ENGINEER'S PATHSHALA

SUGGESTION

OF

ELECTRICAL TESTING AND COMMISIONING

FOR

EVEN SEMESTER (6TH SEM)_DEE_3RD YEAR_2026

Engineers PATHSHALA

Unit : 1 Fundamentals of instrumentation

1: What are the general safety measures to follow when using domestic electrical appliances?

General safety measures while using domestic electrical appliances:

1. Always keep appliances dry and avoid touching them with wet hands.
2. Check wires, cords, and plugs regularly for damage before use.
3. Do not overload sockets to prevent overheating and fire hazards.
4. Ensure proper earthing of appliances with metal bodies.
5. Switch off and unplug appliances when not in use.
6. Handle plugs carefully; pull from the plug, not the cord.
7. Keep appliances away from children and use safety covers on sockets.
8. Use appliances according to their rated voltage and instructions.

2: Explain the key precautions one should take when handling high-voltage domestic appliances.

Key precautions when handling high-voltage domestic appliances:

1. Never touch appliances with wet hands or use them in damp areas.
2. Ensure proper earthing to prevent electric shock.
3. Use insulated tools and wear rubber-soled footwear while handling.
4. Switch off the main power supply before cleaning or repairing.
5. Do not use damaged wires, loose plugs, or faulty sockets.
6. Avoid overloading circuits to prevent overheating and fire.
7. Maintain safe distance and avoid direct contact with live parts.
8. Follow manufacturer instructions and safety guidelines strictly.

3: How can you ensure the safety of electrical appliances to prevent electric shocks and fires in a household?

To ensure safety of electrical appliances and prevent electric shocks and fires in a household:

1. Use properly insulated and good-quality wires, plugs, and appliances.
2. Ensure proper earthing of all appliances, especially those with metal bodies.
3. Avoid overloading sockets and use appropriate fuses or circuit breakers.
4. Keep appliances away from water and never operate with wet hands.
5. Regularly inspect and replace damaged cords or faulty equipment.
6. Switch off and unplug appliances when not in use.
7. Install safety devices like MCBs and fuses to prevent short circuits.
8. Keep inflammable materials away from electrical appliances.

4: What are the key safety practices that must be followed during electrical equipment maintenance in a power station or substation?

Key safety practices during electrical equipment maintenance in a power station or substation:

1. **Isolate and de-energize** the equipment before maintenance (switch off, lockout–tagout).
2. **Ensure proper earthing/grounding** to discharge residual or induced voltage.
3. Use **personal protective equipment (PPE)** like insulated gloves, helmets, and safety shoes.
4. Use **insulated tools** and tested equipment only.
5. Display **warning signs and barricade** the work area to prevent unauthorized access.
6. Follow proper **permit-to-work procedures** and safety protocols.
7. Maintain safe **clearance distance** from live parts and high-voltage lines.
8. Ensure good **communication and supervision** among maintenance staff.

5: What steps should be taken to prevent electrical accidents when operating electrical systems in industrial environments?

Steps to prevent electrical accidents in industrial environments:

1. **Ensure proper installation and insulation** of all wiring and equipment.
2. **Use protective devices** like fuses, MCBs, and circuit breakers to prevent overload and short circuit.
3. **Provide proper earthing/grounding** of machines and electrical systems.
4. **Follow lockout–tagout (LOTO)** procedures before maintenance or repairs.
5. Use **personal protective equipment (PPE)** such as insulated gloves, helmets, and safety shoes.
6. **Avoid overloading circuits** and operate equipment within rated limits.
7. Conduct **regular inspection and maintenance** of electrical systems.
8. Ensure **trained personnel and clear safety instructions/signage** in the workplace.

6: Explain the importance of personal protective equipment (PPE) in the electrical industry.

Importance of Personal Protective Equipment (PPE) in the electrical industry:

1. PPE protects workers from **electric shocks, burns, and arc flash hazards**.
2. It provides **insulation** from live electrical parts, reducing risk of injury.
3. Equipment like helmets and face shields protect against **sparks and flying debris**.
4. Safety shoes and gloves help prevent **current flow through the body**.
5. PPE ensures **compliance with safety standards** and reduces workplace accidents.
6. It increases **worker confidence and efficiency** in hazardous environments.

7: Explain the first aid steps to take when a person receives an electric shock.

When a person receives an electric shock, quick action is needed to ensure safety. First, switch off the power supply and avoid direct contact; use a non-conductive object to separate the victim. Then check breathing and pulse, give CPR if needed, and call for medical help. Keep the person calm and treat burns with a clean, dry cloth.

The steps to be followed are:

1. Switch off the power supply immediately.
2. Do not touch the victim directly; use a non-conductive object.
3. Check breathing and pulse; perform CPR if required.
4. Call for medical help immediately.
5. Lay the person down and keep them warm.
6. Cover burns with a clean, dry cloth.
7. Do not give food or water if the person is unconscious.

8: What are the techniques for providing CPR (Cardiopulmonary Resuscitation) to a victim of an electric shock?

CPR (Cardiopulmonary Resuscitation) is a life-saving technique used when a person's breathing or heartbeat stops due to electric shock. After ensuring the power supply is switched off and the area is safe, the rescuer should check the victim's **response, breathing, and pulse**. If the victim is not breathing, CPR should be started immediately by giving **chest compressions and rescue breaths** to maintain blood circulation and oxygen supply to the brain until medical help arrives.

The techniques to be followed are:

1. Ensure power is off and place the victim on a flat, firm surface.
2. Check responsiveness, breathing, and pulse.
3. Begin chest compressions at the center of the chest (about 100–120 per minute).
4. Press hard and deep (about 5–6 cm) and allow full chest recoil.
5. Give 30 compressions followed by 2 rescue breaths.
6. Tilt the head back and lift the chin before giving breaths.
7. Continue CPR cycles (30:2) until the person recovers or medical help arrives.

9: Describe the different types of fire extinguishers and their application in electrical fires.

Fire extinguishers are classified based on the type of fire they are designed to control, and correct selection is critical in electrical fires to avoid electric shock and equipment damage. Extinguishers like **CO_2 and clean agents** displace oxygen and cool the fire without harming equipment, while **dry chemical powder** interrupts the combustion process effectively. Water and foam are generally unsafe for energized systems due to conductivity. Understanding these types ensures **quick, safe, and effective fire control** in electrical environments.

Types and applications in electrical fires:

1. **CO_2 (Carbon Dioxide) Extinguisher –** Ideal for live electrical fires; non-conductive, leaves no residue, suitable for panels and servers.
2. **Dry Chemical Powder (DCP) Extinguisher –** Effective on electrical fires; breaks the chemical chain reaction, widely used in industries.
3. **Clean Agent Extinguisher (e.g., Halon substitutes) –** Best for sensitive equipment; non-conductive, no residue, protects electronics.
4. **Foam Extinguisher –** Not suitable for live electrical fires; usable only after power is disconnected.
5. **Water Extinguisher –** Never used on electrical fires unless supply is completely isolated.

10: What is the importance of regular inspection and maintenance of electrical equipment to avoid accidents?

Regular inspection and maintenance of electrical equipment are essential to ensure safe and reliable operation.

The importance of regular inspection and maintenance**:**

1. Detects faults early and prevents accidents.
2. Reduces risk of electric shock, fire, and short circuits.
3. Ensures proper functioning and efficiency of equipment.
4. Increases lifespan of electrical appliances and systems.
5. Minimizes downtime and costly repairs.
6. Ensures compliance with safety rules and standards.
7. Improves overall safety in domestic and industrial environments.

It also improves efficiency, extends the lifespan of equipment, and ensures compliance with safety standards. Proper maintenance reduces unexpected breakdowns and creates a safer working environment.

Unit : 2 Installation and Erection

1. **Explain the concept and importance of a foundation for the installation of machinery. Discuss the specific requirements for foundations used for static and rotating electrical machinery. How do these foundations contribute to the effective functioning and longevity of machinery?**

A **foundation** is the base structure on which electrical machinery is installed, designed to support its weight and ensure stability during operation. A well-designed foundation distributes loads uniformly to the ground, prevents settlement, and minimizes vibration. It is essential for maintaining proper alignment of machines, reducing wear and tear, and ensuring safe and efficient operation. For electrical machinery, especially heavy and high-speed equipment, the foundation plays a crucial role in absorbing shocks and vibrations, thereby enhancing performance and increasing service life.

Specific requirements for foundations:

1. For Static Electrical Machinery (e.g., transformers):

- Must be **strong and rigid** to support heavy weight.
- Should provide **uniform load distribution** to avoid uneven settlement.
- Requires **good ventilation and oil drainage arrangements** (for transformers).
- Should be **fire-resistant and moisture-proof**.
- Must ensure **proper earthing provision** for safety.

2. For Rotating Electrical Machinery (e.g., motors, generators):

- Should be **robust and vibration-resistant**.
- Must maintain **accurate alignment** of shafts and couplings.
- Requires **proper anchoring (foundation bolts)**.
- Should have **adequate damping** to absorb dynamic forces.
- Must prevent resonance and ensure smooth operation.

Contribution to effective functioning and longevity:

1. Maintains proper alignment and reduces mechanical stress.
2. Minimizes vibration, noise, and chances of damage.
3. Prevents premature wear and breakdown of components.
4. Ensures safe and stable operation of machinery.
5. Increases efficiency and service life of equipment.
6. Reduces maintenance costs and operational interruptions.

2. **Describe the concept of levelling and alignment in the installation of machinery, especially in direct-coupled drives. What procedures are involved in levelling and aligning? Discuss the effects of misalignment on machinery performance.**

Levelling and alignment are essential steps in machinery installation to ensure smooth and efficient operation. **Levelling** means adjusting the machine so that its base is perfectly horizontal, ensuring uniform load distribution. **Alignment** refers to positioning two or more connected shafts (as in direct-coupled drives) so that their center lines coincide. Proper levelling and alignment reduce vibration, prevent undue stress on bearings and couplings, and improve efficiency. In direct-coupled drives, accurate alignment is especially important because even small errors can lead to serious mechanical problems.

Procedures involved in levelling and aligning:

1. Place the machine on the foundation and check level using a spirit level.
2. Adjust using shims or wedges until the base is perfectly horizontal.
3. Tighten foundation bolts gradually and recheck the level.
4. Align shafts using straight edge, feeler gauge, or dial indicator.
5. Check both **parallel (offset)** and **angular alignment**.
6. Make necessary adjustments by adding/removing shims.
7. Recheck alignment after tightening and during trial run.

Effects of misalignment on machinery performance:

1. Causes excessive vibration and noise.
2. Leads to overheating and increased power consumption.
3. Results in rapid wear of bearings, seals, and couplings.
4. May cause shaft bending or failure.
5. Reduces efficiency and service life of the machine.
6. Increases maintenance cost and risk of breakdown.

3. **Discuss the installation process of transformers as per I.S. 10028 (Part II): 1981 Reaffirmed 2021. What are the key precautions to be taken during the installation? Explain the significance of site preparation, cabling, bushings, and cable boxes**

The installation of transformers as per Bureau of Indian Standards **IS 10028 (Part II): 1981 (Reaffirmed 2021)** involves systematic procedures to ensure safe, reliable, and efficient operation. Proper installation is critical because transformers are sensitive, high-value equipment, and incorrect handling can lead to insulation failure, oil leakage, or operational hazards. The process includes careful site preparation, correct positioning, proper connection of cables and accessories, and thorough inspection before commissioning.

Installation process (as per standard practice):

1. **Site preparation –** Ensure a firm, level, and fire-resistant foundation with proper drainage and ventilation.
2. **Positioning of transformer –** Place the transformer correctly on the foundation and secure it firmly.
3. **Assembly of accessories –** Fix radiators, conservator, breather, and other fittings properly.
4. **Oil filling and checking –** Fill insulating oil (if required) and check for moisture and leakage.
5. **Earthing –** Provide proper earthing for tank and neutral for safety.
6. **Electrical connections –** Connect incoming and outgoing cables securely.
7. **Testing and commissioning –** Perform insulation resistance, ratio test, and functional checks before energizing.

Key precautions during installation:

1. Avoid moisture entry into insulation and oil.
2. Handle bushings and accessories carefully to prevent damage.
3. Ensure all bolts, joints, and connections are tight.
4. Maintain cleanliness to prevent contamination.
5. Follow proper lifting and handling procedures.
6. Verify earthing and protective devices before energizing.

Significance of important aspects:

- **Site Preparation:**
  Ensures stability, proper load distribution, fire safety, and easy maintenance access.
- **Cabling:**
  Proper cable selection and termination prevent overheating, faults, and power loss.
- **Bushings:**
  Provide insulated passage for conductors through the transformer tank; critical for safe operation.
- **Cable Boxes:**
  Protect cable connections from environmental factors and ensure safe, organized terminations.

4. **Discuss the precautions to be taken while drying transformers during installation. What methods are commonly used for drying, and why is this process crucial for transformer performance?**

Drying of transformers during installation is a critical process to remove **moisture from insulation and winding**, as the presence of moisture reduces dielectric strength and may lead to insulation failure or short circuits. During transport or storage, transformers can absorb moisture, so proper drying ensures reliable operation, higher efficiency, and longer service life.

Precautions during drying:

1. Ensure the transformer is **properly sealed** to avoid entry of moisture during the process.
2. Maintain **controlled temperature** to prevent overheating of insulation.
3. Monitor **insulation resistance (IR values)** regularly during drying.
4. Avoid **exposure to atmosphere** after drying is completed.
5. Use clean and dry **insulating oil** if oil filling is involved.
6. Ensure **uniform heating** of windings to avoid damage.
7. Follow manufacturer and standard guidelines strictly.

Common methods of drying:

1. **Hot air drying –** Circulating hot air through the transformer to remove moisture.
2. **Vacuum drying –** Removing moisture under vacuum; highly effective method.
3. **Oil circulation method –** Heating and circulating insulating oil to absorb moisture.
4. **Short-circuit (current) method –** Passing controlled current through windings to generate heat.
5. **Infrared or oven drying –** Used for smaller transformers or components.

Why drying is crucial:

1. Improves **insulation strength** and prevents dielectric failure.
2. Reduces risk of **short circuits and breakdowns**.
3. Enhances **efficiency and reliability** of the transformer.
4. Increases **service life** of insulation and equipment.
5. Ensures safe and trouble-free operation after commissioning.

5. **Explain the installation requirements for induction motors as per I.S. 900: 1992. What are the key steps involved in the installation of motors and control apparatus? Discuss the importance of drying out and commissioning processes.**

The installation of induction motors as per Bureau of Indian Standards **IS 900: 1992** ensures safe, efficient, and reliable operation of motors and their control gear. Proper installation is important to avoid mechanical stress, electrical faults, and premature failure. The process involves correct site preparation, proper mounting, accurate alignment, safe electrical connections, and thorough inspection before starting.

Key steps in installation of motors and control apparatus:

1. **Site preparation –** Provide a clean, dry, well-ventilated location with a strong and level foundation.
2. **Mounting of motor –** Fix the motor securely on the foundation using foundation bolts.
3. **Levelling and alignment –** Ensure correct alignment with the driven equipment to avoid vibration.
4. **Installation of control gear –** Properly install starters, switches, and protective devices.
5. **Electrical connections –** Connect cables as per rating and ensure tight, insulated connections.
6. **Earthing –** Provide effective earthing for motor body and control panel.
7. **Inspection –** Check bearings, lubrication, insulation resistance, and mechanical parts.

Importance of drying out:

- Removes **moisture from windings**, improving insulation resistance.
- Prevents **insulation failure and short circuits**.
- Ensures safe operation, especially after long storage or damp conditions.

Importance of commissioning:

- Verifies proper installation and functioning before full operation.
- Includes **trial run, checking vibration, temperature, and current**.

- Helps detect faults early and ensures reliable performance.
- Confirms safety of protective devices and control systems.

Unit: 3 Testing and Commissioning

1. Discuss the objectives of testing and commissioning in electrical systems.

Testing and commissioning are essential stages carried out before putting an electrical system into service to ensure that it operates **safely, correctly, and efficiently**. Testing verifies that equipment meets design specifications, while commissioning ensures proper integration and performance under actual working conditions.

Objectives of testing and commissioning:

1. Verify **correct installation** as per design and standards.
2. Ensure **safety of equipment and personnel**.
3. Detect and rectify **faults or defects** before operation.
4. Confirm **proper functioning of all components and systems**.
5. Check **insulation strength, continuity, and protection systems**.
6. Ensure **reliable and efficient performance** under load conditions.
7. Validate **control and protection schemes**.
8. Minimize **risk of failure, breakdown, and downtime**.

2. Describe the methods of testing: direct testing, indirect testing, and regenerative testing.

Methods of testing in electrical systems:

1. Direct Testing:

1. Equipment is tested under **actual working conditions**.
2. Input is supplied and **output is measured directly**.
3. Used for determining **efficiency and performance** accurately.
4. Requires **large power** and may be costly for big machines.
5. Example: Load test on motors and transformers.

2. Indirect Testing:

1. Performance is determined by **measuring losses instead of full-load output**.
2. Does not require full-load conditions.
3. More **economical and convenient**, especially for large machines.
4. Efficiency is calculated from **known losses**.
5. Example: Open-circuit and short-circuit tests of transformers.

3. Regenerative Testing (Back-to-back testing):

1. Two identical machines are **mechanically and electrically coupled**.
2. Power circulates between machines; only **losses are supplied from source**.
3. Highly **energy-efficient method** for testing large machines.
4. Provides **full-load conditions without large power consumption**.
5. Example: Hopkinson's test for DC machines.

3. What are the factors affecting the life of insulating materials in electrical machines and transformers?

Factors affecting the life of insulating materials in electrical machines and transformers:

1. **Temperature (Overheating):** High temperature accelerates insulation ageing and reduces dielectric strength.
2. **Moisture (Humidity):** Presence of moisture lowers insulation resistance and may cause leakage currents.
3. **Electrical Stress:** Overvoltage, surges, and continuous high electric stress weaken insulation over time.
4. **Mechanical Stress:** Vibration, expansion, and contraction can cause cracks and deterioration.
5. **Contamination:** Dust, oil impurities, and chemicals degrade insulation properties.
6. **Oxidation and Ageing:** Exposure to oxygen leads to chemical breakdown of insulating materials.
7. **Overloading:** Continuous operation beyond rated load increases temperature and accelerates damage.
8. **Poor Maintenance:** Lack of regular inspection and cleaning reduces insulation life.
9. **Radiation and Environmental Conditions:** Exposure to UV rays or harsh environments can deteriorate insulation.
10. **Quality of Insulating Material:** Inferior material degrades faster compared to high-quality insulation.

4. Classify insulating materials as per IS:1271-1985 (Reaffirmed 2001), and discuss their aging factors and thermal classes.

Classification of insulating materials (as per Bureau of Indian Standards IS:1271–1985, Reaffirmed 2001):

Insulating materials are classified based on their **thermal endurance (maximum permissible temperature)**:

1. **Class Y (90°C) –** Cotton, silk, paper (untreated organic materials).
2. **Class A (105°C) –** Impregnated paper, cotton, silk with varnish or oil.
3. **Class E (120°C) –** Synthetic resins, enamelled wires.
4. **Class B (130°C) –** Mica, glass fibre with suitable binders.
5. **Class F (155°C) –** Improved mica, glass fibre with epoxy resins.
6. **Class H (180°C) –** Silicone rubber, glass fibre with silicone binders.
7. **Class C (>180°C) –** Mica, porcelain, quartz (inorganic materials).

Aging factors affecting insulating materials:

1. **Thermal stress –** High temperature accelerates ageing (most critical factor).
2. **Electrical stress –** Overvoltage and surges weaken insulation.
3. **Moisture –** Reduces insulation resistance and dielectric strength.
4. **Mechanical stress –** Vibration and expansion cause cracks.
5. **Chemical effects –** Oxidation and contamination degrade materials.

Thermal classes (significance):

1. Define the **maximum safe operating temperature** of insulation.
2. Higher class insulation provides **longer life at higher temperatures**.
3. Exceeding temperature limits causes **rapid deterioration and failure**.
4. Helps in **selection of suitable insulation for machines and transformers**.

5. Explain the different methods of determining temperature rise, such as the back-to-back test and open delta test.

Methods of determining temperature rise in electrical machines and transformers:

1. Back-to-Back Test (Regenerative / Sumpner's Test):

1. Two identical transformers are connected in **parallel on no-load**.
2. Their secondaries are connected in **opposition (back-to-back)**.
3. Circulating current is adjusted to produce **full-load current**.
4. Only **losses (iron + copper)** are supplied from the source.
5. Temperature rise is measured under **full-load conditions without actual loading**.
6. It is **economical and accurate** for large transformers.

2. Open Delta Test (V–V Connection):

1. Used when only **two transformers** are available in a three-phase system.
2. Transformers are connected in **open delta (V–V)** configuration.
3. Load is applied and **temperature rise is observed**.
4. Each transformer carries **higher load (about 57.7% capacity of delta system)**.
5. Helps in studying **heating effects under practical load conditions**.

6. Discuss the high voltage test, temperature-rise test, no-load test, and locked rotor test as per IS:4029-2010 for three-phase induction motors.

Tests on three-phase induction motors (as per Bureau of Indian Standards IS:4029–2010):

1. High Voltage Test (Dielectric Test):

1. A high voltage is applied between **windings and earth (frame)**.
2. Ensures **insulation strength** and dielectric integrity.
3. No breakdown or flashover should occur during the test.
4. Confirms safety against **overvoltage conditions**.

2. Temperature-Rise Test:

1. Motor is run at **rated load** until steady temperature is reached.
2. Temperature of windings is measured by **resistance method or sensors**.
3. Ensures temperature remains within **permissible limits of insulation class**.
4. Indicates proper cooling and safe operation.

3. No-Load Test:

1. Motor is run at **rated voltage without load**.
2. Measures **no-load current, power, and losses (core + mechanical)**.
3. Helps determine **efficiency and performance characteristics**.
4. Checks for abnormal noise or vibration.

4. Locked Rotor Test (Blocked Rotor Test):

1. Rotor is **mechanically locked** to prevent rotation.
2. Reduced voltage is applied to circulate **rated current**.
3. Measures **input power, current, and impedance**.
4. Used to calculate **starting torque and copper losses**.
5. Ensures motor can withstand starting conditions safely.

7. Discuss the high voltage testing methods for synchronous machines as per IS 7132-1973.

High voltage testing methods for synchronous machines (as per Bureau of Indian Standards IS 7132:1973):

1. Power Frequency High Voltage Test (AC Withstand Test):

1. AC voltage of specified magnitude is applied between **windings and earth**.
2. Duration is usually **1 minute**.
3. Ensures **dielectric strength of insulation**.
4. No breakdown or flashover should occur.

2. DC High Voltage Test:

1. High DC voltage is applied across **insulation system**.
2. Leakage current is measured during the test.
3. Used to assess **insulation condition and absorption characteristics**.

3. Impulse Voltage Test (Lightning Impulse Test):

1. Simulates **lightning or switching surges** using impulse waves.
2. Applied mainly to **stator windings**.

3. Ensures insulation can withstand **transient overvoltages**.

4. Insulation Resistance (IR) Test:

1. Performed using a **megger**.
2. Measures resistance between **windings and earth**.
3. Indicates **health of insulation** before HV testing.

5. Polarization Index (PI) Test:

1. Ratio of insulation resistance at **10 min to 1 min**.
2. Helps assess **moisture and ageing condition** of insulation.

8. List and describe the type, routine, and acceptance tests of single-phase induction motors as per IS:996-2009.

Tests of single-phase induction motors (as per Bureau of Indian Standards IS:996–2009):

1. Type Tests *(Design verification tests)*

1. **Temperature-rise test** – Motor is run under rated conditions until steady temperature is reached to ensure insulation operates within safe limits.
2. **Efficiency and performance test** – Determines output power, losses, and efficiency to verify design performance.
3. **Locked rotor test** – Rotor is locked and reduced voltage is applied to measure starting current and torque characteristics.
4. **No-load test** – Motor runs without load to measure no-load current, power, and core losses.
5. **High voltage test** – High voltage is applied to check insulation strength and dielectric safety.
6. **Speed and slip test** – Confirms that motor speed and slip are within specified limits.

2. Routine Tests *(Conducted on every motor)*

1. **Insulation resistance (IR) test** – Measures resistance between winding and earth to ensure insulation health.
2. **High voltage test** – Ensures insulation can withstand specified voltage without failure.
3. **No-load test** – Checks normal operation, current, and input power without load.
4. **Winding resistance test** – Verifies continuity and detects loose or faulty connections.

3. Acceptance Tests *(In presence of purchaser)*

1. **Verification of ratings** – Confirms nameplate details like voltage, current, and power rating.
2. **No-load test** – Ensures proper running condition and acceptable current.
3. **Insulation resistance and HV test** – Confirms safety and insulation integrity.
4. **Locked rotor test (if specified)** – Checks starting characteristics as per agreement.
5. **Temperature-rise test (if required)** – Ensures heating is within permissible limits.

Unit: 4 Troubleshooting Plans

1) Discuss in detail the internal and external causes of failure in electrical equipment. Provide examples for each type.

Internal and external causes of failure in electrical equipment:

1. Internal Causes (Originating within the equipment):

1. **Insulation failure** – Ageing, overheating, or manufacturing defects reduce dielectric strength (e.g., winding insulation breakdown in a transformer).
2. **Overheating** – Due to overloading or poor cooling, leading to damage of windings (e.g., motor winding burnout).
3. **Mechanical defects** – Bearing failure, rotor imbalance, or misalignment causing vibration and wear.
4. **Loose connections** – Internal joints becoming loose, leading to sparking and heating.
5. **Manufacturing defects** – Poor quality materials or improper assembly (e.g., defective insulation in cables).
6. **Core faults** – Shorted laminations in transformers increasing losses and heating.

2. External Causes (Due to outside influences):

1. **Overvoltage and surges** – Lightning or switching surges damaging insulation.
2. **Overloading** – Excess load causing overheating and insulation deterioration.
3. **Environmental conditions** – Moisture, dust, chemicals leading to insulation degradation.
4. **Improper maintenance** – Lack of inspection causing undetected faults.
5. **Mechanical damage** – Physical impact, vibration, or mishandling (e.g., cable damage during installation).
6. **Short circuits and faults** – External faults stressing equipment beyond limits.

2) Describe a systematic approach to identifying internal vs. external causes in troubleshooting electrical machinery.

A systematic approach to troubleshooting helps in clearly distinguishing whether a fault is **internal (within the machine)** or **external (supply/environment related)**. The process should follow a logical sequence from simple checks to detailed analysis to avoid misdiagnosis.

Systematic troubleshooting approach:

1. **Observe symptoms –** Note abnormal signs like overheating, noise, vibration, tripping, or smell.
2. **Check external supply conditions –** Verify voltage, frequency, phase sequence, and load conditions.
3. **Inspect external components –** Examine cables, terminals, protection devices, and connections.
4. **Isolate the machine –** Disconnect from supply to separate internal faults from external influences.
5. **Perform electrical tests –** Insulation resistance (IR), continuity, winding resistance, and current tests.
6. **Perform mechanical checks –** Bearings, alignment, shaft rotation, and lubrication.
7. **Compare with standards/records –** Check readings with rated values or past data.
8. **Identify root cause –** Classify fault as internal or external based on findings.

Comparison of Internal vs External Fault Identification:

Aspect	Internal Cause	External Cause
Source of fault	Inside equipment (winding, insulation, bearings)	Outside equipment (supply, environment, load)
Supply condition	Usually normal	Often abnormal (over/under voltage, imbalance)
Isolation test	Fault persists after isolation	Fault disappears after isolation
Example	Winding short, insulation failure	Voltage fluctuation, overload
Repair action	Requires repair/replacement of machine parts	Correct supply, load, or environment

3) List and explain common mechanical, electrical, and magnetic faults in electrical machines. Suggest appropriate remedies for each.

Common faults in electrical machines and their remedies:

1. Mechanical Faults:

1. **Bearing failure –** Caused by wear, poor lubrication, or misalignment.
   Remedy: Proper lubrication, alignment, and timely replacement of bearings.
2. **Rotor imbalance –** Leads to vibration and noise.
   Remedy: Dynamic balancing of rotor.
3. **Misalignment –** Improper alignment with driven equipment.
   Remedy: Correct levelling and alignment using proper tools.
4. **Loose parts –** Causes vibration and mechanical damage.
   Remedy: Tighten bolts and fittings regularly.

2. Electrical Faults:

1. **Insulation failure –** Due to ageing, overheating, or moisture.
   Remedy: Drying, rewinding, or replacing insulation.
2. **Short circuit in windings –** Causes overheating and damage.
   Remedy: Locate fault and repair or rewind winding.
3. **Open circuit –** Break in winding or connection.
   Remedy: Identify and reconnect or repair the broken conductor.
4. **Overloading –** Excess current leading to overheating.
   Remedy: Operate within rated load and use protection devices.

3. Magnetic Faults:

1. **Core losses increase –** Due to damaged laminations or insulation.
   Remedy: Repair or replace core laminations.
2. **Air gap irregularity –** Uneven magnetic field causing vibration.
   Remedy: Adjust and maintain uniform air gap.
3. **Flux imbalance –** Caused by supply imbalance or winding faults.
   Remedy: Correct supply conditions and repair windings.
4. **Hysteresis and eddy current losses –** Due to poor material or damage.
   Remedy: Use proper core material and maintain insulation between laminations.

So, Proper identification and timely remedies of mechanical, electrical, and magnetic faults help in **improving performance, reducing failures, and increasing the life of electrical machines**.

4) Compare mechanical and electrical faults in rotating machines with respect to symptoms, causes, and troubleshooting methods.

Mechanical faults mainly affect **physical movement and structure**, while electrical faults affect **current flow and insulation**.

Comparison of mechanical and electrical faults in rotating machines:

Aspect	Mechanical Faults	Electrical Faults
Symptoms	Excessive vibration, noise, overheating of bearings, shaft misalignment	Overheating of windings, sparking, abnormal current, tripping
Nature of fault	Related to moving/mechanical parts	Related to electrical circuits and insulation
Common causes	Bearing wear, misalignment, imbalance, poor lubrication	Insulation failure, short circuit, open circuit, overloading
Effect on machine	Mechanical damage, reduced efficiency, noise	Electrical damage, loss of performance, possible burnout
Detection methods	Visual inspection, vibration analysis, alignment check	Electrical tests (IR, continuity, current measurement)
Troubleshooting methods	Lubrication, tightening, balancing, alignment correction	Rewinding, insulation repair, correcting connections, load control
Maintenance type	Mechanical maintenance	Electrical maintenance

So, Proper identification helps in applying the correct troubleshooting method and ensures reliable operation.

5) **Describe the process of diagnosing magnetic faults in motors and transformers and suggest corrective measures.**

Diagnosis of Magnetic Faults in Motors:

Diagnosis process:

1. Observe **symptoms** – vibration, humming noise, overheating, unbalanced torque.
2. Measure **no-load current** – higher value indicates magnetic imbalance.
3. Check **air gap uniformity** – uneven air gap causes unbalanced magnetic pull.
4. Verify **supply voltage balance** – imbalance affects flux distribution.
5. Inspect **stator and rotor core** for damage or looseness.

Common faults and remedies:

1. **Air gap irregularity** - Rotor eccentricity, misalignment
   - **Remedy:** Correct alignment and maintain uniform air gap
2. **Flux imbalance** - Unbalanced supply or winding fault
   - **Remedy:** Balance supply and repair windings
3. **Core losses increase** - Damaged laminations
   - **Remedy:** Repair or replace core laminations
4. **Magnetic noise and vibration** - Loose core or uneven flux
   - **Remedy:** Tighten core and correct imbalance

B. Diagnosis of Magnetic Faults in Transformers:

Diagnosis process:

1. Observe **symptoms** – overheating, abnormal humming, reduced efficiency.
2. Measure **no-load current and losses** – increase indicates core issues.
3. Perform **core loss test** to detect eddy current and hysteresis losses.
4. Inspect **core laminations and insulation** condition.
5. Use **thermal scanning** to identify hotspots.

Common faults and remedies:

1. **Increased core loss** - Lamination insulation failure
   - **Remedy:** Re-insulate or repair core
2. **Hotspots in core** - Shorted laminations
   - **Remedy:** Locate and repair affected area
3. **Flux leakage or imbalance** - Core defects or improper assembly
   - **Remedy:** Correct core structure and assembly
4. **Excessive noise (humming)** - Loose core or magnetic vibration
   - **Remedy:** Tighten core and clamps

6) **Describe the steps involved in preparing a troubleshooting plan for electrical equipment failure.**

Steps to prepare a troubleshooting plan for electrical equipment failure:

1. **Define the problem –** Clearly identify symptoms like tripping, overheating, noise, or failure to start.
2. **Collect information –** Gather equipment history, previous faults, maintenance records, and operating conditions.
3. **Ensure safety –** Isolate power supply, follow lockout–tagout (LOTO), and use proper PPE.
4. **Perform preliminary inspection –** Check for visible issues such as loose connections, burnt parts, or damage.
5. **Check external factors –** Verify supply voltage, frequency, load conditions, and environmental effects.
6. **Plan diagnostic tests –** Decide suitable tests (IR test, continuity, voltage, current, etc.).
7. **Isolate the fault –** Separate internal and external causes step-by-step.
8. **Analyze results –** Compare readings with standard or rated values.
9. **Identify root cause –** Determine exact fault location and reason.
10. **Decide corrective action –** Repair, replace, or adjust faulty components.
11. **Test after repair –** Verify proper functioning through trial run.
12. **Document findings –** Record fault, action taken, and recommendations for future prevention.

7) **Explain how troubleshooting documentation helps in preventive maintenance and future problem-solving.**

Troubleshooting documentation records details of faults, tests, causes, and corrective actions taken in electrical equipment. It acts as a valuable reference for maintenance engineers and helps in improving system reliability over time.

How it helps in preventive maintenance and future problem-solving:

1. Provides **history of faults** for quick identification of recurring problems.
2. Helps in **early detection of patterns and trends** leading to failures.
3. Assists in planning **preventive maintenance schedules**.
4. Reduces **diagnosis time** during future breakdowns.
5. Improves **accuracy of troubleshooting decisions**.
6. Serves as a **reference for standard procedures and best practices**.
7. Helps in **training and knowledge sharing** among personnel.
8. Minimizes **downtime and maintenance cost**.

Unit: 5 Maintenance

1.Explain the different types of maintenance. Distinguish between time-based and condition-based preventive maintenance with suitable examples.

Types of maintenance in electrical systems:

1. **Breakdown Maintenance (Corrective Maintenance):**
   - Maintenance is carried out **after failure occurs**.
   - Equipment is repaired or replaced after breakdown.
   - Example: Repairing a motor after it stops working.
2. **Preventive Maintenance:**
   - Maintenance is done **before failure** to avoid breakdown.
   - Includes inspection, cleaning, lubrication, and testing.
   - Example: Periodic inspection of transformers.
3. **Predictive Maintenance (Condition-Based):**
   - Based on **actual condition monitoring** of equipment.
   - Uses data like vibration, temperature, IR values.
   - Example: Replacing bearings when vibration level increases.
4. **Scheduled Maintenance:**
   - Maintenance is performed at **pre-planned intervals**.
   - May be time-based or usage-based.

Difference between Time-Based and Condition-Based Preventive Maintenance:

Aspect	Time-Based Maintenance	Condition-Based Maintenance
Basis	Fixed time intervals	Actual condition of equipment
Approach	Periodic (daily, monthly, yearly)	Monitoring-based
Maintenance action	Done regardless of condition	Done only when required
Cost	May be higher due to unnecessary work	More economical
Reliability	Moderate	High
Example	Changing oil every 6 months	Changing oil when degradation is detected

2.Define preventive maintenance. Discuss the factors affecting preventive maintenance schedules of electrical machines.

Preventive Maintenance:
Preventive maintenance is the **planned and systematic inspection, servicing, and upkeep** of electrical machines carried out at regular intervals to **prevent breakdowns and ensure reliable operation**.

Factors affecting preventive maintenance schedules of electrical machines:

1. **Operating conditions:** Load, duty cycle, and hours of operation affect wear and heating.
2. **Environmental conditions:** Dust, moisture, temperature, and corrosive atmosphere accelerate deterioration.
3. **Type of equipment:** Different machines (motors, transformers) require different maintenance frequency.
4. **Age of equipment:** Older machines need more frequent inspection and servicing.
5. **Manufacturer's recommendations:** Guidelines provided by manufacturers must be followed.
6. **Past maintenance records:** History of faults helps in planning future schedules.
7. **Criticality of equipment:** Machines essential for operation require more frequent maintenance.
8. **Quality of installation:** Poor installation may require frequent maintenance checks.
9. **Operating environment stress:** High voltage, vibration, and thermal stress influence maintenance needs.

3.What is Total Productive Maintenance (TPM)? Describe the key pillars of TPM and explain how TPM helps improve equipment efficiency.

Total Productive Maintenance (TPM):
Total Productive Maintenance (TPM) is a maintenance philosophy that aims to **maximize equipment effectiveness** by involving **all employees (operators, maintenance staff, and management)** in maintaining and improving equipment. It focuses on **zero breakdowns, zero defects, and zero accidents** through proactive and preventive practices.

Pillars of TPM:

1. **Autonomous Maintenance:** Operators perform routine tasks like cleaning, lubrication, and inspection to prevent deterioration.
2. **Planned Maintenance:** Maintenance is scheduled based on time or condition to reduce unexpected failures.
3. **Focused Improvement (Kaizen):** Continuous improvement activities to eliminate losses and increase efficiency.
4. **Quality Maintenance:** Ensures equipment produces defect-free products by maintaining optimal conditions.
5. **Training and Education:** Enhances skills of employees for better operation and maintenance.
6. **Safety, Health, and Environment:** Ensures safe working conditions and reduces accidents.
7. **Early Equipment Management:** Considers maintenance aspects during design and installation of new equipment.
8. **Office TPM:** Applies TPM principles to administrative functions to improve efficiency.

How TPM improves equipment efficiency:

1. Reduces **breakdowns and downtime**.
2. Improves **Overall Equipment Effectiveness (OEE)**.
3. Minimizes **defects and rework**.
4. Enhances **equipment life and reliability**.
5. Promotes **employee involvement and accountability**.
6. Reduces **maintenance cost and production losses**.

4.Describe in detail the preventive maintenance schedule for:
a) Power and Distribution Transformers
b) Three-phase Induction Motors

a) Preventive Maintenance Schedule for Power and Distribution Transformers:

Daily / Routine Checks:

1. Check **oil level** in conservator.
2. Observe **temperature indicators** (oil & winding).
3. Inspect for **oil leakage** and abnormal noise.
4. Check **breather condition** (silica gel color).

Monthly Checks:

1. Clean **bushings and insulators**.
2. Check **earthing connections**.
3. Inspect **cooling system** (fans, radiators).
4. Verify **oil level and condition**.

Quarterly / Half-Yearly Checks:

1. Test **insulation resistance (IR)**.
2. Check **operation of protection devices** (Buchholz relay, alarms).
3. Inspect **gaskets and joints** for leakage.
4. Clean and tighten all **connections and terminals**.

Yearly Maintenance:

1. Conduct **oil testing** (dielectric strength, moisture content, acidity).
2. Perform **winding resistance and ratio test**.
3. Check **core and winding condition** (if required).
4. Overhaul **cooling system and accessories**.

b) Preventive Maintenance Schedule for Three-Phase Induction Motors:

Daily / Routine Checks:

1. Check for **abnormal noise and vibration**.
2. Monitor **temperature and current**.
3. Ensure proper **ventilation and cleanliness**.

Monthly Checks:

1. Inspect and tighten **electrical connections**.
2. Check **bearings and lubrication**.
3. Clean **cooling ducts and fan**.
4. Measure **insulation resistance (IR)**.

Quarterly / Half-Yearly Checks:

1. Check **alignment and coupling**.
2. Inspect **starter and control gear**.
3. Verify **earthing system**.
4. Examine **winding condition** for overheating signs.

Yearly Maintenance:

1. Perform **complete inspection and overhaul**.
2. Check **winding resistance and insulation condition**.
3. Replace or re-grease **bearings** if required.
4. Conduct **performance tests** (no-load, load test).

5.Explain the maintenance practices and schedules for LV and HV switchgear. What are the safety precautions to be followed?

Maintenance practices and schedules for LV and HV switchgear:

A. Low Voltage (LV) Switchgear:

Routine / Daily Checks:

1. Check for **overheating, smell, or abnormal noise**.
2. Observe **indicator lamps and meters**.
3. Ensure **clean and dry condition** of panels.

Monthly Maintenance:

1. Tighten **connections, terminals, and busbars**.
2. Clean **dust and contaminants** from panels.
3. Check **operation of switches and breakers**.
4. Inspect **fuses and protective devices**.

Quarterly / Half-Yearly:

1. Test **insulation resistance (IR)**.
2. Check **contact resistance of breakers**.
3. Inspect **earthing system**.
4. Lubricate **moving parts** of breakers.

Yearly Maintenance:

1. Perform **complete inspection and overhaul**.
2. Test **protective relays and circuit breakers**.
3. Replace worn-out **contacts and components**.
4. Conduct **functional and load tests**.

B. High Voltage (HV) Switchgear:

Routine / Daily Checks:

1. Observe **oil level / gas pressure (SF_6 breakers)**.
2. Check for **abnormal noise, flashover, or leakage**.
3. Monitor **temperature and load conditions**.

Monthly Maintenance:

1. Inspect **insulators and bushings** for cracks or dirt.
2. Check **mechanical operation** of breakers.
3. Verify **control circuits and interlocks**.

Quarterly / Half-Yearly:

1. Measure **insulation resistance and dielectric strength**.
2. Check **contact wear and alignment**.
3. Test **protective relays and tripping circuits**.
4. Inspect **earthing and lightning protection**.

Yearly Maintenance:

1. Conduct **major overhauling of circuit breakers**.
2. Test **oil quality (for oil CBs) or gas quality (SF_6 CBs)**.
3. Perform **high voltage tests and timing tests**.
4. Replace damaged **contacts, seals, and insulation parts**.

Safety precautions to be followed:

1. **Isolate supply** and follow lockout–tagout (LOTO) procedures.
2. Use proper **PPE** (insulated gloves, helmet, safety shoes).
3. Ensure **equipment is properly earthed** before maintenance.
4. Use **insulated tools** and approved testing instruments.
5. Display **warning signs and barricade the area**.
6. Discharge **stored energy** (capacitors, springs, trapped charge).
7. Maintain safe **clearance from live parts**.
8. Only **trained personnel** should perform maintenance.

6.Discuss the importance of preventive maintenance for station batteries. What are the typical maintenance activities involved?

Preventive maintenance of station batteries is essential because they provide **reliable DC supply** for protection, control circuits, emergency lighting, and tripping operations during power failure. Poor battery maintenance can lead to **failure of protection systems**, causing serious damage to electrical equipment and safety risks. Regular maintenance ensures **availability, reliability, and longer service life** of batteries.

Typical maintenance activities for station batteries:

Routine / Daily Checks:

1. Check **battery voltage and charging current**.
2. Observe **electrolyte level** in cells.
3. Inspect for **leakage, corrosion, or damage**.

Monthly Maintenance:

1. Measure **specific gravity** of electrolyte using hydrometer.
2. Clean **terminals and connections** to avoid corrosion.
3. Ensure proper **ventilation** in battery room.
4. Check **float and boost charging system**.

Quarterly / Half-Yearly:

1. Perform **capacity test (if required)**.
2. Check **uniformity of voltage across cells**.
3. Inspect **connectors and tighten terminals**.
4. Verify **charger performance and settings**.

Yearly Maintenance:

1. Conduct **full discharge test (capacity test)**.
2. Replace **weak or defective cells**.
3. Inspect and clean **battery racks and insulation**.
4. Check **overall battery condition and performance**.

7.Compare breakdown maintenance and preventive maintenance. State advantages and disadvantages of both with examples.

Answer:

Comparison between Breakdown Maintenance and Preventive Maintenance:

Aspect	Breakdown Maintenance	Preventive Maintenance
Definition	Maintenance after failure occurs	Maintenance before failure occurs
Approach	Reactive	Proactive
Planning	Unplanned	Planned and scheduled
Downtime	High and unpredictable	Low and controlled
Cost	High (repair + loss of production)	Lower (planned cost)

Aspect	Breakdown Maintenance	Preventive Maintenance
Equipment life	Reduced	Increased
Reliability	Low	High
Example	Repairing a burnt motor after failure	Periodic inspection of transformer oil

Advantages and Disadvantages:

1. Breakdown Maintenance:

Advantages:

1. No initial planning or scheduling required.
2. Useful for **non-critical or low-cost equipment**.

Disadvantages:

1. Causes **unexpected downtime**.
2. Higher **repair and replacement cost**.
3. Risk of **major damage and safety hazards**.
4. Reduces **equipment life and reliability**.

2. Preventive Maintenance:

Advantages:

1. Reduces **breakdowns and downtime**.
2. Improves **efficiency and reliability**.
3. Increases **equipment lifespan**.
4. Enhances **safety of operation**.

Disadvantages:

1. Requires **planning and scheduling**.
2. May involve **unnecessary maintenance** at times.
3. Higher **initial maintenance cost**.

8.What are the steps involved in preparing a preventive maintenance schedule for an industrial plant containing transformers, motors, and switchgear?

Steps for Preparing Preventive Maintenance Schedule – Transformers:

1. Identify all **power and distribution transformers**.
2. Classify based on **capacity and criticality**.
3. Refer manufacturer guidelines and Bureau of Indian Standards standards.
4. Study **load conditions and environment** (temperature, dust, moisture).
5. Review **past oil test and fault records**.
6. Fix schedule:
   - Daily: oil level, temperature
   - Monthly: cleaning bushings
   - Yearly: oil testing, IR, ratio test
7. Plan **oil testing, protection checks, and cooling system maintenance**.
8. Assign manpower, tools, and safety procedures.
9. Record and update maintenance data.

Steps for Preparing Preventive Maintenance Schedule – Motors:

1. List all **motors with ratings and applications**.
2. Classify based on **duty and importance**.
3. Refer manufacturer instructions and standards.
4. Analyze **operating hours, load, and environment**.
5. Check **failure history and maintenance records**.
6. Fix schedule:
   - Daily: noise, vibration
   - Monthly: lubrication, cleaning
   - Yearly: IR test, overhaul
7. Plan **alignment, bearing inspection, and electrical testing**.
8. Allocate personnel and safety measures.
9. Maintain records for future planning.

Steps for Preparing Preventive Maintenance Schedule – Switchgear:

1. Identify all **LV and HV switchgear**.
2. Classify based on **voltage level and critical circuits**.
3. Refer standards and manufacturer guidelines.
4. Study **load conditions and switching frequency**.
5. Review **fault and tripping history**.
6. Fix schedule:
   - Daily: visual inspection
   - Monthly: cleaning, tightening
   - Yearly: relay testing, overhaul
7. Plan **contact inspection, insulation testing, and protection checks**.
8. Ensure safety (LOTO, PPE, isolation).
9. Document maintenance activities and update schedule.

THANK YOU