5 kW) in poultry farms, Egg Incubators (1 kW – 5 kW) for hatcheries.
- **Renewable Energy Integration-** Many farmers are adopting solar and wind power to reduce dependency on the grid. Examples: Solar Water Pumps (1 HP – 10 HP) reduce energy costs, Biogas Plants (5 kW – 50 kW) provide sustainable energy for farm use.

Load Characteristics:

- **Seasonal and Variable Demand**- Agricultural power demand is highly seasonal, peaking during the Rabi and Kharif crop seasons. Demand fluctuates based on:
    - Monsoon Dependency: Higher demand in non-monsoon seasons due to groundwater pumping.
    - Day vs. Night Use: Power is required mostly during daylight for irrigation and processing, but also at night for storage and lighting.
- **Power Factor and Voltage Stability Issues**- Agricultural loads, especially pumps and motors, have a low power factor (0.6 – 0.8) due to inductive characteristics. Many rural areas face: Voltage drops (below 200V in single-phase, below 380V in three-

phase) due to long transmission distances and frequent power fluctuations, outages affecting irrigation schedules.

- **Rural Electrification and Energy Losses-** Many Indian farms lack proper transmission infrastructure, leading to: High transmission losses (~20-30%) in rural power supply networks, Use of diesel generators (5 kVA – 100 kVA) as backup power for irrigation and processing.

Equipment	Power Consumption (W/kW)	Voltage (V)
Submersible Pump	2 HP – 50 HP (1.5 kW – 37 kW)	230V/415V
Centrifugal Pump	1 HP – 30 HP (0.75 kW – 22 kW)	230V/415V
Thresher	3 kW – 20 kW	415V
Cold Storage Unit	5 kW – 500 kW	415V – 11 kV
Dairy Milking Machine	2 kW – 15 kW	230V/415V
Solar Water Pump	1 HP – 10 HP (750W – 7.5 kW)	230V/415V

Table 5. Power Ratings of Common Agricultural Equipment

Agricultural Electricity Supply in India: Farmers receive subsidized electricity to support agriculture. Power is supplied as:

- Single-phase 230V for small farms (up to 5 HP pumps).
- Three-phase 415V for medium farms (5 HP – 20 HP pumps).
- High-tension 11 kV for large-scale agro-industries.

Many states provide free or highly subsidized electricity for farmers, but this leads to overuse of water resources (groundwater depletion), power theft and unauthorized connections, financial burden on state electricity boards (SEBs).

Renewable Energy Solutions for Agriculture: With rising energy costs, farmers are shifting to solar-powered irrigation- Solar Water Pumps (2 HP – 10 HP) reduce grid dependency, micro grids for rural farms provide off-grid electricity, government Schemes (PM-KUSUM) subsidize solar installations for farmers.

5.) MUNICIPAL LOAD

Municipal load refers to the electricity consumption by public infrastructure and services managed by municipal corporations and local government bodies. This includes street lighting, water supply, drainage systems, public transport, hospitals, government buildings, and waste management.

In India, municipal loads are primarily supplied at low tension (LT) 415V for smaller installations and high tension (HT) 11kV – 33kV for large-scale municipal services. The municipal sector constitutes around 8-12% of the total electricity consumption in urban areas.

Components of Municipal Load:

- **Street Lighting Load-** Public street lighting is a major component of municipal electricity consumption. It includes: LED Street Lights (20W – 250W) replacing traditional sodium vapour lamps (150W – 400W) to reduce energy consumption, High-Mast Lights (400W – 2000W) for highways and public spaces, Automatic Timer and Sensor-based Lighting Systems for energy efficiency.
- **Water Supply and Drainage Load**- Municipalities operate water pumping stations and sewage treatment plants that require continuous power supply. Examples: Water Pumping Stations (10 HP – 500 HP per pump) for water distribution, Sewage Treatment Plants (STPs) (50 kW – 5 MW) for wastewater management, Lift Irrigation Systems (50 HP – 1000 HP) for transporting water in hilly or elevated regions.
- **Public Transport and Metro Systems**- Major cities have electrified public transport which includes: Metro Rail (750V DC – 25kV AC overhead supply), Electric Buses (Battery charging stations, 50 kW – 350 kW per charger), Traffic Signals (100W – 500W per signal) using LED technology.
- **Public Buildings and Facilities-** Government offices, hospitals, and municipal buildings require power for: Lighting (10 kW – 500 kW per building), Air Conditioning (5 kW – 200 kW per facility), IT and Communication Systems (5 kW – 50 kW per installation).
- **Waste Management and Solid Waste Processing Load-** Garbage Processing Units (100 kW – 5 MW) for waste-to-energy projects, Incinerators (500 kW – 2 MW) for biomedical and hazardous waste disposal.

Load Characteristics:

- **Continuous vs. Peak Demand-**
    - Continuous Load: Water supply pumps, sewage treatment plants, hospitals, and streetlights operate 24/7.
    - Peak Load: Public transport and traffic signals experience morning and evening peaks (7 AM – 10 AM, 5 PM – 9 PM).
- **Power Factor and Voltage Fluctuations**- Municipal loads, especially water pumps and streetlights, have inductive loads that result in a low power factor (0.7 – 0.9).

This leads to: Voltage fluctuations (below 400V in three-phase supply).
Need for capacitor banks to improve power factor.

- **Seasonal Variations**- Higher electricity demand in summer due to increased water pumping and cooling requirements. Lower demand in monsoon as water supply pumping reduces.

Equipment	Power Consumption	Voltage Level
LED Street Light	20W – 250W	230V
High-Mast Light	400W – 2000W	415V
Water Pump Station	10 HP – 500 HP	415V – 11kV
Sewage Treatment Plant	50 kW – 5 MW	415V – 33kV
Metro Rail System	750V DC – 25kV AC	25kV
Electric Bus Charging	50 kW – 350 kW	415V – 11kV
Waste-to-Energy Plant	500 kW – 10 MW	11kV – 33kV

Table 6. Power Ratings of Common Municipal Equipment

Smart City Initiatives:

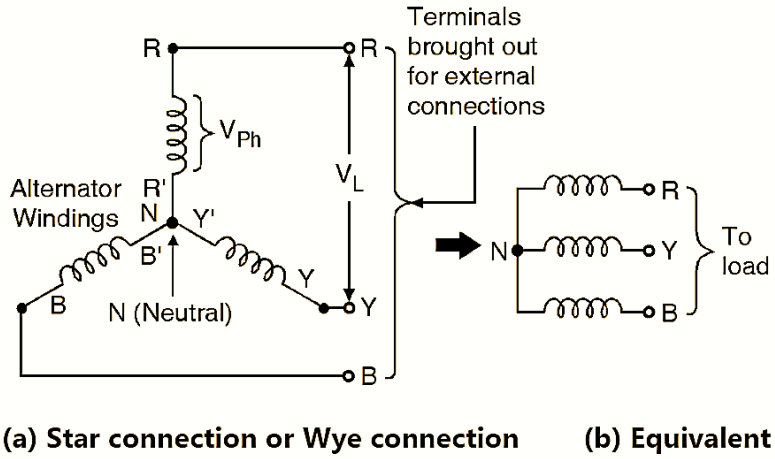
- **Smart LED Street Lighting**- Cities are replacing sodium vapor lamps with automatic LED streetlights (20W – 150W) that consume 60% less energy.
- **Energy-Efficient Water Pumping**- VFD (Variable Frequency Drive) pumps adjust speed based on water demand, saving 30% energy. SCADA-based monitoring systems improve efficiency in water and sewage treatment plants.
- **Electric Vehicles and Charging Infrastructure-** Metro systems in Delhi, Bengaluru, and Mumbai are shifting to solar-powered charging stations. Smart traffic systems optimize signals to reduce congestion and energy use.
- The Indore Smart City project has installed solar streetlights and rooftop solar panels on municipal buildings, saving over ₹5 crore annually.

6.) STAR DELTA CONNECTION

The star-delta connection is a prevalent method in three-phase electrical systems, primarily used to connect generators and loads. This technique offers flexibility in managing voltage and current levels, making it integral in various applications.

Star (Wye) Connection: In a star connection, each of the three-phase windings is connected to a common neutral point, forming a configuration that resembles the letter 'Y'. This setup allows for two types of voltage measurements-

- Line-to-Neutral Voltage (Phase Voltage): The voltage between any one phase and the neutral point.
- Line-to-Line Voltage (Line Voltage): The voltage between any two phases.



(a) Star connection or Wye connection **(b) Equivalent**

Figure 1.

A key relationship in star connections is that the line-to-line voltage is √3 times the line-to-neutral voltage (V_L = √3 × V_Ph). Additionally, the current flowing through each line is equal to the current in each phase winding.

This configuration is commonly employed in power distribution systems where both line-to-line and line-to-neutral voltages are required.

Delta (Δ) Connection: In a delta connection, the ends of the three-phase windings are connected end-to-end, forming a closed loop that resembles a triangle (Δ). In this arrangement:

- Line Voltage (V_L): The voltage across each winding is equal to the line voltage.
- Line Current (I_L): The current in each line is √3 times the current in each winding

Delta connections are typically used in systems where high starting torque is necessary, such as in industrial motors and heavy machinery.

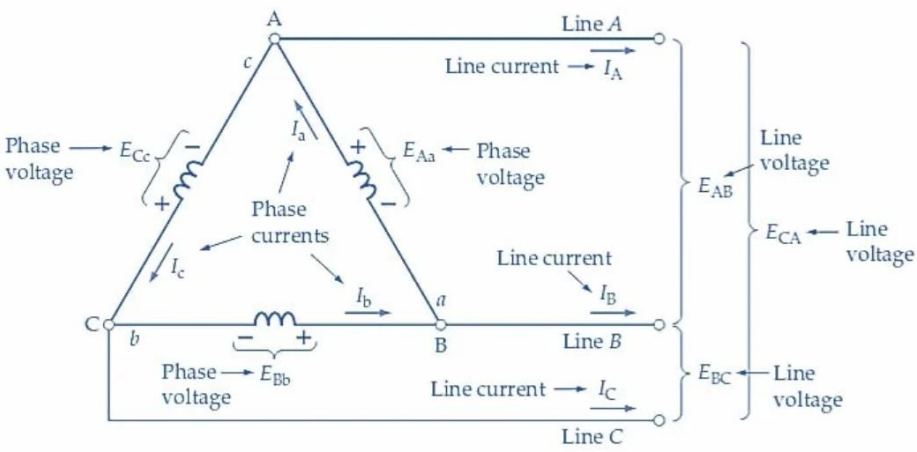


Figure 2. Delta Connection

Applications of Star and Delta Connections:

- **Star Connection-** Widely used in power distribution networks, especially where a neutral connection is needed to supply both single-phase and three-phase loads.
- **Delta Connection-** Commonly found in industrial settings for connecting motors and transformers, particularly where high starting torque and robust performance are required.

7.) NEUTRAL WIRE CONCEPT

A neutral wire is typically connected to the neutral point of a system and is intended to carry current under normal conditions. It serves as a critical component in AC power systems, providing a return path for current and maintaining system stability. In single-phase systems, it completes the circuit by returning current from the load back to the power source. In multiphase systems, it carries the unbalanced current that results when the sum of currents in the phase conductors is not zero.

Difference between Neutral Wire and Ground Wire: Neutral wire carries current during normal operation and is usually connected to the system's neutral point whereas Ground wire serves as a safety path for fault currents and does not carry current during normal operation. While both may be at zero potential relative to earth, their roles are distinct and should not be interchanged.

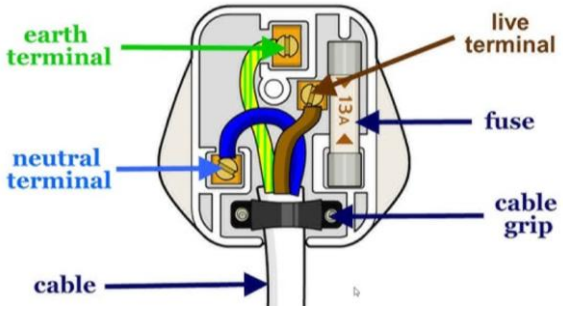


Figure 3. Electric Plug

Proper sizing and protection of the neutral wire are vital-

- **Sizing**: The neutral must be capable of handling the maximum unbalanced current. In certain cases, oversizing may be necessary to accommodate harmonic currents, especially in systems with nonlinear loads.
- **Protection**: Overcurrent protection for the neutral conductor is generally not required if it meets specific conditions, such as being protected against short circuits by the phase conductors' protective devices and carrying a current less than its rated capacity under normal operation.

8.) UTILITY FACTOR

The Utilization Factor (UF) measures how effectively the installed capacity of a power station or electrical system is being used. It is given by:

$$\text{Utilization Factor} = \frac{\text{Maximum Demand}}{\text{Rated Capacity}}$$

Where:

- Maximum Demand is the highest power demand recorded during a specific period.
- Rated Capacity is the total installed capacity of the system.

A higher utilization factor indicates better efficiency in power generation and distribution. It ensures economic efficiency, reduced energy wastage, and improved reliability.

In well-optimized power plants, the utilization factor is typically in the range of 0.75 to 0.90.

Ways to Improve Utilization Factor:

- **Load Management and Demand Side Control**
  - Implement demand response programs to shift non-essential loads during off-peak hours.
  - Use Time-of-Use (ToU) tariffs to encourage consumers to reduce peak demand.
  - Employ smart grids and IoT-based monitoring to optimize load distribution.
- **Efficient Capacity Planning**
  - Invest in energy storage systems (ESS) like batteries to store excess power and use it during peak hours.
  - Install distributed generation sources (e.g., solar and wind farms) near load centers to reduce transmission losses.
  - Implement grid interconnections to balance loads across different regions.
- **Use of Load Forecasting Techniques**
  - Utilize AI and Machine Learning for predictive demand analysis.
  - Implement weather-based forecasting models to adjust generation schedules.

- **Reducing Transmission & Distribution (T&D) Losses**
    - Upgrade transmission lines to higher voltage levels to reduce losses.
    - Improve power factor using capacitor banks and synchronous condensers.
    - Regular maintenance of transformers and substations to minimize losses.
- **Energy Efficiency Measures in Industries and Households**
    - Encourage industries to use energy-efficient motors and variable frequency drives (VFDs).
    - Promote LED lighting and energy-efficient appliances in residential areas.
    - Conduct power audits to identify and eliminate wastage.

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