Unit-IV

Electrical Machine and Batteries and UPS

- Transformer

A Transformer is a device used in the power transmission of electric energy. The transmission current in AC is IT is commonly used to increase or decrease the supply voltage without a change in the frequency of AC b/w circuits.

The transformer works on the basic principal of electromagnetic induction and mutual indication.

Transformer Types:-

Transformer are used in various fields like power generator grid distribution sector transmission and electric energy consumption.

- working voltage range.
- The medium used in the core.
- winding arrangement
- Installation location.

* Based on voltage levels:
Commonly used Transformer types depending on the voltage are classified as follows:-

• Step-up Transformer:-
They are used b/w the power generator and the power grid. The Secondary output voltage is higher than the Input voltage.

• Step-down Transformer:-
These transformers are used to convert high-voltage primary supply to low-voltage Secondary output.

* Based on the medium of core used
In a transformer, we will different types of cores that are used.

• Air core Transformer:-
The flux linkage b/w primary and Secondary winding is through the air. The coil or windings wound on the non-magnetic strip.

- Iron Core Transformer

winding are wound on multiple iron plates together, which provides a perfect linkage path to generate flux.

* working principal of a Transformer.

The transformer works on the principal of Faraday's laws of electromagnetic induction and mutual induction.

They are usually two coils - primary coil and Secondary coil - on the transformer core. The core combination are joined in the form of strips. The two coils have high mutual inductance.

When an alternating current passes through the primary coil, it creates a varying magnetic flux.

As per Faraday's law of electromagnetic induction this change in magnetic flux induces and emf (electromotive force) in the Secondary coil, which is linked to the core having a primary coil. This is mutual induction.

1. Overall a Transfer carries out the following operations:-

1. Transfer of electrical energy from one circuit to another.

2. Transfer of electrical power through electromagnetic inductance.

3. Electrical power transfer without any change in frequency.

4. Two circuit linked with mutual induction.

* Applications

- Power distribution:- Used to step up (increase) the voltage for transmission and step down (decrease) the voltage for distribution to homes and industries.

- Electronic Device:- Used in power supplies to convert voltage levels suitable for different devices.

- Isolation Transformers:-
  - Provide electrical isolation b/w two circuits.

* Safety Consideration:-

- proper insulation and cooling are necessary to prevent overheating and electrical hazards.
- Ensure transformers are rated for the specific voltage and current to avoid overloading.

* Transformation Ratio

The transformation ratio of a transformer is a crucial concept that determine how the transformer converts voltage levels b/w its primary and secondry windings.

* The Transformation ratio (also called the turns ratio) of a transformer is the ratio of the number of turns in the secondry winding (N_2) to the number of turns in the primary winding (N_1).

It is also directly related to the voltage ratio b/w the primary and secondary windings.

Formulas

The transformation ratio (K) can be expressed as:

$$K = \frac{N_2}{N_1}$$

Voltage Relationship

The transformation relationship ratio determines the relationship b/w the primary voltage (V_1) and the secondary voltage (V_2).
The voltage ratio is given by:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = K$$

Current Relationship
Similarly, The current in the primary winding (I_1) and the current in the

Secondary winding (I_2) are inversely proportional to the transformation ratio:

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} = K$$

* Types of Transformer Based on Transformation Ratio:

1. Step-up-Transformer:-
- Purpose :- Increase voltage from primary to Secondary.
- Turns Ratio :- ($N_2 > N_1$) (more turns in the Secondary winding)
- Voltage Relationship : ($V_2 > V_1$)
- Current Relationship : ($I_2 < I_1$)

2. Step-Down Transformer:-
- Purpose :- Decrease voltage from primary to Secondary.
- Turn Ratio : ($N_2 < N_1$) (fewer turns in the Secondary winding)
- Voltage Relationship :- ($V_2 < V_1$)
- Current Relationship :- ($I_2 > I_1$)

Ex

Step-up Transformer

- primary turns (N-1) = 100
- Secondary turns (N-2) = 200
- primary voltage (V-1) = 110V

$$K = \frac{N_2}{N_1} = \frac{200}{100} = 2$$

$$V_2 = \frac{V_2}{V_1 \times K} = \frac{V_2}{110 \times 2}$$

$$V_2 = 220V$$

Step-down Transformer

- N-1 = 200
  N-2 = 100
  V-1 = 220V

$$K = \frac{N_2}{N_1} = \frac{100}{200} = 0.5$$

$$V_{e2} = \frac{V_{e2}}{V_1 \times K} = \frac{200\ V_{e2}}{220 \times}$$

$V_2 = \frac{V_1}{K} \Rightarrow \frac{220}{0.5} = 110\,V$ As

* Importance of Transformation Ratio :-

1. Voltage Regulation
- Allow for the adjustement of voltage levels to match the requirement of different applications.

2. power Transmission :
- High - voltage Transmission reduces current, minimizing power losses over long distance.

3. Safty
Helps in providing electrical ~~to~~ Isolation and appropriate voltage levels for safe operation of electrical devices.

* The transformation ratio is fundamental in understanding how a transformer modifies voltage and current level b/w its primary and secondry winding.

* Types and application with their rating transformer:

Transformer comes in various types, each designed for specific application and rated based on their power handling capacity, voltage and current.

Types of Transformers and Application

i) power Transformers:

- Application:-

used in transmission networks to step up (increase) or stepdown (decrease) the voltage levels for long distance power transmission.

- Rating,
  - Voltage : 110 Kv to 765 Kv
  - power .. 10 MVA to 1000 MVA

2. Distribution Transformer:-

- Application:

used in distribution network to step down

voltage for residential, commercial and industrial use.
• Ratings.
- voltage : 11KV to 33KV (primary), 240V to 480V (secondary).
- power : 25KVA to 5000KVA

3. Instrument Transformers :-
• Types : current Transformer (CT) and potential Transformer (PT)
• Application :-
used for measurement and protection in high-voltage circuits.
• Rating
→ voltage : CT (0.66 KV to 36KV) ; PT (up to 765 KV)
→ Current : CT (5A, 1A) , PT (depends on the voltage rating.)

4. Isolation Transformer :-
Application :-
provide electrical isolation b/w two circuit, often used for safety and noise reduction.
Rating :-
- voltage : 120V to 480V
- power : 1KVA to 500 KVA

5. phase-shifting Transformers:-

•Application:-

used to control the flow in transmission networks by changing the phase angle of the voltage.

Ratings:-

- Voltage: High voltage, typically up to 400 KV
- Power: Large ratings, often up to 2000 MVA.

* Application of Transformer

i) used at power generation station to increase the voltage level.

ii) used at substation to decrease the voltage level for safe distribution.

iii) used in steel manufacturing and other heavy industries.

iii) Transformers are used in heating, ventilation and air conditioning systems to power various components.

iv) Transformers in power adapters step down the voltage for electronic devices like phones, laptops and television.

Induction motor

An induction motor is an electric motor that operates on the principal of electromagnetic induction. It is one of the most commonly used types of electric motors, especially for industrial and commercial applications.

Types of Induction motors.

1. Squirrel-cage Induction motor

Construction

- The rotor consists of aluminium or copper bars short-circuited by end rings, resembling a squirrel cage.
- The Stator has laminated steel core with winding connected to an AC power supply.

Characteristics.

- Simple and robust construction.
- low cost and low maintenance.
- Fixed rotor resistance leading to constant speed.

Application

- pumps and fans :- commonly used in water supply system, HVAC system and cooling fans.
- compressors :- used in AC and refrigeneratory.
- conveyors :- used in material handling and manufacturing processes.
- Machine tools :- found in lathes, milling machine and drilling machine.
- Household Application :- used in ~~wate~~ washing machine, refrigeneratory and air conditionery.

2. Wound - Rotor Induction Motor (Slip Ring motor)

construction

- The motor has winding connected to external slip rings, allowing the addition of external resistors for better control.

- The Stators is similar to that of the squirrel-cage motor.

Characteristics

- Adjustable starting torque and speed control.
- Higher maintenance due to slip rings and brushes.
- Suitable for high-inertia and heavy-load applications.

Application

- Cranes and Hoists :- provide high starting torque and smooth acceleration.
- Elevators and Escalators :- used for control starting and stoping.
- Winders and unwinders :- In textile and papery industries for controlling the tension of materials.

* Difference between single and three phase motors.

Aspect	Single phase motor	Three phase motor
Power Supply	Single phase AC (120V or 240V)	Three phase AC (208V, 230V, 400V, 480V etc)
Construction	Single set of windings requires starting mechanism.	Three sets of windings, no additional start mechanism.
Efficiency	less efficient	more efficient
Torque	pulsating torque	constant torque
Application	Residential, light commercial (appliances, small pumps)	Industrial, heavy commercial (large pumps, machinery).
Cost	less expensive, simpler installation	more expensive. higher installation cost.
Starting mechanism	Requires start capacitor or switches	start automatically.

*Necessesty of starters for AC motors.

Function	Necessisty
Starting current limitation	prevents high inrush current, protecting electrical components and maintaining voltage stability.
Controlled Acceleration	Reduces mechanical stress and ensures smooth motor startup and shutdown.
• protection	protects against overloads, short circuit and other electrical faults.
voltage drop mitigation.	maintains voltage stability in the network, ensuring reliable operation of other equipment.
• Improved motor lifespan	Reduces wear and tear, leading to longer motor and equipment life.

* Different types of starters and application.

1. Direct - on - line (DOL) starter

working principle :-
- directly connects the motor to the power supply.
- The simplest form of starter, where the full line voltage is applied to the motor terminals.

Application
- small motors where the inrush current is not an issue.
- pumps, fans, compressors and small machine tools.

2. Star - Delta Starter

working principle :-

- Starts the motor in a star (wye) configuration, reducing the starting voltage to about $1/\sqrt{3}$ (58%) of the line voltage.

- After the motor reaches a certain speed, it switches to a delta configuration.

Applications :-

- Motors above 5HP where reduced starting current is necessary.
- Pumps, compressors, conveyors belts and industrial machinery.

3. Autotransformer starter

working principle :-

- uses an autotransformer to reduce the voltage applied to the motor during startup.
- After the motors reaches a specific speed, the autotransformer is bypassed and the full line voltage is applied.

Application

- medium to large motors where high starting torque is needed.
- large pumps, compressors, and heavy industrial machinery.

4. Soft starter

working principle :

- uses solid-state device to gradually increase the voltage to the motor.
- controls the voltage ramp-up providing a smooth start.

Application
- Application requiring smooth starts and stop.
- pumps, fans, conveyord system, and HVAC system.

5. Variable frequency Drive (VFD)

working principale:-
- controls the frequency and voltage supplied to the motor.
- uses power electronic to convert the fixed frequency AC supply to variable frequency.

Application
- Application requiring variable speed control and high efficiency.
- Fans, pumps, conveyors, extruders and various industrial processes.

* Different causes and remedies of a failure of starter and induction motor.

** Cause of Starter failure:-

1. overload conditions:-

• Cause:- Excessive current ~~down~~ drawn by the motor.
• Remedy :- Ensure the starter is rated for the motor's full load current.

2. Short circuit
• Cause :- Electrical faults that cause direct contact b/w phases or b/w phase ground.
Remedy :- Install short circuit protection devices such as fuses or circuit breakers.

3. Incorrect sizing or selection :-
• cause :- Choosing a starter not suited for the motors voltage, current.
• Remedy :- properly size and select the starter based on the motor's specification.

4. poor maintenance.
• cause :- lack of regular inspection, cleaning and lubrication.
• Remedy :- Implement a preventive maintainance schedule.

* Cause of Induction motor failure :-

1. Overheating

- Cause:- Excessive operating temperature due to overload, ambient temperature, poor ventilation.
- Remedy:- Ensure proper ventilation around the motor.

2. Bearing failure:-

- Cause:- Lack of lubrication, contamination, or mechanical stress.
- Remedy:- ~~Ease~~ maintain proper lubrication as per manufacturer recommendation.

3. Electrical faults:

Cause:- Voltage spikes, phase imbalance, or insulation breakdown.

- Remedy:- Install surge protectors and voltage regulators.

* Battery

A battery is a device that converts chemical energy into electrical energy through a chemical reaction. It consist of one or more electrochemical cells, each containing positive and negative electrodes (terminals) an electrolytes (conduct ions b/w electrodes)

Types of Batteries

1. Lead - Acid Battery
- Description.
- Construction :- Consist of lead plates submerged in an electrolyte solution of sulfuric acid.
- operation :- During discharge, lead sulfate forms on the plates.
- Application :- Commonly used in automotive starting (SLI batteries, backup power system (UPS), and stationary application.

Advantage
- Relatively low cost.
- Well - understood technology.
- Suitable for high current applications.

Disadvantage.
- Heavy and bulky.
- Limited cycle life compared to some newer technologies.
- Require regular maintenance (checking electrolyte level, occasional equalization charging.

2. Lithium Ion Battery

- Description:

Construction:-

Uses lithium compounds in the electrodes (typically lithium cobalt oxide, lithium iron phosphate or other variation.

Operation:- Lithium ions move b/w the +ve and -ve electrodes during charge and discharge cycle.

- Application:- found in consumer electronics (smart phone, laptops, electric vehicles (EVs) and energy storage system,

Advantage:

- High energy density (stores more energy per unit weight and volume)
- longer cycle life compared to lead-acid batteries,
- Lightweight and compact.

- Disadvantages:

- Higher cost compared to lead-acid batteries.
- Requires protection circuitry to prevent overcharging and overheating.

3. Sealed maintenance free (SMF) Battery.

* Description

- Construction :- Similar to lead acid batteries but designed to be maintance-free with no need to add water or check.
- operation :- uses immobilized electrolyte to prevent spillage.
- Application :- Often used in uninterruptible power supplies (UPS), emergency lighting and alarm system.

Advantage

- No maintance required.
- Leak-proof and suitable for indoor use.
- Better resistance to vibration and shocks compared to flooded lead-acid batteries.

Disadvantages.

- Typically more expensive than flooded lead acid batteries.
- may have lower tolerance for deep discharge cycle compared to flooded types.

* modular Battery

- Construction :- Refers to a battery system composed of modular units that can be achieved.
- operation :- Each module typically consist of interconnected cells.

- Application :- ideal in grid-scale energy storage, electric vehicles and other application requiring scalable energy storage.

Advantage
- Scalable design allow flexibility in capacity and voltage.
- Simplified installation and maintenance compared to large monolithic battery system.

Disadvantage
- Higher initial cost due to the need for modular components and integration system.
- complexity in system design and integration.

* Ampere hour capacity (Ah)

* Ampere-hour (Ah) capacity refers to the total amount of electrical charge ~~the~~ a battery can deliver over a specified period when discharged at a constant rate.

unit ; Ah (ampere-hours) is a measure of charge, indicating the amount of current a battery can supply over one hour.

Application:-

Ah rating is crucial for determining how long a battery can power a device before needing recharging.

* Efficiency of Batteries:

Efficiency refers to how effectively a battery converts stored chemical energy into electrical energy ~~is lost as heat during chemical~~ and vice versa.

* Factors affecting efficiency:

- Chemical Reaction efficiency:- Some energy is lost as heat during chemical reaction with the battery.
- Internal Resistance:-

Higher resistance results in energy loss as heat during charge and discharge.

- Temperature: Efficiency can decrease at extreme temperatures due to increased internal resistance.
- Application:-

understanding efficiency helps in selecting batteries for application where minimizing energy loss is crucial.

Summary

- Ampere - Hour Capacity (Ah) :- measure the total charge a battery can deliver over time.

- Efficiency :-
Indicates how effectively a battery converts chemical energy into electrical energy and vice versa, influencing its overall performance effectiveness in various applications.

* UPS

UPS stands for uninterruptible power supply. It is a device that provides emergency power to a load when the main power source fails or drops to an unacceptable voltage level.

Types of UPS:-

1. Standby UPS :-
- Description :- The load is normally powered directly by the mains supply.
- Switching time :- Typically has a switching time of a few milliseconds.

Applications :- Suitable for protecting computer, small servers, networking equipment.

2. Line interactive UPS :-

- Description :- Includes automatic voltage regulation (AVR) to stabilize fluctuations in the mains voltage without switching to battery power.
- Switching time :- Faster response compared to offline UPS.

Applications :- Used for protecting more sensitive equipment, including servers, medical devices, and telecommunications equipment.

3. Double conversion UPS :

- Description :- Continuously powers the load from its battery while also converting AC input power to DC and then back to AC for the output.
- Advantage :- Provides the highest level of protecting against all types of power problems.
- Application :

Essential for critical application such as data centers, hospitals etc.

* Application of UPS:-

- Data centres:- protects servers, storage device and networking equipment to prevent data loss and downtime.
- Telecommunication:- Ensures uninterrupted operation of communication system and Networks.
- Medical Equipment:- Critical for maintaining power to life-support systems, diagnostic equipment, etc.
- Industrial Automation:- Guards against power interruption that could disrupt manufacturing processes and control system.
- Home and office:- Safeguards computers, modem, routers and home entertainment etc.
- Emergency Services:- provide backup power for emergency response communication systems and control centres.

* Selection criterial of UPS

1. Load Capacity (VA/watts)
- The maximum electrical load (in volts-Amperes or watts) that the UPS can support.
- Criteria:— Ensure the UPS capacity matches or exceeds the total power consumption of the equipment it will protect.

2. Runtime Requirements:

- Defination:- The duration the UPS can provide backup power during a power outage.
- Criteria:- Determine how long the UPS needs to support your equipment until normal power is restored or until a backup generator kicks in.
- Factors:- Consider battery capacity, load size and power consumption.

3. UPS Topology
- Types: Choose b/w offline/standby, line-Interactive or online/double-conversion UPS depending on the level of protection needed.

4. Voltage Regulation and Surge protection.

- Features :- Look for AVR (Automatic Voltage Regulation) to stabilize fluctuating voltage without switching to battery power.
- Criteria :- protects sensitive equipment from voltage fluctuations and ensure consistent power delivery.

5. Scalability and Redundancy.

- Capability: Determine if the UPS can be expanded with additional battery packs or modules for increased runtime or load capacity.
- Criteria: Plan for future growth and ensure the UPS scale with increasing power demands.

Sizing of UPS

Sizing of UPS involves determining the appropriate capacity (in VA or watts) that matches the power requirement of your equipment and provides adequate backup

during outages:

1. Identify total load Requirements:

- List Equipment:- make a comprehensive list of all equipment that will be connected to the UPS.
- power Ratings: Note down the power rating of each piece of equipment.

2. Calculate Total power Consumption

- Add up power Requirements:- Sum up the power rating of all equipment to determine the total power consumption.
- Account for Efficiency:- If using watts consider the VA rating by applying a power factor.

3. Determine UPS capacity.

- Select UPS Type:- choose the UPS type based on your application needs (Standby, Line-Interactive, or Double-Conversion)
- Capacity Calculation:-
  - VA vs watts:→ Determine if your equipment lists power requirement in VA or watts. Convert b/w VA and watt if necessary (VA = watts / Power factor).
- Safety margin:- Apply a safety margin to account for future growth, efficiency losses, and to ensure the UPS operates.