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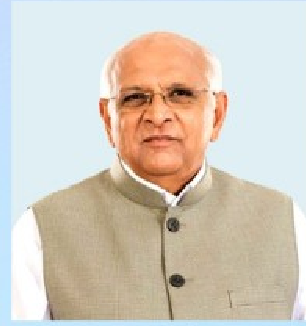

## AI CONTENT FOR

# Electrical Installation Commissioning and Maintenance

## DIPLOMA IN ELECTRICAL ENGINEERING

**Subject Code: 4360901**

**Semester: VI**



**Directorate of Technical Education**

**Gujarat**

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**Index: - Electrical Installation Commissioning and Maintenance (4360901)**

***Page numbers are approximate.***

**Unit–I Study Plan: Installation of Electrical Equipment**

Course: Electrical Installation, Commissioning & Maintenance (4360901)

Total Teaching Hours: 8 Hours

Target CO: CO1 – Install various electrical equipments/machines

| Detailed Topic-wise Study Plan |
|---|

| Sr. No. | Syllabus Topic | Topic Nature | Time (Hrs) | Exam Importance | Practical Relevance | OBE / NEP Alignment |
|---|---|---|---|---|---|---|
| 1 | Unloading of electrical equipment at site | Core | 0.75 | High | Very High | Safety, Skill-based |
| 2 | Inspection of electrical equipment at site | Core | 1.0 | Very High | Very High | Industry QA |
| 3 | Storage of electrical equipment at site | Supporting | 0.75 | Medium | High | Preventive mindset |
| 4 | Foundation for electrical equipment | Core | 1.0 | High | Very High | Engineering application |
| 5 | Alignment of electrical machines | Core/Application | 1.25 | Very High | Extremely High | Hands-on skills |
| 6 | Tools & instruments for installation | Supporting | 0.75 | Medium | High | Employability |
| 7 | Technical report & Field Quality Plan | Application | 1.25 | Very High | Extremely High | Professional practice |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | Installation of Solar & Wind plant | Advanced | 1.25 | High | Very High | Green skills |

Teaching & Learning Notes

This unit emphasizes real-site practices, safety procedures, documentation, and modern renewable energy installations in alignment with NEP-2020 and OBE.

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### 📘 Unit–I Study Plan

**Installation of Electrical Equipment**

**Course:** Electrical Installation, Commissioning & Maintenance (4360901)
**Total Teaching Time: 8 Hours**
**CO Alignment:** CO1 – *Install various electrical equipments/machines*

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### 🎯 Unit Purpose (Motivational Context for Students)

*"A good electrical engineer is judged not only by calculations, but by how safely, correctly, and professionally equipment is installed at site."*
This unit builds **real-site readiness**—from unloading heavy equipment to installing modern solar and wind plants.

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### 🧠 Logical Learning Flow (Simple → Applied)

1. Site handling & inspection
2. Storage & foundation readiness
3. Mechanical precision (alignment)
4. Tools & documentation
5. Industry-standard procedures
6. Renewable energy installations

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### 📊 Detailed Topic-wise Study Plan (As per Syllabus)

#### 🔹 Unit–I: Installation of Electrical Equipment (8 Hours)

| Sr. No. | Syllabus Topic | Topic Nature | Suggested Time (hrs) | Exam Importance | Practical / Industry Relevance | OBE & NEP Alignment |
|---|---|---|---|---|---|---|
| 1 | **Unloading of electrical equipment at site** | Core | 0.75 | High (Short/Long Qs) | Very High – site safety, cranes, rollers | Skill-based, Safety awareness |
| 2 | **Inspection of electrical equipment at site** | Core | 1.0 | Very High | Very High – acceptance testing, damage checks | Industry-readiness, QA mindset |
| 3 | **Storage of electrical equipment at site** | Supporting | 0.75 | Medium | High – insulation protection, moisture control | Preventive maintenance thinking |
| 4 | **Foundation for electrical equipment** | Core | 1.0 | High | Very High – transformers, motors, panels | Engineering application & precision |
| 5 | **Alignment of electrical machines** | Core + Application | 1.25 | Very High | Extremely High – vibration, bearing life | Hands-on competence (Psychomotor) |
| 6 | **Tools & instruments required for installation** | Supporting | 0.75 | Medium | High – spanners, spirit level, dial gauge | Tool literacy & employability |
| 7 | **Technical report, inspection, storage & handling of transformer, switchgear & motors + Standard** | Application-Oriented | 1.25 | Very High | Extremely High – documentation & audits | Professional practice, documentation |

| Sr. No. | Syllabus Topic | Topic Nature | Suggested Time (hrs) | Exam Importance | Practical / Industry Relevance | OBE & NEP Alignment |
|---|---|---|---|---|---|---|
| | **Field Quality Plan** | | | | | |
| 8 | **Standard procedure for installation of domestic & industrial Solar plant and Wind plant** | Advanced / Emerging | 1.25 | High (NEP focus) | Very High – green energy sector | Sustainability, future skills |

✅ **Total = 8 Hours**

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🧩 **Classification of Topics (For Teaching Strategy)**

🔵 **Core Topics (Must-master for Exams & Jobs)**

- Unloading at site
- Inspection at site
- Foundation of equipment
- Alignment of machines

🟢 **Supporting Topics (Strengthen Understanding)**

- Storage of equipment
- Tools & instruments

🔴 **Application / Industry-Oriented Topics**

- Technical reports & Field Quality Plan
- Solar and Wind plant installation

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📝 **Exam Orientation (GTU Pattern Insight)**

- **Frequently Asked:** Inspection steps, alignment, foundation requirements
- **Descriptive Questions:** Handling & storage, technical reports
- **Application Questions:** Solar/wind installation procedures
- **Expected Weightage: ≈14 Marks** from Unit–I

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### 🔧 Practical & Micro-Project Linkage

This unit directly supports:

- Layout preparation before installation
- Tool identification
- Inspection & planning charts
- Solar rooftop maintenance micro-projects

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### 👩‍🏫 Teaching Tip (Mentor Advice)

"Whenever you teach or study this unit, visualize a **real site**—not a classroom. Ask: *What can go wrong if this step is ignored?* That's how engineers think."

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### 📘 Lecture Content

**Unit–I: Installation of Electrical Equipment**

**Topic 1.1 & 1.2 – Unloading of Electrical Equipment at Site & Inspection at Site**

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### 1️⃣ Hook / Introduction (≈ 5 minutes)

*"Before switching ON any electrical machine, the most important work is done when the machine is still OFF."*

Imagine this: a **₹50-lakh power transformer** arrives at site. The crane operator makes one wrong move, or inspection is skipped due to hurry. Result? Hidden internal damage, oil leakage, insulation failure—and a breakdown **before commissioning**.

As future electrical engineers, your responsibility begins **the moment equipment reaches the site**, not after wiring or testing. Today's lecture will teach you **how professionals unload and inspect equipment safely**, preventing accidents, failures, and financial loss.

👉 **Think:** Why do you think most equipment failures are blamed on "manufacturing defects" when the real cause is poor handling?

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## 2️⃣ Core Concepts (≈ 40 minutes)

### 🔹 Part A: Unloading of Electrical Equipment at Site

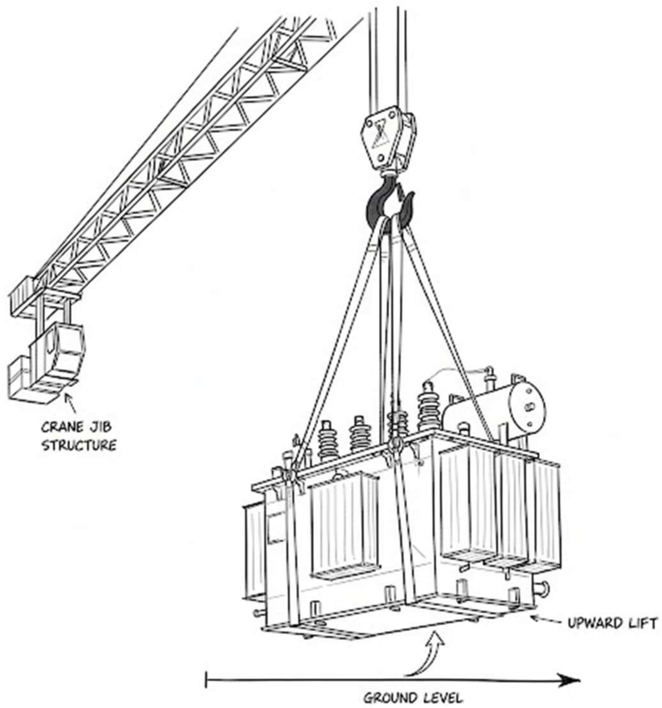
**Unloading** means safely transferring electrical equipment from transport vehicle to its foundation or storage area **without mechanical or electrical damage**.

**Step-by-Step Procedure:**

1. **Pre-unloading planning**
    - Study equipment weight, center of gravity, lifting points
    - Check site layout and foundation readiness
    - Select suitable lifting equipment (crane, chain pulley block, forklift)
2. **Safety precautions**
    - Barricade unloading area
    - Ensure workers wear helmet, gloves, safety shoes
    - Never stand under suspended load (Golden safety rule)
3. **Unloading methods**
    - **Crane unloading** – for transformers, HT motors
    - **Roller method** – slow movement on rails or pipes
    - **Forklift** – small panels and control equipment
4. **Key do's and don'ts**
    - Use manufacturer-provided lifting lugs
    - Avoid jerks and sudden movements
    - Never drag equipment on ground

📌 *Fun Fact:* Most transformer core damages occur not in factories—but during transportation and unloading.

🖊️ **Diagram to draw:**
A labeled sketch showing a transformer being lifted using a crane with slings, hook, and lifting lugs.

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🔹 **Part B: Inspection of Electrical Equipment at Site**

**Inspection** ensures that equipment received is **mechanically sound, electrically safe, and as per specification**.

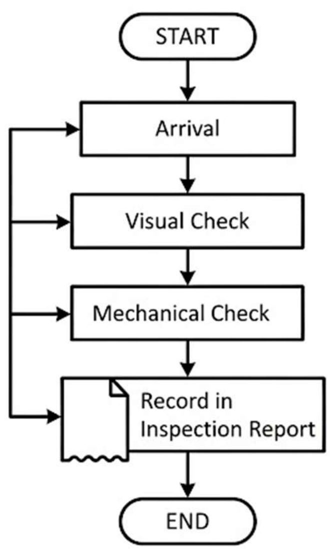
**Types of Inspection:**

1. **Visual Inspection**
   - Check for dents, cracks, rust, oil leakage
   - Inspect bushings, terminals, cooling fins
2. **Mechanical Inspection**
   - Tightness of bolts and nuts

- Alignment of shafts (for rotating machines)
- Free rotation of motor shaft by hand

3. **Electrical Inspection**
    - Insulation resistance using Megger
    - Continuity check of windings
    - Earthing terminals condition
4. **Document Verification**
    - Nameplate data (rating, voltage, current)
    - Test certificates from manufacturer
    - Packing list and delivery challan

🖉 **Flowchart to draw:**
Arrival → Visual Check → Mechanical Check → Electrical Check → Record in Inspection Report

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**3 Real-World / Industry Applications (≈ 10 minutes)**

- In **substations**, engineers prepare a **pre-commissioning checklist** based on unloading and inspection steps.
- In **industries**, failure to inspect motors leads to bearing damage and vibration problems.
- In **solar plants**, improper unloading of inverters causes internal PCB cracks—detected only after failure.

📍 Site engineers who master inspection skills are trusted with **critical assets** and often promoted faster.

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### 4️⃣ Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways:**

- Installation starts **before foundation and wiring**
- Proper unloading prevents mechanical damage
- Inspection detects hidden faults early
- Documentation is as important as physical checks

❓ **Typical Student Doubts:**

- *Is inspection compulsory if equipment is new?* → **Yes**
- *Who is responsible for damage at site?* → **Installation engineer**

---

### 🎓 Mentorship Note (Career Tip)

Mastering unloading and inspection makes you **industry-ready from Day One**. These skills are tested during:

- Site engineer interviews
- Apprenticeships & PSUs
- Commissioning and maintenance roles

👉 Engineers who understand **ground reality**, not just theory, become **leaders on site**.

*"Good engineers install equipment. Great engineers protect it before it ever runs."*

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📘 **Lecture Content**

**Unit–I: Installation of Electrical Equipment**

**Topic 1.3 – Storage of Electrical Equipment at Site**

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## 1️⃣ Hook / Introduction (≈ 5 minutes)

*"If electrical equipment is installed late, but stored wrongly, it will fail early."*

Let me start with a real site story. A brand-new **HT motor** was delivered on time, but installation got delayed by two months. During commissioning, the insulation resistance was found extremely low. Why? The motor was stored **in open air during monsoon** without protection.

So today's question is simple but powerful:
👉 **Can an electrical machine get damaged without even being switched ON?**

Yes—and improper storage is one of the **silent killers** of electrical equipment. This lecture will teach you how engineers **protect equipment during idle time**, which is a critical responsibility at site.

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## 2️⃣ Core Concepts (≈ 40 minutes)

### 🔹 What is Storage of Electrical Equipment?

**Storage** means keeping electrical equipment in a **safe, clean, dry, and controlled condition** from the time it is unloaded until it is installed and commissioned.

Storage is required when:

- Installation is delayed
- Equipment arrives before foundation readiness
- Seasonal or project-based scheduling exists

### 🔹 Objectives of Proper Storage

- Prevent moisture absorption
- Avoid corrosion and rusting
- Protect insulation quality

- Maintain mechanical alignment and finish

---

## ◆ Factors Affecting Storage Conditions

1. **Moisture & Humidity**
    - Moisture reduces insulation resistance
    - Most dangerous during monsoon
2. **Dust & Chemical Fumes**
    - Cement dust, acid fumes damage insulation
    - Common in industrial sites
3. **Temperature Variations**
    - Expansion and contraction cause cracks
    - Affects bushings and seals

---

## ◆ General Storage Guidelines (Step-by-Step)

1. **Location of Storage**
    - Indoor storage preferred
    - Well-ventilated and dust-free room
    - Raised platform to avoid water contact
2. **Protection Methods**
    - Cover equipment with plastic sheets or tarpaulin
    - Use silica gel or heaters for moisture control
    - Apply rust preventive oil on exposed metal parts
3. **Positioning**
    - Motors: store horizontally as recommended
    - Transformers: store upright only
    - Avoid stacking heavy equipment

4. **Electrical Care**
    - Periodic insulation resistance (IR) measurement
    - Rotate motor shafts weekly to avoid bearing damage

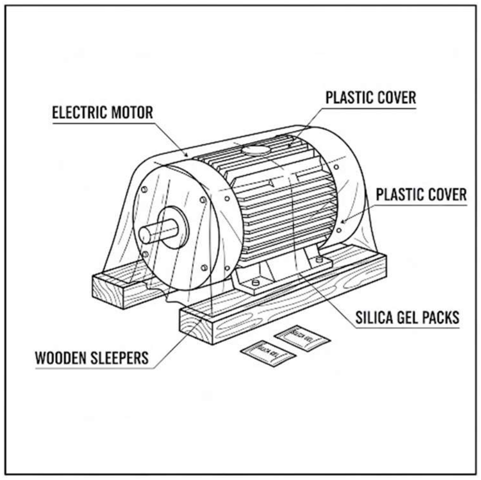
📌 *Fun Fact:* Many manufacturers void warranty if improper storage is recorded in site inspection reports.

---

🔹 **Storage of Specific Equipment**

- **Transformers**
    - Store with oil filled as per manufacturer
    - Seal conservator and breather
    - Check oil level regularly
- **Motors & Generators**
    - Keep windings dry
    - Use space heaters if provided
- **Switchgear & Panels**
    - Store in original packing
    - Protect from dust and insects

🖊️ **Diagram to draw:**
A neat layout showing a motor stored on wooden sleepers, covered with plastic sheet, with silica gel packs placed nearby.

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### 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **power projects**, equipment may be stored for 6–12 months before installation.
- In **thermal power plants**, improper storage causes bearing pitting and insulation failure.
- In **solar plants**, inverters stored in humid conditions develop PCB corrosion.

📍 Site engineers maintain a **Storage Inspection Register** with periodic checks—this document is often audited.

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### 4️⃣ Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways:**

- Storage is as important as installation
- Moisture is the biggest enemy
- Periodic inspection during storage is mandatory
- Proper storage saves money and time

❓ **Typical Student Doubts:**

- *Is storage needed for short duration?* → Yes, even for weeks
- *Can plastic cover alone protect equipment?* → No, moisture control is required

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### 🎓 Mentorship Note (Career Tip)

Engineers who understand **storage practices** are trusted with **high-value equipment** at site. These skills help you in:

- Site engineer roles
- PSU and EPC projects
- Maintenance & reliability engineering

👉 Remember: *"A good engineer installs equipment well. A smart engineer protects it even when idle."*

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### 📘 Lecture Content

**Unit–I: Installation of Electrical Equipment**

**Topic 1.4 – Foundation for Electrical Equipment**

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### 1️⃣ Hook / Introduction (≈ 5 minutes)

*"Would you build a powerful motor on a weak base?"*

Think about a ceiling fan at home. If its clamp is loose, the fan vibrates and makes noise. Now imagine a **5-ton induction motor** or a **power transformer** installed on an uneven or weak foundation. The result is not just noise—it leads to **misalignment, bearing failure, cracks, and accidents**.

So remember this golden rule:
👉 **Strong machines need stronger foundations.**
Today's lecture explains how proper foundations ensure **safety, stability, and long equipment life**.

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### 2️⃣ Core Concepts (≈ 40 minutes)

#### 🔹 What is a Foundation?

A **foundation** is a rigid, stable base on which electrical equipment is installed to:

- Support weight

- Absorb vibrations
- Maintain alignment
- Ensure safe operation

In electrical installations, foundations are usually made of **cement concrete (PCC/RCC)** with embedded **foundation bolts**.

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◆ **Objectives of a Proper Foundation**

- Prevent vibration and noise
- Maintain accurate alignment
- Avoid settlement and tilting
- Increase service life of equipment

📌 *Fun Fact:* Many motor failures blamed on "poor bearings" are actually due to **bad foundations**.

---

◆ **Types of Foundations (Diploma Level)**

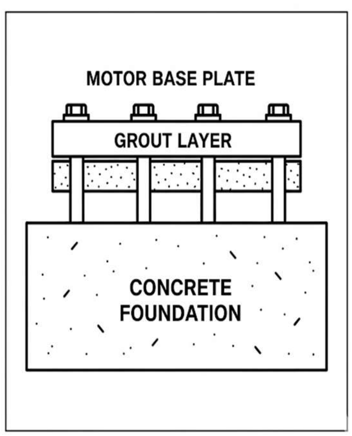
1. **Block Foundation**
    - Used for motors, generators
    - Simple concrete block above ground level
2. **Grout Foundation**
    - Grout fills the gap between machine base and concrete
    - Improves load transfer and alignment
3. **Inertia Block Foundation**
    - Heavy foundation to absorb vibrations
    - Used for reciprocating machines

---

◆ **Foundation Preparation – Step by Step**

1. **Site Selection**
    - Solid soil
    - Away from water accumulation
2. **Marking & Excavation**
    - As per foundation drawing
    - Proper depth and dimensions
3. **Concreting**
    - Use specified cement, sand, aggregate
    - Ensure level surface using spirit level
4. **Foundation Bolts**
    - Embedded during concreting
    - Correct spacing and projection height
5. **Curing**
    - Minimum 7–14 days
    - Prevents cracks and improves strength

🖉 **Diagram to draw:**
Cross-section view showing motor base plate, grout layer, foundation bolts, and concrete foundation.



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### ◆ Foundation for Common Electrical Equipment

- **Induction Motor**
    - Flat, level foundation
    - Accurate bolt alignment essential
- **Transformer**
    - Heavy RCC foundation
    - Oil drainage slope provided
- **Switchgear Panels**
    - Channel base frame on concrete
    - Perfect leveling required
- **DG Set**
    - Inertia block to absorb vibration

---

### ◆ Common Foundation Defects

- Uneven surface
- Loose foundation bolts
- Poor curing
- Insufficient strength

These lead to **misalignment, vibration, overheating, and early failure**.

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### 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **industries**, foundation checks are done before machine erection.
- In **power plants**, foundation drawings are approved by civil & electrical engineers together.
- In **solar plants**, inverter foundations must be vibration-free and waterproof.

📍 Site engineers often use **spirit level, plumb bob, and laser level** during foundation inspection.

---

### 4️⃣ Summary & Q&A (≈ 5 minutes)

### 🔑 Key Takeaways

- Foundation is the backbone of installation
- Proper leveling and curing are critical
- Foundation bolts ensure mechanical stability
- Poor foundation = frequent breakdowns

### ❓ Typical Student Doubts

- *Can wooden base be used?* → No, only temporary use
- *Is curing really important?* → Yes, for strength and durability

---

### 🎓 Mentorship Note (Career Tip)

Understanding foundations makes you a **complete site engineer**, not just a wiring expert. These skills help you in:

- EPC and power plant projects
- Maintenance & reliability roles
- Supervisory and site leadership positions

👉 Remember: *"Machines don't fail suddenly—weak foundations make them fail slowly."*

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### 📘 Lecture Content

**Unit–I: Installation of Electrical Equipment**

**Topic 1.5 – Alignment of Electrical Machines**

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### 1️⃣ Hook / Introduction (≈ 5 minutes)

*“Have you ever seen a vehicle tyre wear out unevenly? The reason is misalignment.”*

Now imagine the same problem inside a **motor–pump set** running at 1500 RPM. Even a **1 mm alignment error** can cause excessive vibration, noise, bearing failure, and shaft breakage.

Let me ask you a simple question:
👉 **If a motor and load are bolted tightly, are they automatically aligned?**

The answer is **NO**. Alignment is a **precision activity**, not a tightening job. Today’s lecture will teach you how correct alignment ensures **smooth, efficient, and long-lasting machine operation**.

---

## 2️⃣ Core Concepts (≈ 40 minutes)

### 🔹 What is Alignment of Electrical Machines?

**Alignment** means positioning the **shaft of the driving machine (motor)** and the **shaft of the driven machine (pump, generator, fan)** so that:

- Their centers lie on the **same straight line**
- They rotate smoothly without stress

📌 *Fun Fact:* Most bearing failures occur not due to load—but due to **poor alignment**.

---

### 🔹 Why Alignment is Necessary

- Reduces vibration and noise
- Prevents bearing and coupling damage
- Improves efficiency
- Increases machine life

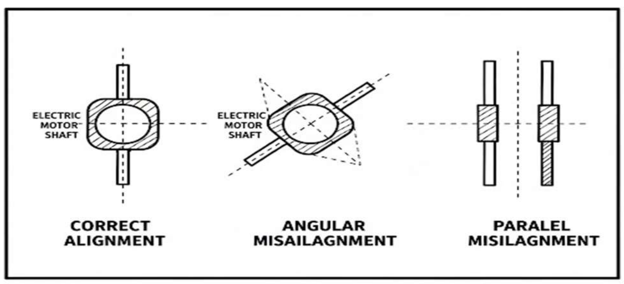
---

### 🔹 Types of Misalignment

1. **Angular Misalignment**
    - Shafts meet at an angle
    - Causes uneven coupling wear

2. **Parallel (Offset) Misalignment**
    - Shafts are parallel but not in same line
    - Causes shaft bending
3. **Combined Misalignment**
    - Most common in practice
    - Combination of angular and parallel

🖉 **Diagram to draw:**
Three sketches showing correct alignment, angular misalignment, and parallel misalignment between motor and pump shafts.

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◆ **Methods of Alignment (Diploma Level)**

## 1. Straight Edge and Feeler Gauge Method

- Simple and economical
- Used for small machines
- Straight edge checks parallel alignment
- Feeler gauge checks angular alignment

## 2. Dial Gauge Method

- Used for medium and large machines
- High accuracy

- Measures shaft displacement during rotation

### 3. Laser Alignment (Modern Method)

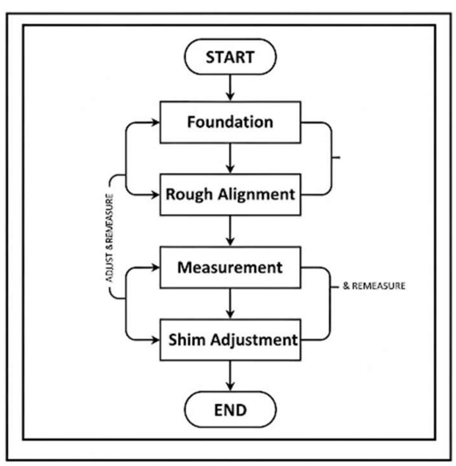
- Used in industries
- Very accurate and fast
- Requires skilled handling

---

🔹 **Step-by-Step Alignment Procedure**

1. Place motor and load on foundation
2. Level both machines using spirit level
3. Rough alignment by eye and straight edge
4. Fine alignment using feeler gauge or dial gauge
5. Adjust shims under motor feet
6. Tighten bolts and recheck alignment

✏️ **Flowchart to draw:**
Foundation → Rough Alignment → Measurement → Shim Adjustment → Final Alignment




🔹 **Effects of Poor Alignment**

- Excessive vibration
- Overheating
- Coupling failure
- Increased power consumption

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### 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **thermal power plants**, turbine–generator alignment is critical.
- In **industries**, misaligned pumps cause seal leakage.
- In **maintenance**, alignment is checked after bearing replacement.

📍 Skilled alignment engineers are highly valued because proper alignment **reduces maintenance cost drastically**.

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### 4️⃣ Summary & Q&A (≈ 5 minutes)

### 🔑 Key Takeaways

- Alignment ensures smooth power transmission
- Small error can cause big damage
- Shims are used for adjustment
- Alignment must be checked periodically

### ❓ Typical Student Doubts

- *Is alignment needed after bolt tightening?* → Yes
- *Can alignment change over time?* → Yes, due to vibration and thermal expansion

---

### 📘 Lecture Content

**Unit–I: Installation of Electrical Equipment**

**Topic 1.6 – Tools and Instruments Required for Installation**

---

## 1️⃣ Hook / Introduction (≈ 5 minutes)

*"Can a surgeon perform an operation without proper instruments?"*

In the same way, an electrical engineer **cannot install equipment safely or accurately without the right tools and instruments.** Many site accidents and installation failures happen not due to lack of knowledge, but due to **using the wrong tool for the job**.

So here's a simple question for you:
👉 **Is a spanner just a spanner, or does its correct size and type matter?**

Today's lecture will help you understand how tools and instruments are the **extended hands and eyes of an engineer**.

---

## 2️⃣ Core Concepts (≈ 40 minutes)

### 🔹 Why Tools and Instruments Are Important

- Ensure safety of personnel
- Improve accuracy and quality of installation
- Reduce time and effort
- Prevent damage to equipment

📌 *Fun Fact:* Professional engineers are often judged by **how they handle tools**, not just by their certificates.

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### 🔹 Classification of Tools and Instruments

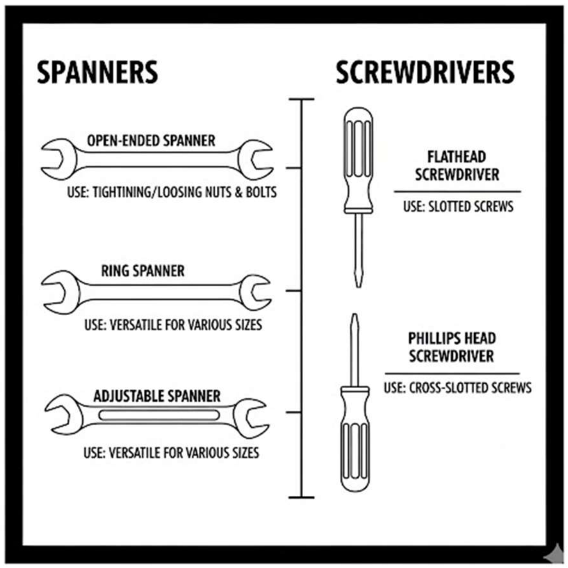
### 1️⃣ Hand Tools (Mechanical Tools)

Used for fitting, tightening, and mechanical assembly.

Examples:

- Spanners (open end, ring, adjustable)
- Screwdrivers (flat, Philips)
- Pliers (combination, nose plier, cutting plier)
- Hammer, chisel, hacksaw

🖉 **Visual to draw:**
A labeled sketch showing different types of spanners and screwdrivers with their uses.

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## 2 Measuring Tools

Used to ensure correct dimensions and alignment.

Examples:

- Steel tape
- Vernier caliper
- Spirit level
- Feeler gauge

Purpose:

- Check leveling of foundation
- Measure shaft gaps and clearances

---

### 3️⃣ Electrical Testing Instruments

Used to check electrical health and safety.

Examples:

- **Megger** – insulation resistance
- **Multimeter** – voltage, current, resistance
- **Test lamp** – presence of supply
- **Clamp meter** – current without breaking circuit

📌 *Safety Tip:* Always test instruments before use.

---

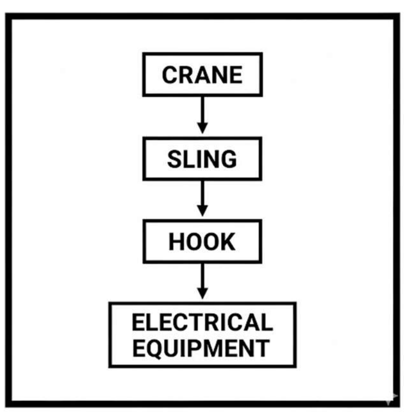
### 4️⃣ Lifting and Handling Tools

Used for safe movement of heavy equipment.

Examples:

- Chain pulley block
- Slings and shackles
- Crane hooks
- Hydraulic jack

🖉 **Visual to draw:**
A block diagram showing crane → sling → hook → electrical equipment.



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## 5️⃣ Alignment and Special Tools

Used during precision work.

Examples:

- Straight edge
- Dial gauge
- Shim sheets
- Torque wrench

Purpose:

- Proper alignment
- Uniform tightening of bolts

---

## 🔹 Care and Safety While Using Tools

- Use insulated tools for electrical work
- Do not use damaged tools
- Clean and store tools properly
- Follow PPE rules

---

## 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **substations**, torque wrenches ensure correct tightening of busbar joints.
- In **industries**, megger testing avoids insulation failure.
- In **solar plants**, clamp meters are used for quick current checks.

📍 Industries maintain a **tool checklist** before starting installation work.

---

## 4️⃣ Summary & Q&A (≈ 5 minutes)

### 🔑 Key Takeaways

- Right tool ensures right installation
- Testing instruments ensure safety
- Lifting tools prevent accidents
- Proper tool care increases life

### ❓ Typical Student Doubts

- *Can we use ordinary tools for HT work?* → No
- *Is megger compulsory before installation?* → Yes

---

### 🎓 Mentorship Note (Career Tip)

Engineers who **respect tools** become trusted professionals on site. Tool knowledge helps you in:

- Site engineer interviews
- Maintenance and commissioning jobs
- Industrial and EPC projects

👉 Remember: *"A skilled engineer is recognized by the tools he chooses and how safely he uses them."*

---

### 📘 Lecture Content

**Unit–I: Installation of Electrical Equipment**

****Topic 1.7 – Technical Report, Inspection, Storage & Handling of Transformer, Switchgear & Motors**

- Standard Field Quality Plan (SFQP)**

---

### 1️⃣ Hook / Introduction (≈ 5 minutes)

*"What is more powerful—an expensive machine or a well-written report?"*

Imagine two identical transformers installed at two sites. One runs smoothly for 20 years; the other fails in 6 months. The difference? **Documentation and quality control.** In professional electrical engineering, **"If it is not written, it is not done."**

Today's topic teaches you how engineers **record, verify, and control quality** during inspection, storage, and handling of costly equipment like transformers, switchgear, and motors—using **technical reports and Field Quality Plans**.

---

## 2️⃣ Core Concepts (≈ 40 minutes)

### 🔹 Importance of Technical Reports

A **technical report** is a written record that proves:

- Equipment condition
- Correct handling & storage
- Compliance with standards
- Responsibility and accountability

Reports are legally important in **warranty claims, audits, and failures**.

---

### 🔹 Inspection, Storage & Handling – Equipment-Wise Overview

### 🔸 Transformers

**Inspection:**

- Visual check for oil leakage, bushing cracks
- Nameplate verification
- IR value measurement

**Storage:**

- Store upright
- Maintain oil level
- Protect breather with silica gel

**Handling:**

- Lift using provided lugs
- Avoid tilting and jerks

---

◆ **Switchgear (VCB / SF6 / Panels)**

**Inspection:**

- Check insulation, contact alignment
- Verify interlocks and control wiring

**Storage:**

- Keep in original packing
- Dry and dust-free room

**Handling:**

- Avoid mechanical shock
- Use trolleys or forklifts

---

◆ **Motors**

**Inspection:**

- Check shaft rotation
- Measure insulation resistance

**Storage:**

- Use space heaters if provided
- Rotate shaft weekly

**Handling:**

- Lift from eye bolts only
- Avoid shaft bending

---

◆ **What is a Standard Field Quality Plan (SFQP)?**

A **Standard Field Quality Plan** is a **step-by-step checklist** used at site to ensure quality installation.

It includes:

1. Activity description
2. Tools & instruments required
3. Inspection checkpoints
4. Acceptance criteria
5. Responsibility (Engineer / Supervisor)

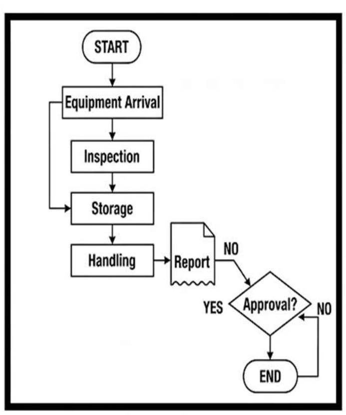
📌 *Fun Fact:* Many EPC companies reject work if SFQP is not followed—even if equipment works perfectly.

---

🔹 **Contents of a Technical Report**

- Equipment details (rating, serial no.)
- Inspection observations
- Test results
- Storage conditions
- Signature & date

🖉 **Flowchart to draw:**
Equipment Arrival → Inspection → Storage → Handling → Report → Approval



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### 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **substations**, every transformer has a **life-long documentation file**.
- In **industries**, SFQP avoids rework and penalties.
- In **solar & wind projects**, reports are required for subsidy and inspection clearance.

📍 Engineers who maintain proper reports are trusted with **high-value assets**.

---

### 4️⃣ Summary & Q&A (≈ 5 minutes)

#### 🔑 Key Takeaways

- Documentation ensures accountability
- Inspection prevents hidden failures
- SFQP standardizes quality
- Reports protect engineers legally

#### ❓ Typical Student Doubts

- *Is documentation really required if equipment works?* → Yes
- *Who signs the report?* → Site engineer / authorized person

---

### 🎓 Mentorship Note (Career Tip)

If you master **technical reporting and quality plans**, you move beyond "helper-level" roles and enter **engineer-level responsibility**. These skills help you in:

- PSU and EPC jobs
- Commissioning & QA roles
- Leadership and site-in-charge positions

👉 Remember: *"Machines show performance, but reports show professionalism."*

---

📘 **Lecture Content**

**Unit–I: Installation of Electrical Equipment**

**Topic 1.8 – Standard Procedure for Installation of Domestic and Industrial Solar Plant and Wind Plant**

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### 1️⃣ Hook / Introduction (≈ 5 minutes)

*"What if your house could generate its own electricity?"*

Today, electricity is no longer produced only in big power stations. With **solar rooftops and wind plants**, power generation has moved **closer to consumers**. India is rapidly shifting towards **renewable energy**, creating huge demand for skilled technicians and engineers.

So here's a question for you:
👉 **Is installing a solar plant just fixing panels on a roof?**

The answer is **NO**. Renewable energy installation follows **strict electrical, mechanical, and safety procedures**. Today's lecture will teach you the **standard installation process** for domestic and industrial solar and wind plants.

---

### 2️⃣ Core Concepts (≈ 40 minutes)

🔹 **Part A: Installation of Solar Power Plant**

🔸 **Types of Solar Plants**

- **Domestic rooftop solar** (1–10 kW)
- **Industrial solar plant** (above 10 kW)

---

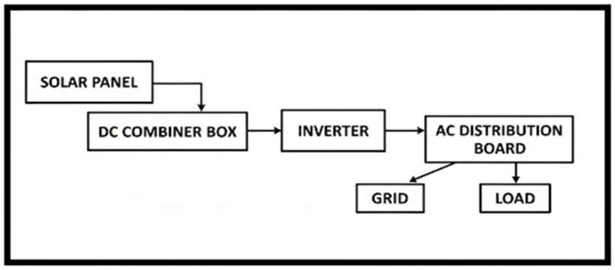
🔸 **Step-by-Step Installation Procedure**

1. **Site Survey**
    - Roof strength analysis
    - Shadow-free area identification

- Orientation towards south (India)

2. **Foundation & Mounting Structure**
    - Fix aluminum or GI mounting structure
    - Proper tilt angle (≈ latitude angle)
    - Strong foundation for wind load
3. **Module Installation**
    - Fix solar panels on structure
    - Maintain proper spacing for ventilation
4. **DC Wiring**
    - Use UV-resistant DC cables
    - Proper polarity and connectors (MC4)
5. **Inverter Installation**
    - Mount inverter in shaded, ventilated area
    - Connect DC input and AC output
6. **AC Side Connection**
    - Connection to distribution board
    - Install MCB, RCCB, surge protection device
7. **Earthing & Lightning Protection**
    - Separate earthing for DC and AC
    - Lightning arrestor installation

🖉 **Diagram to draw:**
Block diagram showing Solar Panel → DC Combiner Box → Inverter → AC Distribution Board → Grid / Load

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◆ **Part B: Installation of Wind Power Plant**

◆ **Types of Wind Plants**

- **Small wind turbines** (domestic / rural)
- **Industrial wind farms**

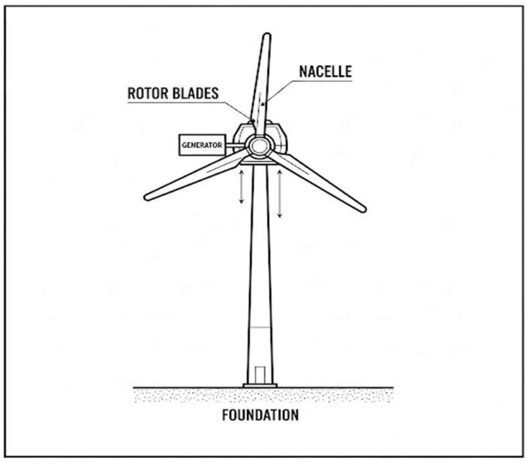
---

◆ **Step-by-Step Installation Procedure**

1. **Site Selection**
   - High wind velocity area
   - Open land without obstructions
2. **Foundation Construction**
   - Strong RCC foundation
   - Designed to withstand dynamic load
3. **Tower Erection**
   - Tower assembled section-wise
   - Proper vertical alignment

4. **Nacelle & Rotor Installation**
    - Generator and gearbox mounted
    - Blades fixed carefully
5. **Electrical Connections**
    - Generator output to control panel
    - Power fed to grid or battery system
6. **Earthing & Safety**
    - Multiple earth pits
    - Emergency stop system

🖉 **Diagram to draw:**
Wind turbine showing foundation, tower, nacelle, rotor blades, generator.




📌 *Fun Fact:* A single industrial wind turbine can power **more than 1,500 homes**.

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3️⃣ **Real-World / Industry Applications (≈ 10 minutes)**

- Rooftop solar reduces electricity bills by **50–90%**.
- Industries use solar and wind plants for **carbon-neutral operations**.
- Wind farms contribute significantly to **state power grids**.

📍 Skilled solar and wind technicians are in high demand due to government incentives and green policies.

---

### 4️⃣ Summary & Q&A (≈ 5 minutes)

#### 🔑 Key Takeaways

- Renewable energy installation follows strict procedures
- Safety and earthing are critical
- Solar is easy to maintain; wind requires precision
- Proper installation ensures long-term efficiency

#### ❓ Typical Student Doubts

- *Can solar plant work during cloudy days?* → Yes, with reduced output
- *Is wind plant suitable everywhere?* → No, wind speed matters

---

### 🎓 Mentorship Note (Career Tip)

Renewable energy is the **future of electrical engineering**. Mastering solar and wind installation opens doors to:

- Green energy companies
- Government and PSU projects
- Entrepreneurship in rooftop solar

👉 Remember: *"Today's green skills are tomorrow's job security."*

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## 🎓 STUDENT AI TOOLKIT

**Unit–1: Installation of Electrical Equipment**

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### 🔹 A. LOW-LEVEL PROMPTS

*(Remember & Understand – 10 Prompts)*

1. **“Explain the concept of installation of electrical equipment in simple diploma-level language with examples.”**
2. **“Define unloading, inspection, storage, foundation, and alignment in the context of electrical equipment installation.”**
3. **“Explain why inspection of electrical equipment is necessary before installation.”**
4. **“List the objectives of proper storage of electrical equipment at site and explain each briefly.”**
5. **“Explain the purpose of foundation for electrical equipment using a simple analogy.”**
6. **“Describe alignment of electrical machines and state why it is important.”**
7. **“List the common tools and instruments required for installation work and mention their basic uses.”**
8. **“Explain what a technical report is and why it is important in electrical installation.”**
9. **“Explain the basic steps involved in installation of a solar power plant in simple words.”**
10. **“Summarize Unit–1: Installation of Electrical Equipment in short revision-friendly points.”**

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- **B. MODERATE-LEVEL PROMPTS**

*(Apply & Analyze – 10 Prompts)*

11. **“Explain the step-by-step procedure for unloading heavy electrical equipment at site, including safety precautions.”**
12. **“Compare good storage practices and poor storage practices for electrical equipment and their effects.”**
13. **“Analyze the problems that may occur if foundation is weak or uneven for electrical machines.”**
14. **“Explain how misalignment affects performance and life of electrical machines with practical examples.”**

15. **“Classify tools and instruments used during installation and explain where each category is used.”**
16. **“Explain the inspection, storage, and handling procedure for any one electrical equipment of your choice.”**
17. **“Explain the role of documentation and technical reports during installation and commissioning.”**
18. **“Apply installation principles to explain how safety is ensured during site work.”**
19. **“Explain the difference between domestic and industrial renewable energy installations based on installation requirements.”**
20. **“Analyze how proper installation practices reduce maintenance cost and equipment failure.”**

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🔹 **C. HIGH-LEVEL PROMPTS**

***(Design & Create – 5 Prompts)***

21. **“Design a step-by-step workflow for installation of an electrical equipment starting from site arrival to commissioning readiness.”**
22. **“Create a checklist for inspection, storage, and handling of electrical equipment suitable for a site engineer.”**
23. **“Prepare a logical layout explaining how tools, foundation, alignment, and inspection are interconnected in installation.”**
24. **“Develop a sample format of a technical report for electrical equipment installation with key headings.”**
25. **“Create an exam-oriented concept map for Unit–1 showing relationships between unloading, inspection, storage, foundation, alignment, and documentation.”**

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✅ **MASTERY CHECK – UNIT–1**

**Installation of Electrical Equipment**

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1️⃣ **Key Definitions / Glossary**

*(Top 15 Exam-Important Terms)*

1. **Installation** – The process of placing, fixing, and connecting electrical equipment safely for operation.
2. **Unloading** – Safe removal of electrical equipment from transport to site without damage.
3. **Inspection** – Systematic checking of equipment condition before installation.
4. **Storage** – Safe keeping of electrical equipment before installation to prevent damage.
5. **Foundation** – A strong base that supports electrical equipment and absorbs vibration.
6. **Alignment** – Correct positioning of shafts of coupled machines on the same centerline.
7. **Misalignment** – Incorrect shaft positioning causing vibration and mechanical stress.
8. **Handling** – Proper lifting and movement of electrical equipment using suitable methods.
9. **Technical Report** – Written record of inspection, test results, and observations at site.
10. **Field Quality Plan (FQP)** – A checklist ensuring quality and standard procedures during installation.
11. **Insulation Resistance (IR)** – Resistance offered by insulation against leakage current.
12. **Tools** – Mechanical devices used for fitting, tightening, and installation work.
13. **Instruments** – Devices used for measurement and testing during installation.
14. **Earthing** – Connection of equipment body to ground for safety.
15. **Renewable Energy Plant** – Power generation system using solar or wind energy.

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## 2️⃣ FAQ & Assessment Section

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### A. Multiple Choice Questions (MCQs)

*(20 Questions – Exam Oriented)*

1. The first activity after arrival of electrical equipment at site is:
   A) Wiring
   B) Commissioning
   C) Unloading and inspection
   D) Testing

2. Which factor mainly affects insulation during storage?
   A) Noise
   B) Moisture
   C) Load
   D) Speed

3. Foundation of electrical equipment mainly provides:
   A) Electrical insulation
   B) Mechanical support
   C) Cooling
   D) Lubrication

4. Alignment is required between:
   A) Panel and wall
   B) Shaft and bearing
   C) Motor and driven machine
   D) Cable and conduit

5. Which tool is used to measure insulation resistance?
   A) Multimeter
   B) Clamp meter
   C) Megger
   D) Voltmeter

6. Misalignment mainly causes:
   A) Voltage drop
   B) Vibration
   C) Power factor improvement
   D) Insulation increase

7. Storage of equipment in open area is allowed when:
   A) Covered and protected
   B) During night only
   C) Equipment is new
   D) Never

8. Foundation bolts are used to:
   A) Conduct current
   B) Fix equipment firmly

C) Cool equipment
D) Reduce losses

9. Which document proves inspection and quality at site?
   A) Wiring diagram
   B) Technical report
   C) Load curve
   D) Nameplate

10. Field Quality Plan ensures:
   A) Speed of work
   B) Low cost
   C) Standard installation procedure
   D) High voltage

11. Which is a lifting tool?
   A) Spanner
   B) Hammer
   C) Chain pulley block
   D) Screwdriver

12. Poor storage mainly affects:
   A) Paint only
   B) Insulation quality
   C) Size of equipment
   D) Rating

13. Alignment error mainly affects which part first?
   A) Shaft
   B) Bearing
   C) Winding
   D) Terminal

14. Which is preferred storage location?
   A) Open ground
   B) Damp room
   C) Dry and covered area
   D) Near chemicals

15. Solar plant installation requires special attention to:
   A) Colour of panel
   B) Earthing and protection
   C) Panel weight only
   D) Meter reading

16. Which instrument checks level of foundation?
    A) Dial gauge
    B) Spirit level
    C) Ammeter
    D) Megger

17. Technical report is important for:
    A) Decoration
    B) Warranty and audit
    C) Increasing load
    D) Speed control

18. Which misalignment is most common in practice?
    A) Angular
    B) Parallel
    C) Combined
    D) None

19. Wind plant foundation must be:
    A) Light weight
    B) Temporary
    C) Strong and rigid
    D) Wooden

20. Proper installation mainly improves:
    A) Colour
    B) Equipment life
    C) Cost only
    D) Weight

---

**B. Short Answer / Viva Questions**

*(10 Questions – Frequently Asked)*

1. Why is inspection necessary before installation of electrical equipment?

2. State any four precautions during unloading of heavy electrical equipment.

3. Explain the importance of proper storage of electrical equipment.

4. What is the function of foundation in electrical installation?

5. Define alignment and state its importance.

6. What are the effects of poor alignment of electrical machines?
7. List any four tools used for installation work with their purpose.
8. What is a technical report? Why is it important?
9. State the purpose of a Field Quality Plan.
10. Why is earthing essential in solar and wind plant installation?

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## 📚 DIGITAL RESOURCE LIBRARY

**Unit–1: Installation of Electrical Equipment**

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### 1️⃣ AI Tools & Digital Learning Tools

*(Free / Easily Accessible | Student-Friendly)*

#### 🔹 1. AI Conversational Tutors (e.g., Chat-based AI Assistants)

**Purpose / Use-case:**

- Concept explanation, doubt clearing, summaries, viva practice

**How it helps in this unit:**

- Explains installation steps, alignment, storage, foundation, tools in simple language
- Helps students generate short answers, MCQs, and revision notes
- Useful for viva-voce practice using question–answer style prompts

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#### 🔹 2. Virtual Electrical Labs (Government / Academic)

**Purpose / Use-case:**

- Simulation of basic electrical tests and equipment behavior

**How it helps in this unit:**

- Visualizes insulation testing, earthing concepts, and safety practices
- Helps students understand testing instruments used during installation
- Builds confidence before real laboratory or site work

### ◆ 3. 3D Equipment Visualizers & Animations

**Purpose / Use-case:**

- Visualization of machines, foundations, alignment, and layouts

**How it helps in this unit:**

- Helps students clearly see motor–pump alignment, foundation bolts, panels, solar layouts
- Reduces fear of "heavy equipment" by showing internal structure
- Excellent for students who struggle with imagination from textbooks

---

### ◆ 4. Online Diagram & Flowchart Tools

**Purpose / Use-case:**

- Drawing block diagrams, flowcharts, and layouts digitally

**How it helps in this unit:**

- Helps students create neat diagrams for inspection flow, installation steps, SFQP
- Useful for exam preparation and project documentation
- Encourages logical sequencing of installation procedures

---

### ◆ 5. Digital Note & Flashcard Apps

**Purpose / Use-case:**

- Revision, memorization, and quick recall

**How it helps in this unit:**

- Store definitions, tools list, steps of installation, alignment types
- Useful for last-minute exam revision and viva preparation
- Supports micro-learning as per NEP-2020

---

## 2️⃣ Video Learning Repository

*(Reliable, Diploma-Level, Exam-Oriented)*

🔎 **Note for Students:** Use the given *Search Keywords* exactly in YouTube / SWAYAM / NPTEL search bars.

| **Topic Name** | **Recommended Channel / Course / Lecturer Name** | **Search Keywords** |
|---|---|---|
| Installation of Electrical Equipment | NPTEL / SWAYAM (Electrical Engineering) | "Electrical equipment installation basics diploma" |
| Unloading & Inspection at Site | Skill India / Industrial Training Channels | "Electrical equipment unloading inspection site" |
| Storage of Electrical Equipment | Electrical Maintenance Channels | "Storage of electrical equipment at site" |
| Foundation for Electrical Machines | Polytechnic Electrical Lectures | "Foundation for electrical machines diploma" |
| Alignment of Electrical Machines | Maintenance Engineering Channels | "Alignment of electrical machines dial gauge" |
| Tools & Instruments for Installation | ITI / Polytechnic Training Channels | "Tools used in electrical installation" |
| Technical Report & Quality Plan | Industrial Engineering Lectures | "Electrical installation technical report field quality plan" |
| Solar Power Plant Installation | MNRE / SWAYAM / NPTEL | "Solar rooftop installation procedure diploma" |
| Wind Power Plant Basics & Installation | NPTEL Renewable Energy | "Wind power plant installation basics" |
| Electrical Safety & Site Practices | CEA / Power Utility Channels | "Electrical safety practices installation" |

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## 📘 PREDICTED QUESTION BANK

**Unit–1: Installation of Electrical Equipment**

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## 1 MOST REPEATED / HIGH-PROBABILITY QUESTIONS

*(Based on syllabus weightage & common exam trends)*

### ◆ A. Definition & Short Questions (2–4 Marks)

1. Define **installation of electrical equipment**.
2. Define **inspection of electrical equipment at site**.
3. What is meant by **proper storage** of electrical equipment?
4. Define **foundation of electrical equipment**.
5. What is **alignment of electrical machines**?
6. List any four **tools used for electrical installation work**.
7. What is a **technical report** in electrical installation?
8. Define **Field Quality Plan (FQP)**.
9. State the need of **handling procedures** for heavy electrical equipment.
10. List precautions taken during **unloading of electrical equipment**.

---

### ◆ B. Explanatory / Descriptive Questions (5–7 Marks)

11. Explain the **procedure for unloading electrical equipment at site with safety precautions**.
12. Explain **inspection of electrical equipment before installation**.
13. Explain **storage methods for electrical equipment at site**.
14. Explain the **importance of foundation for electrical machines**.
15. Explain **alignment of electrical machines with neat sketch**.
16. Explain **tools and instruments required for installation work**.
17. Explain **inspection, storage, and handling of transformers**.
18. Explain **inspection, storage, and handling of switchgear**.

19. Explain **inspection, storage, and handling of electrical motors**.
20. Explain the **standard procedure for installation of a domestic solar power plant**.
21. Explain the **standard procedure for installation of an industrial solar power plant**.
22. Explain the **basic installation steps of a wind power plant**.
23. Write short notes on **technical report and documentation in installation work**.
24. Explain the **importance of Field Quality Plan in electrical installation projects**.

---

🔹 **C. Diagram / Concept-Focused Questions**

25. Draw and explain **foundation layout of electrical machine**.
26. Draw a **flowchart for inspection–storage–installation sequence**.
27. Draw and explain **alignment of motor and driven load**.

---

## 2️⃣ APPLICATION & LOGICAL THINKING QUESTIONS

*(High-Scoring / Distinction-Level – 5 Questions)*

1. **If electrical equipment is installed without proper inspection, what problems may occur during operation? Explain logically.**
2. **Why is proper foundation essential for rotating electrical machines? Explain its effect on vibration, noise, and machine life.**
3. **Explain how improper storage of electrical equipment can lead to insulation failure and breakdown.**
4. **A motor shows excessive vibration after installation. Analyze possible causes related to alignment and foundation.**
5. **Explain how proper installation practices reduce maintenance cost and improve reliability of electrical systems.**

## 📘 UNIT–2 STUDY PLAN

**Commissioning and Testing**

**Course:** Electrical Installation, Commissioning & Maintenance
**Total Teaching Hours: 10 Hours**
**Mapped CO: CO2 – Commission & Test various electrical equipments/machines**

🔹 **Logical Learning Flow (Pedagogical View)**

**Pre-commissioning → Equipment-specific tests → Insulation & oil testing → Drying & loading → Advanced systems → Documentation**

This mirrors **real industry practice**, helping students move from **concept → procedure → application**.

---

🧠 **Topic-wise Detailed Study Plan (As per Syllabus)**

| Sr. No. | Syllabus Topic | Topic Nature | Suggested Time (hrs) | Exam Importance | Practical Relevance | OBE / NEP-2020 Alignment |
|---|---|---|---|---|---|---|
| **2.1** | Tests before commissioning of electrical equipment – Electrical & Mechanical tests, preparation before commissioning of power transformer, instruments required | **Core** | **1.5** | Very High | Very High | Industry readiness, safety, skill-based |
| **2.2** | Specific tests on transformer, induction motor, alternator & synchronous motor | **Core** | **2.0** | Very High | Extremely High | Hands-on competency, psychomotor skills |
| **2.3** | Commissioning of power transformer, three-phase induction motor & switchgear | **Core / Application** | **1.5** | Very High | Extremely High | Real-system commissioning workflow |

| Sr. No. | Syllabus Topic | Topic Nature | Suggested Time (hrs) | Exam Importance | Practical Relevance | OBE / NEP-2020 Alignment |
|---|---|---|---|---|---|---|
| **2.4** | Transformer insulation oil – properties as per IS, sampling, testing, filtering, standard tests, classification of IR | **Core** | **1.5** | High | Very High | Quality control, standards awareness |
| **2.5** | Measurement of insulation resistance, Polarization Index, factors affecting IR | **Core** | **1.5** | Very High | Extremely High | Diagnostic thinking, testing skills |
| **2.6** | Drying of winding of electrical equipment and record keeping | **Supporting** | **0.75** | Medium | High | Preventive maintenance mindset |
| **2.7** | Tests before & after commissioning of transformer, induction motor & HV circuit breaker | **Application-Oriented** | **0.75** | High | Very High | Comparative analysis, safety checks |
| **2.8** | Test report on commissioning and test certificate | **Application** | **0.5** | High | High | Documentation, audit & compliance |
| **2.9** | Gradual loading of electrical equipment & commissioning/testing of GIS substation | **Advanced / Application** | **0.75** | Medium–High | High | System-level understanding |
| **2.10** | Standard procedure for commissioning of domestic & industrial solar plant and wind plant | **Advanced** | **0.75** | High | Very High | Green skills, future-ready competency |

✅ **Total = 10 Hours**

📘 **Lecture Content**

**Unit–2: Commissioning and Testing**

**Topic 2.1 – Tests before Commissioning of Electrical Equipment

(Electrical & Mechanical Tests, Preparation before Commissioning of Power Transformer, Instruments Required)**

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1️⃣ **Hook / Introduction (≈ 5 minutes)**

*"Would you start a new vehicle without checking brakes, oil, and tyres?"*

In electrical engineering, commissioning without testing is even more dangerous. Many major electrical failures happen **not during operation**, but **during first energization**, because pre-commissioning tests were skipped or done casually.

So ask yourself this question:
👉 **Is switching ON an electrical machine the first step of commissioning?**

The correct answer is **NO**. Before energizing, engineers perform **systematic electrical and mechanical tests** to ensure safety, reliability, and long life. Today's lecture will teach you these **essential pre-commissioning tests**, with special focus on **power transformers**.

---

2️⃣ **Core Concepts (≈ 40 minutes)**

🔹 **What is Pre-Commissioning Testing?**

**Pre-commissioning tests** are checks carried out **before electrical equipment is energized** to confirm:

- Correct installation
- Electrical health
- Mechanical readiness
- Safety compliance

📌 *Fun Fact:* Many manufacturers clearly mention: *"Warranty is valid only if pre-commissioning tests are recorded."*

🔹 **A. Electrical Tests before Commissioning**

These tests check the **electrical condition** of equipment.

## 1. Insulation Resistance (IR) Test

- Done using a **Megger**
- Confirms insulation health between windings and earth
- Low IR indicates moisture or insulation damage

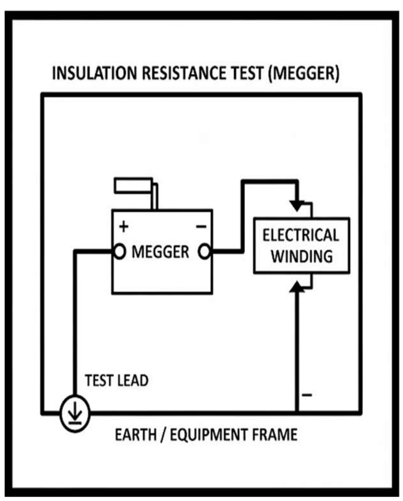
## 2. Continuity Test

- Ensures proper electrical connections
- Confirms no open circuits

## 3. Polarity Test

- Confirms correct terminal connections
- Important for transformers and CTs

🖉 *Visual to draw:*
Simple block showing Megger connected between winding and earth.




🔹 **B. Mechanical Tests before Commissioning**

These tests ensure **physical and mechanical readiness**.

## 1. Alignment Check

- Motor shaft and load shaft must be aligned
- Prevents vibration and bearing damage

## 2. Tightness Check

- Foundation bolts, terminals, and clamps checked
- Loose connections cause heating

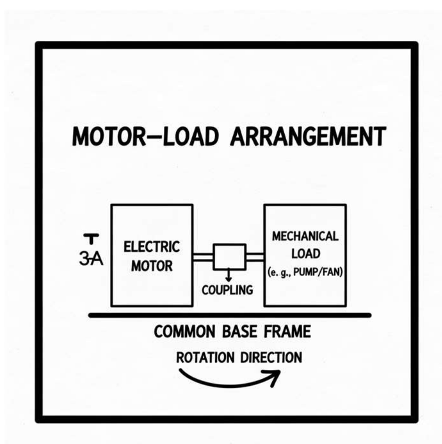
## 3. Lubrication Check

- Bearings must have proper lubrication

## 4. Free Rotation Test

- Shaft should rotate smoothly by hand

🖉 *Diagram to draw:*
Motor–load arrangement showing aligned shafts.




◆ **C. Preparation before Commissioning of Power Transformer**

Power transformers are **high-value equipment**, so preparation is critical.

Steps include:

1. **Visual Inspection**
   - Check bushings, oil level, leaks

2. **Oil Testing**
    - Check dielectric strength
3. **IR Measurement**
    - HV–LV, HV–Earth, LV–Earth
4. **Earthing Check**
    - Tank and neutral properly earthed
5. **Breather Check**
    - Silica gel must be dry (blue/pink condition)

📌 *Exam Tip:* Questions on transformer preparation are **frequently asked for 5–7 marks**.

### 🔹 D. Instruments Required for Pre-Commissioning Tests

Common instruments include:

- **Megger** – insulation resistance
- **Multimeter** – voltage, resistance
- **Clamp meter** – current measurement
- **Spirit level** – leveling
- **Torque wrench** – proper tightening
- **Oil test kit** – transformer oil testing

## 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **substations**, no equipment is energized without test approval.
- In **industries**, pre-commissioning tests prevent accidents and shutdowns.
- In **renewable energy plants**, inverter and transformer tests are mandatory before grid synchronization.

📍 Site engineers maintain **test records**, which are checked during audits and safety inspections.

### 4️⃣ Summary & Q&A (≈ 5 minutes)

### 🔑 Key Takeaways

- Pre-commissioning tests ensure safety and reliability
- Electrical and mechanical tests are equally important
- Transformer preparation requires special attention
- Instruments are essential tools of commissioning engineers

### ❓ Common Student Doubts

- *Can commissioning be done without IR test?* → Never
- *Are mechanical tests compulsory?* → Yes

### 🎓 Mentorship Note (Career Tip)

Commissioning engineers are **highly trusted professionals**. If you master pre-commissioning tests:

- You gain confidence in labs and viva
- You become site-ready for industries and power projects
- You build a strong base for **maintenance, testing, and QA roles**

👉 Remember: *"An engineer who tests well, energizes safely."*

### 📘 Lecture Content

**Unit–2: Commissioning and Testing**

**Topic 2.2 – Specific Tests on Transformer, Induction Motor, Alternator & Synchronous Motor**

### 1️⃣ Hook / Introduction (≈ 5 minutes)

*"Two machines may look identical, but only one survives long-term operation. Why?"*

The difference often lies in **testing**. In electrical engineering, we don't trust equipment just because it is new. Every major machine must **prove its health through tests** before and after commissioning.

Let me ask you:
👉 **Can one single test confirm that a machine is ready to run?**

The answer is **NO**. Each machine—transformer, induction motor, alternator, or synchronous motor—has **specific tests** designed for its construction and function. Today's lecture will help you understand **what to test, why to test, and what the results mean**.

### 2️⃣ Core Concepts (≈ 40 minutes)

🔹 **A. Specific Tests on Transformer**

Transformers are static but **high-value** equipment, so testing is critical.

## 1. Insulation Resistance (IR) Test

- Measures insulation between HV–LV, HV–Earth, LV–Earth
- Done using Megger
- Low IR indicates moisture or insulation damage

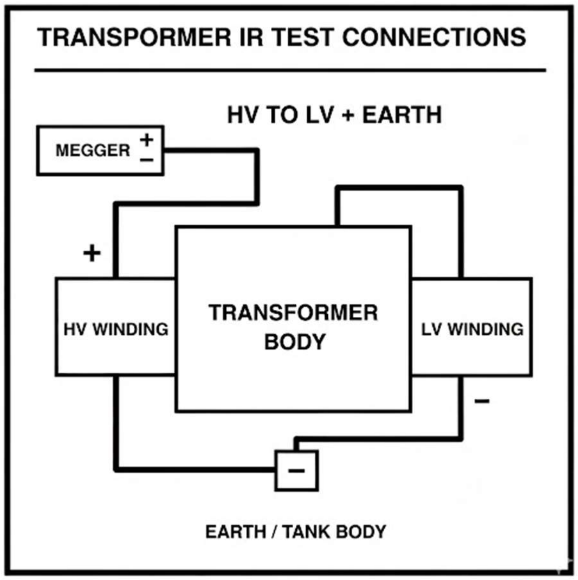
## 2. Turns Ratio Test (TTR)

- Confirms correct voltage ratio
- Detects shorted or open turns

## 3. Winding Resistance Test

- Measures resistance of HV and LV windings
- Identifies loose connections or damaged windings

🖉 *Diagram to draw:*
Block diagram of transformer showing HV and LV winding connections for IR testing.




◆ **B. Specific Tests on Induction Motor**

Induction motors are widely used, so **reliable testing ensures long life**.

## 1. Insulation Resistance Test

- Between stator winding and earth
- Between phases

## 2. No-Load Test

- Motor is run without load
- Checks current, vibration, noise

## 3. Direction of Rotation Test

- Ensures correct shaft rotation
- Important before coupling load

📌 *Fun Fact:* Many pumps fail simply because motors run in **reverse direction** after installation.

◆ **C. Specific Tests on Alternator**

Alternators generate power, so **output quality and stability** are checked.

## 1. Insulation Resistance Test

- Checks stator and rotor insulation

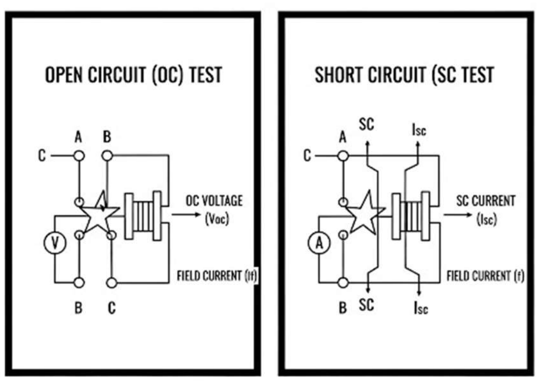
## 2. Open Circuit Test (OC Test)

- Measures no-load voltage at different field currents
- Helps understand voltage regulation

## 3. Short Circuit Test (SC Test)

- Measures current under short-circuit condition
- Used to determine machine reactance

✏️ *Diagram to draw:*
OC and SC test connection diagram of alternator.




◆ **D. Specific Tests on Synchronous Motor**

Synchronous motors require **proper excitation and synchronization**.

## 1. Insulation Resistance Test

- Checks stator and field winding insulation

## 2. V-Curve Test

- Shows relationship between armature current and field current
- Helps operate motor at unity power factor

## 3. Pull-In Test

- Confirms ability of motor to synchronize with supply

### 3️⃣ Real-World / Industry Applications (≈ 10 minutes)

- In **power plants**, alternators undergo OC and SC tests before synchronization.
- In **industries**, induction motors are tested to avoid unplanned shutdowns.
- In **substations**, transformer test results decide whether energization is allowed.

📍 Site engineers record all test results in **commissioning reports**, which are verified during audits.

### 4️⃣ Summary & Q&A (≈ 5 minutes)

### 🔑 Key Takeaways

- Each electrical machine has specific tests
- IR test is common but not sufficient alone
- Test results indicate machine health
- Proper testing prevents costly failures

### ❓ Common Student Doubts

- *Is testing required for new machines?* → Yes
- *Can we skip OC or SC test?* → No, for large machines

### 🎓 Mentorship Note (Career Tip)

Engineers skilled in **machine testing** are preferred for:

- Commissioning teams
- Maintenance & reliability roles

- Power plants and EPC projects

👉 Remember: *“A machine that passes tests earns the engineer’s trust.”*

**Unit–2: Commissioning and Testing**

**Topic 2.3 – Commissioning of power transformer, three phase induction motor and switchgear**

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## 1. Introduction: The "First Breath" of a Machine (5 Minutes)

Imagine you’ve spent weeks designing a foundation and months waiting for a massive 10 MVA transformer to arrive at your site. It’s sitting there—silent and heavy. How do you know it’s safe to connect it to the grid? If you make a mistake now, you don't just blow a fuse; you could cause an explosion that costs crores of rupees and puts lives at risk. **Commissioning** is the formal process of verifying that the equipment is ready to perform its duties safely and efficiently[1111]. Today, we learn how to give these machines their "first breath."

## 2. Core Concepts: The Commissioning Roadmap (40 Minutes)

Commissioning is essentially a "Final Exam" for the equipment after installation[22]. We will focus on three heavyweights of the electrical world:

**A. Power Transformers**

Before we energize, we must ensure the "internal health" is perfect.

- **Mechanical Checks:** Verify oil levels in the conservator, check for leaks, and ensure the Buchholz relay is properly mounted[33].
- **Insulation Resistance (IR) Test:** Use a Megger to check the insulation between windings and between winding and earth[44].
- **Voltage Ratio & Polarity:** We verify the turns ratio to ensure the output voltage will be as expected[55].
- **Oil Testing:** We perform a BDV (Breakdown Voltage) test to ensure the oil can withstand high voltage[666].

**B. Three-Phase Induction Motors**

For motors, the goal is smooth rotation and thermal safety.

- **Rotation Check:** We briefly "jog" the motor to ensure it rotates in the correct direction[7].

- **Air Gap & Alignment:** Ensure the rotor isn't rubbing against the stator and that the motor shaft is perfectly aligned with the load[88].
- **No-Load Test:** Run the motor without a load to measure the "no-load current" and check for abnormal vibrations or noise[9].

**C. Switchgear (Circuit Breakers)**

Switchgear is the "Bodyguard" of the system. If it fails, nothing else is protected.

- **Tightness & Cleaning:** Ensure all busbar connections are tight (preventing sparking) and insulators are dust-free[10].
- **Operational Tests:** We manually trip and close the breaker multiple times to ensure the mechanism doesn't jam[11].
- **Contact Resistance:** High resistance at the contacts causes heating, which can melt the breaker[12].

## 3. Real-World / Industry Applications (10 Minutes)

In industries like GETCO (Gujarat Energy Transmission Corporation), commissioning follows a strict Standard Field Quality Plan (SFQP).

Fun Fact: Did you know that in large substations, we sometimes use Thermal Imaging Cameras during the first hour of commissioning? This allows us to "see" heat. If a connection was left slightly loose, it will glow bright red on the camera, allowing us to fix it before it melts!

## 4. Summary & Q&A (5 Minutes)

- **Key Takeaway:** Commissioning is the transition from "Static" to "Dynamic"[14141414].
- **Revision:** Transformers need oil and IR tests; Motors need alignment and rotation checks; Switchgear needs mechanical operation verification[151515].
- **Common Doubt:** *"Can we skip the No-Load test if the motor is brand new?"* **Never.** A factory defect or shipping damage could cause a phase-to-ground fault that only appears when energized.

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**Topic 2.4: Transformer Insulation Oil – Properties, Sampling, Testing, Filtering, Standard Tests, Classification of Insulation Resistance**

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## 1. Hook / Introduction (≈ 5 minutes)

Imagine a 50 MVA transformer running in a substation. Thousands of homes, hospitals, and industries depend on it. Now think—**what protects this transformer from internal short-circuits, overheating, and insulation failure?**
Just as **blood in our body** carries nutrients and removes heat, **transformer insulation oil** cools, insulates, and protects the transformer. If the oil becomes weak or contaminated, the transformer can fail catastrophically.

Connect to prior knowledge:

- You already studied **dielectric materials** and **transformer construction**
- Today, we focus on **the life-blood of a transformer** — insulation oil

**Fun fact:** More transformers fail due to **poor oil quality** than due to electrical faults!

---

## 2. Core Concepts (≈ 40 minutes)

**(a) Properties of transformer oil as per IS (IS-335 / IS-1866)**

Key desirable properties:

- **High dielectric strength** (withstand high voltage without breakdown)
- **Low viscosity** (easy circulation for cooling)
- **High flash and fire point** (safety against fire)
- **Good oxidation stability** (resists aging)
- **Moisture content very low** (water drastically reduces insulation strength)
- **Chemical stability** (no sludge formation)
- **High thermal conductivity** (better heat removal)

Analogy: *Good transformer oil is like clean engine oil in a bike — reduces heat, prevents wear, and increases life.*

---

**(b) Sampling of transformer oil**

Correct sampling is essential because **wrong sampling = wrong result**
Steps (explain as flow chart when drawing on board):

1. Clean sampling valve

2. Flush out a small quantity
3. Collect in **airtight, dry, glass bottle**
4. Label with date, location, transformer details
5. Avoid air bubbles and moisture

Tip: Emphasize “**No moisture entry**” — even **1 drop of water** damages insulation strength.

---

**(c) Testing of transformer oil**

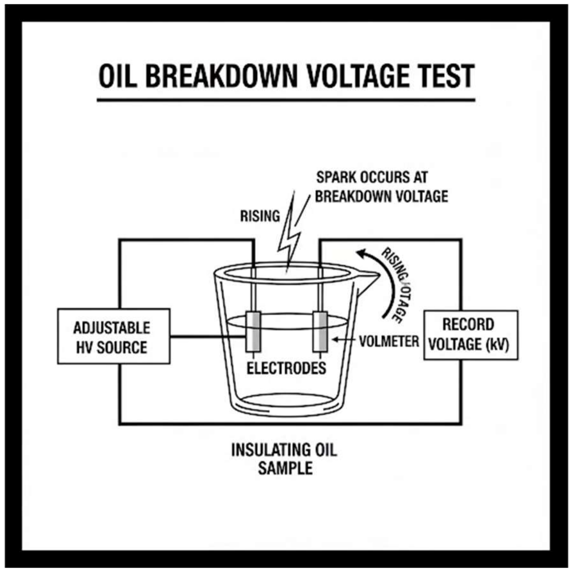
Tests are divided into:

- **Electrical tests**
- **Physical tests**
- **Chemical tests**

Common tests:

- **BDV Test (Breakdown Voltage Test)**
  Measures voltage at which oil breaks down → using **oil testing kit**
- **Moisture content test (PPM)**
- **Acidity (neutralization value)**
- **Flash point test**
- **Sludge content**
- **Color & appearance**

**Diagram description for board:**
Draw a simple **oil testing kit**: two electrodes inside a glass test cup filled with oil, connected to HV source. Show rising voltage until spark occurs.

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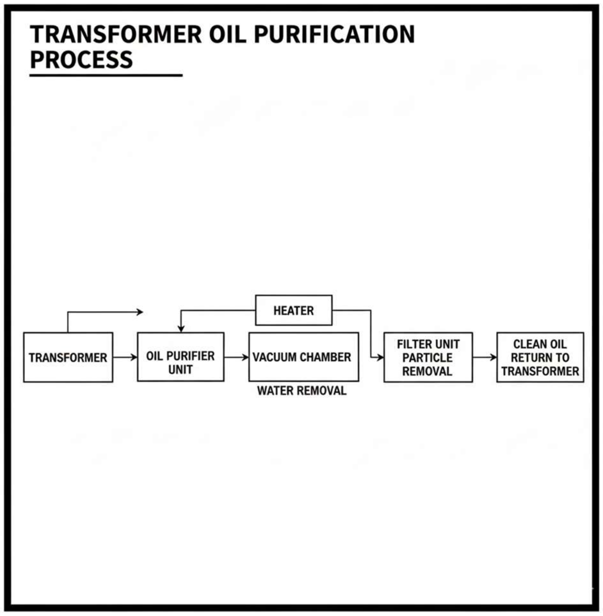
**(d) Filtering and purifying transformer oil**

Contaminants: moisture, dirt, dissolved gases, sludge
Methods used:

- **Filtration through paper filters**
- **Centrifuging**
- **Vacuum dehydration**
- **Thermal treatment**

Explain as a **block diagram**:
Transformer → Oil purifier → Heater → Vacuum chamber → Filter → Clean oil return




Outcome: BDV increases, moisture decreases, life of transformer improves.

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### (e) Classification of Insulation Resistance (IR)

Measured using **Megger**

- **Excellent:** above 1000 MΩ
- **Good:** 100–1000 MΩ
- **Weak:** 1–100 MΩ
- **Unsafe:** below 1 MΩ

Factors affecting IR:

- Temperature rise
- Humidity
- Aging
- Presence of moisture or dirt

Also mention **Polarization Index (PI)** = IR at 10 min / IR at 1 minPI > 2 → good insulation health

## 3. Real-World / Industry Applications (≈ 10 minutes)

Where will you see this in real life?

- Substations
- Power plants
- Wind and solar evacuation transformers
- Distribution transformers

Industry practices include:

- annual oil testing schedules
- online oil monitoring sensors
- dissolved gas analysis (DGA)
- maintenance reports & certification

**Case example:** A utility detected low BDV through routine testing, filtered oil, and **prevented transformer explosion** — saving crores of rupees.

---

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Transformer oil provides **cooling and insulation**
- Properties must meet **Indian Standards**
- Correct sampling is as important as testing
- BDV test is the **most common field test**
- Filtering improves life and reliability
- IR & PI help judge insulation health

**Typical doubts**

- Why does moisture reduce BDV?
  → Water conducts electricity → lowers dielectric strength

- Why filtration instead of replacement?
  → Cost saving + sustainability

- Is vegetable-based bio-oil used?
  → Yes, in eco-friendly transformers

---

🔎 **Mentorship Note – Career Tip**

Mastering transformer oil testing makes you **job-ready** for roles in:

- substation commissioning companies
- power utilities
- maintenance & testing contractors
- renewable energy plants

During interviews, if you confidently explain **BDV testing, oil filtration, and IR measurement**, you stand out as a **hands-on diploma engineer**—not just a theory learner.

**Topic 2.5: Measurement of Insulation Resistance, Polarization Index & Factors Affecting IR**

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## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a question:
**If a machine looks perfectly fine from outside, how do we know whether its internal insulation is healthy or about to fail?**

Just like a doctor uses an ECG to check heart condition, **electrical engineers use insulation resistance tests** to check the "health" of electrical equipment. A transformer, motor, generator or cable may run today — but weak insulation can suddenly cause **flashover, fire, or complete breakdown** tomorrow.

You already know:

- Conductors carry current
- Insulators block current

Today we study how to **measure how good an insulator actually is**, using a very special instrument — the **Megger**.

**Fun fact:** The Megger was invented more than 100 years ago and is still used worldwide!

---

## 2. Core Concepts (≈ 40 minutes)

### (a) What is Insulation Resistance (IR)?

Insulation resistance is the resistance offered by the insulating material **between live parts and earth** or **between two conductors**.
Good insulation → very high resistance
Weak insulation → low resistance

Analogy:
Think of a raincoat. A new raincoat stops water completely (high resistance). Torn raincoat leaks (low resistance).

---

### (b) Measurement of IR – Using Megger

**Megger = High-voltage ohmmeter**

It applies DC test voltage and measures leakage current through the insulation.

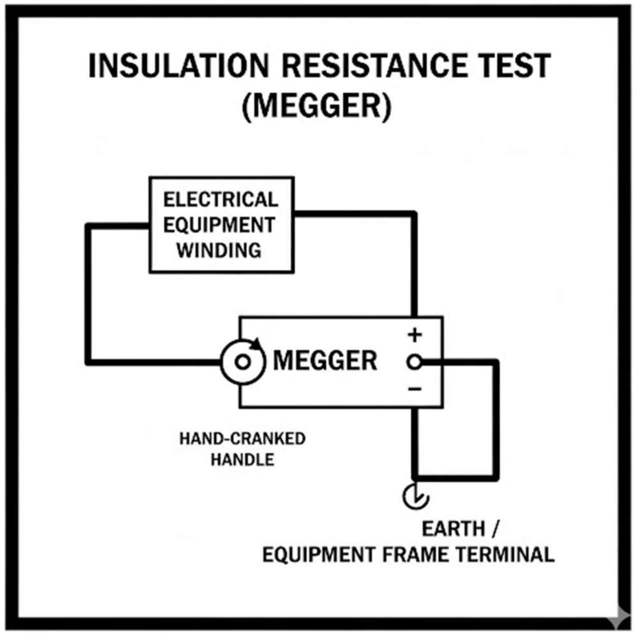
Typical test voltages:

- 500 V DC → low-voltage systems
- 1000 V DC → motors, cables
- 2500 V DC or higher → EHV equipment

**Step-by-step testing procedure**

1. Disconnect equipment from supply
2. Discharge stored energy to ground
3. Connect Megger leads between conductor and earth
4. Rotate handle/apply test button for 1 minute
5. Note IR value in **mega-ohms**

**Board sketch description:**
Draw the equipment winding, earth terminal, and Megger connected between them with hand-cranked handle.

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**(c) Typical IR values (general guideline)**

- Above 100 MΩ → excellent
- 10–100 MΩ → satisfactory
- Below 10 MΩ → weak / risky

(Actual limits depend on voltage rating and standards.)

---

**(d) Polarization Index (PI)**

PI is a **health indicator** of insulation.

[\text{PI} = \frac{\text{IR at 10 minutes}}{\text{IR at 1 minute}}]

Interpretation:

- PI > 2 → Very good insulation
- PI between 1–2 → Fair / aging insulation
- PI < 1 → Bad insulation / moisture present

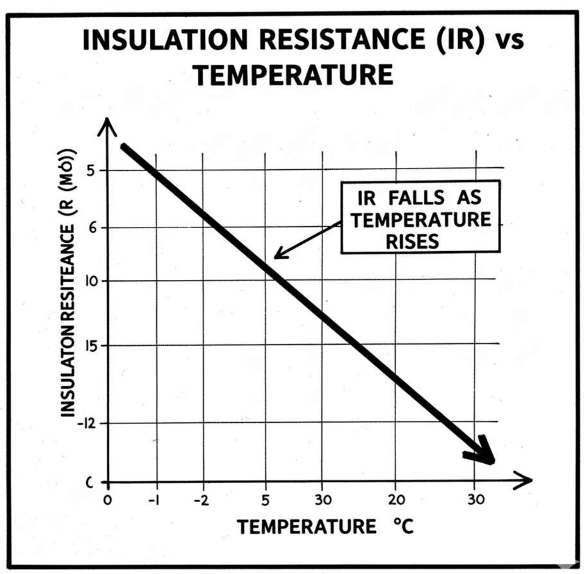
Why does IR increase with time?
Because DC voltage aligns molecules in insulation and **reduces leakage**, showing trend of insulation condition.

Explain with analogy:
Like stretching your legs before running — stability improves with time.

**(e) Factors affecting insulation resistance**

1. **Temperature** – Higher temperature → lower IR
2. **Moisture / humidity** – Water drastically reduces IR
3. **Dust and contamination**
4. **Aging of insulation**
5. **Mechanical stress and vibration**
6. **Chemical contamination and oil deterioration**

Show with graph description:
Draw a graph of **IR vs Temperature** sloping **downward** indicating IR falls as temperature rises.




## 3. Real-World / Industry Applications (≈ 10 minutes)

Where IR/PI testing is used?

- commissioning of motors, transformers, cables

- preventive maintenance
- before energizing equipment after shutdown
- after flood/water ingress
- during overhauling in power plants

**Example:**
A 3-phase induction motor tripped repeatedly. IR test showed very low resistance due to moisture. After **drying & varnishing**, IR recovered and motor worked normally — expensive replacement avoided.

Modern industries use:

- digital Meggers
- automatic PI calculators
- cloud-based health monitoring

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- IR tells **how healthy insulation is**
- Megger is used to measure IR
- PI is a ratio of 10-min to 1-min readings
- Temperature and moisture strongly affect IR
- IR testing is essential before commissioning

**Typical student doubts**

- Why do we test for 10 minutes?
  → To observe insulation behavior over time
- Why DC instead of AC?
  → AC causes heating and charging currents; DC gives stable readings
- Is higher IR always better?
  → Yes, but extremely high readings may indicate open circuit

**Topic 2.6: Drying of Winding of Electrical Equipment and Record Keeping**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple question:

👉 *What happens if a wet mobile phone is switched ON immediately?*
It may short-circuit, heat up, or get permanently damaged.

Similarly, **moisture inside windings of electrical equipment**—like transformers, motors, alternators, and generators—can reduce insulation resistance, cause flashover, and even **burn the equipment**.

You already know from earlier topics that:

- insulation must have **very high resistance**
- moisture **reduces insulation strength**

Today, we will learn **how engineers remove this moisture**. This process is called **drying of windings**. And equally important—**how to maintain proper records**, because in industry: "What is not recorded is considered not done."

## 2. Core Concepts (≈ 40 minutes)

**(a) Why is drying of windings necessary?**

Windings absorb moisture due to:

- long storage periods
- flooding or rain
- humid environment
- oil leakage or aging
- opening of equipment for maintenance

Moisture causes:

- low insulation resistance (IR)
- partial discharge
- formation of tracking and carbonization
- failure during high-voltage tests

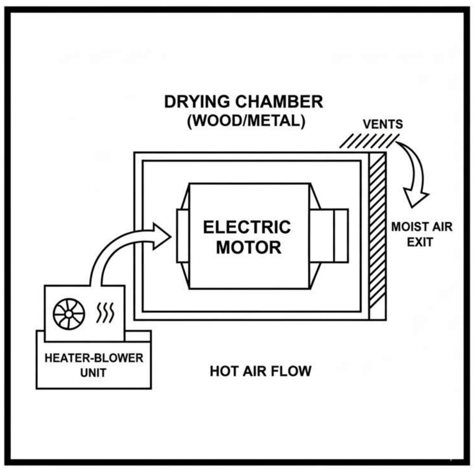
Analogy: *Think of a wet blanket on winter days—heavy, inefficient, and uncomfortable. Drying restores comfort.*

**(b) Methods of drying of windings**

## 1. Hot air drying

- warm air circulated using blower
- temperature controlled to avoid overheating
- commonly used for **motors and small transformers**

**Diagram description:**
Draw a motor placed in a wooden/metal chamber; arrows showing hot air flow from heater-blower into chamber and exiting through vents.




## 2. Oven / furnace drying

- equipment placed in an electric or gas oven
- uniform heating
- used for **coils and small machines**

## 3. Vacuum drying

- moisture evaporates at lower temperature under vacuum
- protects insulation from thermal damage

- widely used in **power transformers**

## 4. Oil-circulation drying (for transformers)

- hot transformer oil is circulated through windings
- removes moisture and dissolved gases
- improves insulation oil BDV simultaneously

**(c) Monitoring during drying**

Very important to emphasize for safety and quality:

- measure **insulation resistance (IR)** regularly
- measure **Polarization Index (PI)**
- monitor **temperature** of winding
- prevent overheating of insulation varnish

Students should remember:
👉 Drying is complete when **IR and PI stabilize and reach safe values**.

**(d) Record Keeping**

In industry, **documentation is as important as the work itself**.

Records include:

- equipment identification (rating, serial number, location)
- initial IR & PI before drying
- method used for drying
- temperature, duration, and readings every hour
- final IR & PI after drying
- signatures of responsible engineer/supervisor

These records help in:

- audit and safety compliance
- warranty claims
- future maintenance planning

- failure investigation

Think of it like a **medical history card** of the machine.

## 3. Real-World / Industry Applications (≈ 10 minutes)

Drying of windings is used:

- before commissioning new transformers
- after long storage in warehouses
- after flood or fire accidents
- during major overhauls
- in rewinding workshops

**Case example:**

After a monsoon flood, a 11 kV substation transformer showed very low IR. Instead of scrapping it, engineers used **vacuum drying and hot oil circulation**. IR improved, transformer was saved, and large replacement costs were avoided.

Fun fact:

Power transformer manufacturers use **vacuum oven drying** as a **standard factory process** before sealing tanks.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Moisture is enemy of insulation
- Drying restores insulation strength and reliability
- Hot air, oven, vacuum, and oil circulation are common methods
- IR and PI monitoring is essential
- Record keeping ensures traceability and safety

**Typical student doubts**

- *Why not just sun-dry equipment?*
  → Uneven heating damages insulation

- *How do we know drying is complete?*
  → IR and PI reach stable acceptable values

- *Can overheating occur?*
  → Yes — hence temperature control is critical

🎓 **Mentorship Note – Career Tip**

Engineers in **testing, commissioning, maintenance, and utility companies** handle equipment affected by moisture every monsoon or shutdown. If you understand **drying methods, IR/PI interpretation, and record keeping**, you become highly valuable as a **reliable field engineer**.

These concepts directly link to:

- substation maintenance
- transformer repair industry
- thermal & hydro power plants
- renewable energy systems

**Topic 2.7: Tests Before and After Commissioning of Power Transformer, Induction Motor and HV Circuit Breaker**

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## 1. Hook / Introduction (≈ 5 minutes)

Let's start with a real situation.

An 11 kV substation is ready. Equipment is installed. Cables are connected. The operator's hand is on the switch.

**Question:**
👉 *Can we energize directly? Or must we ensure that every equipment is healthy and safe?*

Commissioning tests are like a **full body check-up before starting heavy exercise**. They ensure that:

- the equipment is correctly installed
- insulation is healthy
- operation is safe

- performance is satisfactory

Today, we will learn **what to test, how to test, and why the tests matter** for:

- power transformers
- induction motors
- high-voltage circuit breakers

**Fun fact:** In industry, energizing equipment without tests is called *"blind switching"*—and no responsible engineer does that!

## 2. Core Concepts (≈ 40 minutes)

**A) Power Transformer Tests**

## 1. Tests before commissioning

- **Insulation Resistance (IR) test** using Megger
- **Polarization Index (PI)**
- **Turns ratio test (TTR)** – checks correct transformation ratio
- **Winding resistance test** – detects loose joints and open turns
- **Vector group test** – phase displacement verification
- **Oil BDV test** – insulation oil quality
- **Dielectric tests** as per standards
- **Check of tap changer operation**
- **Check of cooling system** (oil circulation/fans)

## 2. Tests after commissioning

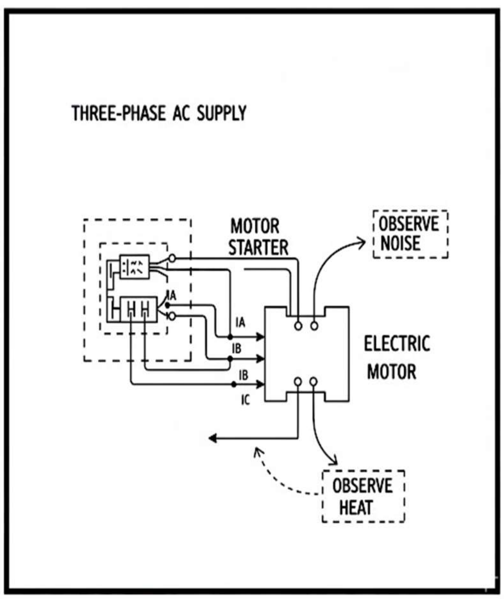
- **Loading observation**
- **Temperature rise check**
- **Noise and vibration check**
- **Monitoring of oil level and color**
- **Recording of readings at intervals**

**B) Induction Motor Tests**

## 1. Tests before commissioning

- **Continuity test** of winding
- **IR test between phase–phase and phase–earth**
- **Phase sequence test** (using phase sequence meter)
- **No-load run test** – observe noise, heating, abnormal current
- **Alignment and coupling checks**
- **Starter operation check** (DOL, Star-Delta, Soft starter)

Visual description to draw:
Motor, supply, starter, ammeter in each phase and observation arrows for noise/heat.




## 2. Tests after commissioning

- **Full-load performance observation**
- **Measurement of input current and voltage**
- **Temperature rise of stator and bearings**

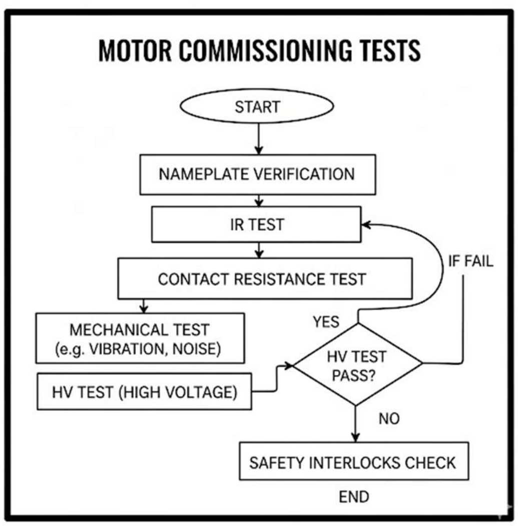
- **Vibration analysis and lubrication check**

**C) High-Voltage Circuit Breaker (HV CB) Tests**

## 1. Tests before commissioning

- **Contact resistance test**
- **Insulation resistance test** of poles and control circuit
- **High-voltage withstand test** (as per rating)
- **Mechanical operation test** – open/close timing
- **$SF_6$ / vacuum level check**

Flow-chart visual description:
Nameplate verification → IR → Contact resistance → Mechanical test → HV test → Safety interlocks.




## 2. Tests after commissioning

- **Trip and close operation under load**
- **Timing measurement using analyzer**
- **Gas pressure or vacuum level monitoring**

- **Thermal scanning of contacts**

## 3. Real-World / Industry Applications (≈ 10 minutes)

Commissioning tests are used in:

- power substations
- industries with large motors
- renewable plants evacuation systems
- metro/railway traction systems

**Case example:**

A transformer passed visual checks but failed **oil BDV test**. Drying and filtration were carried out; catastrophic failure during energization was avoided. The testing team literally **saved the substation**.

Modern industry tools:

- digital test kits
- thermal imagers
- online DGA and online breaker monitoring systems

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Testing is essential before and after commissioning
- Transformers: IR, PI, TTR, oil BDV, ratio & vector group
- Motors: IR, phase sequence, no-load & full-load tests
- HV breakers: contact resistance, timing, insulation tests
- Post-commissioning observation is as important as initial tests

**Typical student doubts**

- *Why test again after commissioning?*
  → To confirm that equipment behaves properly under real load
- *Why phase sequence test for motors?*
  → Wrong sequence changes direction of rotation

- *Why are breaker timing tests important?*
  → Slow operation damages system protection coordination

🎓 **Mentorship Note – Career Tip**

Commissioning engineers are among the **most respected professionals** in the power sector. If you can confidently perform and interpret:

- Megger testing
- TTR testing
- Contact resistance and timing tests

you become directly employable in:

- testing & commissioning companies
- power utilities and switchgear firms
- transformer and motor manufacturers

**Topic 2.8: Test Report on Commissioning and Test Certificate**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple but powerful thought:

👉 *In engineering, doing the work is only half the job — proving that you did it correctly is the other half.*

When a power transformer, induction motor, or high-voltage circuit breaker is commissioned, many technical tests are performed. But how will the owner, utility, insurance company, or future maintenance team know:

- what was tested
- what results were obtained
- whether the equipment was safe to energize

The answer is: **Test Report and Test Certificate**.

They are like the **discharge summary of a patient from a hospital** — a permanent technical record of the machine's "health condition" at the time of commissioning.

**Fun fact:** In many industries, if a test report is missing, the commissioning is considered "not done", even if the equipment was actually energized!

## 2. Core Concepts (≈ 40 minutes)

### (a) What is a Test Report?

A **test report** is a structured technical document that records:

- details of equipment
- tests performed
- instruments used
- test results
- final remarks and recommendations

It is prepared **immediately after commissioning** by the testing engineer or team.

### (b) Contents of a test report

A good commissioning test report usually includes:

1. **Heading**
    - "Commissioning and Testing Report"
2. **Equipment details**
    - type, rating, voltage, kVA/kW, serial number, manufacturer
3. **Site and location**
    - substation/industry name and address
4. **Test team details**
    - names, designations, signatures
5. **Environmental conditions**
    - temperature, humidity
6. **List of tests performed**
    - IR, PI, ratio test, contact resistance, etc.
7. **Test instruments used**

    - type, model, serial number, calibration due date

8. **Test procedure (brief)**
9. **Test results table**
10. **Remarks**

- satisfactory / not satisfactory

11. **Safety notes**
12. **Final conclusion**

- equipment is “fit for commissioning”

13. **Signatures and stamps**

- engineer, owner representative, witness

**(c) What is a Test Certificate?**

A **test certificate** is an official declaration that:

✓ tests have been completed
✓ results are within permissible limits
✓ the equipment is **safe and ready for service**

It is usually shorter than a test report, more formal, and often printed on **company letterhead**.

Analogy: *Report is the full medical record; certificate is the “Fitness Certificate”.*

**(d) Importance of test reports and certificates**

They are essential for:

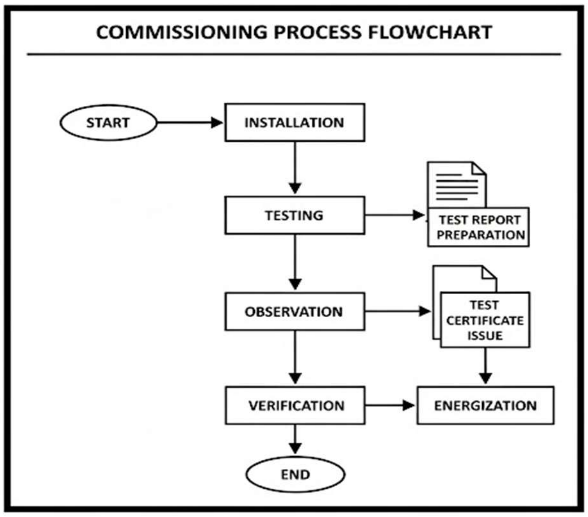
- warranty claims
- insurance settlements after failures
- future troubleshooting
- preventive maintenance planning
- audits and legal compliance

They also build **professional accountability**—an engineer is responsible for the statement signed.

**(e) Flow of documentation**

Explain as flowchart to draw on the board:

Installation → Testing → Observation → Test Report Preparation → Verification → **Test Certificate Issue** → Energization




## 3. Real-World / Industry Applications (≈ 10 minutes)

In actual industry practice:

- every transformer or breaker has a **file of test reports** from installation to scrapping
- reports are checked during **third-party inspection**
- International standards (IEC/IS) require written proof of testing
- digital records are now stored in **CMMS/Enterprise software**

**Case example:**
A transformer failed after lightning. Because a commissioning test certificate was available, the utility successfully claimed warranty from manufacturer.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Test report = detailed document of tests and results

- Test certificate = official declaration of fitness
- Both are essential for safety, warranty, and legal compliance
- Contents include equipment data, test results, remarks, and signatures
- Documentation is as important as testing itself

**Typical student doubts**

- *Can we energize without certificate?*
  → In industry, **No** — it is unsafe and legally risky
- *Who signs the test certificate?*
  → Authorized commissioning/test engineer
- *Are handwritten reports accepted?*
  → Yes, but digital records are preferred today

🎓 **Mentorship Note – Career Tip**

If you master preparing **professional test reports and certificates**, you gain a powerful career advantage. Testing and commissioning companies, utilities, and EPC contractors value engineers who can:

✔ perform tests
✔ interpret results
✔ **prepare clear documentation**

This is a core skill in **maintenance, quality assurance, auditing, and project commissioning** fields.

**Topic 2.9: Gradual Loading of Electrical Equipment and Commissioning & Testing of GIS Substation Equipment**

## 1. Hook / Introduction (≈ 5 minutes)

Let me start with a simple question:

👉 *If you buy a new bike, do you immediately ride it at full speed, or do you run it gently at first?*
You normally run it slowly, check brakes, listen to engine sound, and then gain speed.

Electrical equipment behaves the same way.

When a **transformer, motor or substation** is newly installed or repaired, we **never load it suddenly to 100%**. Instead, we **increase the load gradually**, observe behaviour, and ensure safe operation. Similarly, when a **GIS (Gas Insulated Substation)** is commissioned, every component is carefully tested before being connected to the grid.

Today's lecture combines two powerful ideas:

- **gradual loading** of electrical equipment
- **commissioning & testing of GIS substation equipment**

## 2. Core Concepts (≈ 40 minutes)

**A) Gradual Loading of Electrical Equipment**

## 1. What is gradual loading?

Gradual loading means **increasing load step-by-step**, while monitoring:

- current and voltage
- temperature rise
- vibration and noise
- insulation condition

Analogy: *Athletes warm up before running — machines "warm up" too.*

## 2. Why gradual loading is necessary

- protects insulation from sudden stress
- allows oil or air cooling to stabilize
- detects hidden internal faults
- avoids mechanical shock to rotating machines
- confirms proper alignment and balancing

## 3. Procedure for gradual loading

Typical steps (draw as a flowchart on the board):

No-load → 25% Load → 50% Load → 75% Load → 100% Full Load

At each stage observe:

- winding temperature
- bearing temperature (motors)
- oil level and color (transformers)
- load current balance
- abnormal sound/smell

If abnormal conditions are found → stop → investigate → rectify.

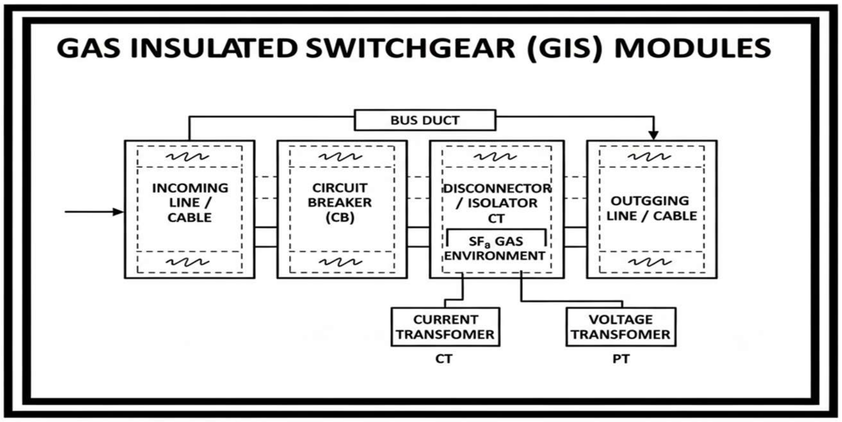
**B) Commissioning & Testing of GIS Substation Equipment**

## 1. What is GIS?

**Gas Insulated Substation (GIS)** uses **$SF_6$ gas** as insulating medium instead of air.
Advantages:

- compact size
- high reliability
- suitable for cities and hilly regions
- less maintenance

**Visual description:**
Draw sealed metal enclosures connected in modules containing CB, isolator, CT, PT, and bus ducts filled with gas.




## 2. GIS Components

- Gas insulated circuit breaker
- Gas insulated bus bar
- Isolators and earthing switches
- Current Transformers (CTs)
- Potential Transformers (PTs/VTs)
- Lightning arresters
- Gas monitoring system

## 3. Commissioning tests for GIS

Before energization, engineers perform:

- **Gas pressure and density check**
- **Gas leakage test**
- **Insulation resistance test**
- **High-voltage withstand test**

- **Contact resistance test of CB**
- **Mechanical operation test** (open–close timing)
- **Interlock and control circuit verification**
- **Partial discharge test** (for insulation health)

## 4. Safety considerations

- $SF_6$ must not be inhaled
- proper gas handling equipment required
- earthing and interlocking must be verified
- enclosure must be sealed to avoid moisture entry

**Fun fact:** A GIS of 400 kV may fit in a building smaller than your college auditorium!

## 3. Real-World / Industry Applications (≈ 10 minutes)

Gradual loading is applied when:

- new transformer or motor is installed
- after major overhaul/rewinding
- after flood or long storage
- during trial run of industrial plants

GIS substations are used in:

- metro cities (space limitation)
- underground substations
- offshore wind farms
- mountainous terrain

Case example:
A metropolitan power utility replaced old air-insulated substation with **GIS** to save space and improve reliability. Gradual loading prevented sudden failure during first energization.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Gradual loading prevents thermal and electrical shocks
- Stepwise loading allows monitoring of equipment health
- GIS uses $SF_6$ gas and is compact and reliable
- Commissioning tests ensure safety before energization
- Testing includes insulation, mechanical, gas, and control checks

**Typical student doubts**

- *Why not directly load to 100%?*
  → Risk of insulation failure and overheating
- *Is $SF_6$ dangerous?*
  → Non-flammable but must be handled carefully
- *Why GIS instead of AIS?*
  → Space saving and reliability

🎓 **Mentorship Note – Career Tip**

Industries need **commissioning engineers** who understand gradual loading, modern substations, and safety. Knowledge of **GIS technology** is highly valued in transmission utilities, metro projects, and renewable integration.

Master this topic and you are preparing yourself for roles in:

- substation commissioning
- transmission utilities
- EPC power projects
- testing and maintenance services

**Topic 2.10: Standard Procedure for Commissioning of Domestic & Industrial Solar Plants and Wind Plants**

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## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a question that connects directly to your future:

👉 *India is rapidly moving toward renewable energy. Are you ready to commission the plants that will power the next generation?*

Solar and wind plants are not just "green technology"—they are among the **fastest growing job sectors** for diploma electrical engineers. You already know the basics of **solar PV systems** and **wind turbines**. Today we learn something very practical:

✔ How to **commission** them step-by-step
✔ How to **test** that everything is safe and working
✔ What **documents and approvals** are required

**Fun fact:** India is one of the world's top countries in **solar rooftop installations** and **onshore wind farms**.

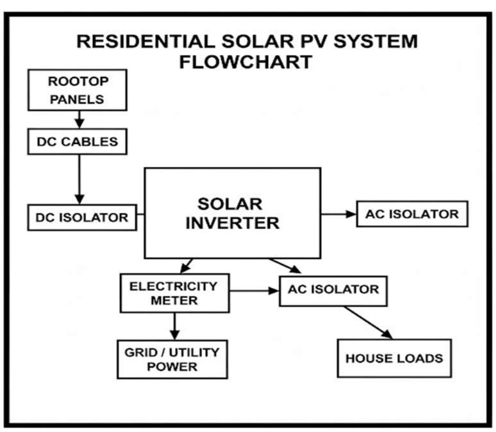
## 2. Core Concepts (≈ 40 minutes)

**A) Commissioning of Domestic Solar PV Plant (Rooftop System)**

## 1. Pre-commissioning checks

- verify module mounting structure and tilt angle
- check mechanical tightness of nuts and bolts
- ensure proper **earthing and lightning protection**
- check wiring polarity (+ and −) carefully
- verify capacity of inverter and cables
- ensure shade-free panel installation
- check DC isolator and AC isolator positions

**Visual description:**
Draw simple rooftop: panels → DC cables → DC isolator → inverter → AC isolator → meter → grid/house load.



## 2. Electrical testing

- open-circuit voltage and short-circuit current of strings
- insulation resistance of cables/modules
- continuity test of earthing system
- inverter functional checks (start/stop, display, alarms)

## 3. Synchronization and grid connection

- check grid voltage and frequency limits
- anti-islanding protection verification
- export/import meter functioning
- initial trial run at low irradiance, then normal operation

## 4. Documentation

- single-line diagram
- commissioning checklist
- test report & photographs
- net-metering application where applicable

**B) Commissioning of Industrial Solar PV Plants (Ground-mounted or Large Rooftop)**

Steps are similar but at **higher capacity** with additional elements:

- string combiner boxes test
- SCADA communication check
- protection relay testing
- transformer and HT breaker commissioning
- performance ratio (PR) measurement
- cleaning arrangement check (water/wipers)

Industrial systems require **team coordination and detailed safety permits**.

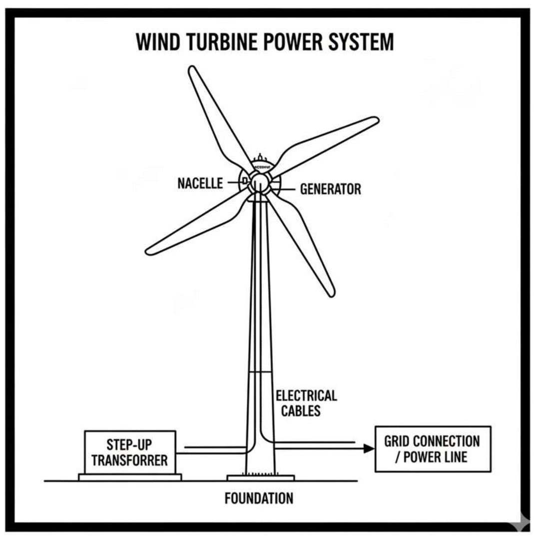
**C) Commissioning of Wind Power Plant**

## 1. Pre-commissioning inspection

- tower alignment and bolt tightening
- blade condition and pitch alignment
- nacelle and gearbox oil level
- yaw system and braking system check
- cable terminations in tower sections

**Visual description to draw:**

Wind turbine tower with nacelle on top, three blades, cables going down tower to transformer and grid connection.




## 2. Electrical testing

- insulation resistance of generator winding
- continuity of control and signal cables
- operation of yaw, pitch, and brake motors
- inverter/power converter functional checks

## 3. Trial run

- low-speed rotation

- gradual loading
- vibration and noise monitoring
- synchronization with grid
- power curve observation

## 4. Safety and permits

- lock-out tag-out (LOTO) procedure
- climbing safety equipment
- high-wind shutdown testing
- environmental and wildlife considerations

## 3. Real-World / Industry Applications (≈ 10 minutes)

You will find commissioning activities in:

- rooftop residential solar projects
- industrial EPPC solar parks
- government solar schemes
- utility-scale wind farms
- hybrid wind–solar plants

Example case:

A coastal wind farm turbine tripped frequently. Commissioning engineers detected **loose earthing and signal cable faults**, corrected them, and restored generation—saving massive power loss.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Commissioning ensures **safety + performance** before regular operation
- Domestic solar: modules, inverters, meters, earthing, anti-islanding checks
- Industrial solar adds SCADA, transformers, HT protection and PR testing

- Wind plant commissioning includes tower, blades, yaw/pitch, generator and grid synchronization
- Documentation is essential at every stage

**Typical student doubts**

- *Can I connect solar directly to grid?* — Only after protection checks
- *Why is anti-islanding important?* — To protect linemen during outages
- *Do wind turbines work in very high wind?* — They shut down for safety

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🎓 **Mentorship Note – Career Tip**

Commissioning of **solar and wind plants** is one of the **hottest employment areas** for diploma engineers. If you master:

✔ step-by-step commissioning procedures
✔ testing and documentation
✔ safety practices

✅ **A. Low-Level Prompts (10 prompts – Remember & Understand)**

**Focus:** definitions • basic concepts • short explanations • summaries

1. **"Explain in simple words what commissioning means in engineering and why it is important before operating any system."**
2. **"Give short definitions of installation, commissioning, testing, maintenance, and troubleshooting in engineering."**
3. **"Explain the difference between type testing and routine testing in simple language."**
4. **"Describe, in easy terms, what insulation resistance is and why engineers measure it."**
5. **"Give a brief note on safety precautions that must be followed during testing and commissioning activities."**
6. **"Explain the meaning of preventive maintenance and breakdown maintenance with simple examples."**

7. **“Write short notes on the purpose of test reports and test certificates used after commissioning.”**
8. **“Explain what gradual loading of equipment means and why sudden loading is avoided.”**
9. **“Describe in simple points what is done during drying of windings before commissioning.”**
10. **“Give a simple summary of the steps involved in commissioning an engineering system of your choice.”**

🧩 **B. Moderate-Level Prompts (10 prompts – Apply & Analyze)**

**Focus:** application • comparisons • real-life cases • reasoning

11. **“Compare installation and commissioning: how are they different in purpose, steps, and outcomes? Give practical examples.”**
12. **“Explain how you would check whether an electrical machine is ready for commissioning after long storage.”**
13. **“A machine shows low insulation resistance. Explain possible causes and suggest corrective actions in clear steps.”**
14. **“Create a table comparing preventive maintenance and corrective maintenance with advantages and limitations.”**
15. **“Explain how gradual loading helps detect hidden faults in newly installed equipment. Give real-life situations.”**
16. **“Describe step-by-step how you would carry out testing before energizing any industrial equipment for the first time.”**
17. **“Analyze why record keeping during commissioning and maintenance is important for safety, warranty, and future troubleshooting.”**
18. **“Explain how environmental conditions such as temperature and humidity affect test results and equipment performance.”**
19. **“Give practical examples where improper commissioning led to equipment failure or unsafe operation. Explain what should have been done correctly.”**
20. **“Explain how testing procedures change when dealing with small domestic systems versus large industrial systems.”**

### 🚀 C. High-Level Prompts (5 prompts – Design & Create)

**Focus:** design thinking • workflow creation • complex systems • decision-making

21. **“Design a step-by-step checklist for commissioning any newly installed engineering system, including safety, testing, and documentation stages.”**
22. **“Create a logical flowchart showing the complete process from installation to commissioning, testing, gradual loading, and final approval.”**
23. **“Develop a template format for a professional test report and test certificate that engineers can use after commissioning work.”**
24. **“Propose a systematic maintenance strategy for an engineering plant that includes routine inspection, testing, record keeping, and fault diagnosis.”**
25. **“Design a learning plan for yourself to master commissioning and testing concepts, including what to study first, practice activities, and self-evaluation methods.”**

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### 💡 How students should use this toolkit

- copy any prompt
- paste into your preferred AI assistant
- read, question, and practice actively
- ask follow-up “why/how/explain deeper” style questions

This toolkit supports:
✓ exam preparation
✓ viva/practical readiness
✓ project and internship learning
✓ concept clarity & confidence

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### 🎓 Mentor’s note

Learning with AI is like learning with a **24×7 tutor** — but **you** are the driver.
Use these prompts to:

- explore
- question

- visualize
- compare
- design

✅ **1. Key Definitions / Glossary (15 terms – one-line, Diploma level)**

1. **Commissioning** – The process of checking, testing, and making equipment ready for regular service after installation.
2. **Installation** – Physical placement, wiring, and mechanical fixing of equipment at the site.
3. **Insulation Resistance (IR)** – The resistance offered by insulating material to leakage current between live parts and earth.
4. **Polarization Index (PI)** – Ratio of insulation resistance measured at 10 minutes to that measured at 1 minute, indicating insulation health.
5. **Breakdown Voltage (BDV)** – Minimum voltage at which insulating oil loses dielectric strength and allows sparkover.
6. **Preventive Maintenance** – Planned periodic maintenance done to avoid breakdown of equipment.
7. **Breakdown Maintenance** – Maintenance carried out after equipment has failed or stopped working.
8. **Test Certificate** – Official document confirming that tests are completed and equipment is fit for service.
9. **Test Report** – Detailed record of test procedures, instruments used, readings, and conclusions during commissioning.
10. **No-Load Test** – Test performed on equipment without connecting load to check basic operation and losses.
11. **Gradual Loading** – Step-by-step increase of load on new or repaired equipment while observing performance.
12. **Drying of Winding** – Removal of moisture from insulation and windings to improve insulation resistance.
13. **High-Voltage Test** – Test in which high voltage is applied to check insulation strength without causing failure.

14. **Troubleshooting** – Systematic process of finding and rectifying faults in equipment or systems.

15. **Earthing** – Intentional connection of equipment body to earth to protect human beings and equipment during faults.

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## ✅ 2. FAQ & Assessment Section

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### 📝 A. Multiple Choice Questions (20)

**Select the most appropriate answer.**

1. Commissioning of equipment is normally carried out
   a) before installation
   b) during transportation
   c) after installation and testing
   d) only during failure

2. Insulation resistance is measured using
   a) voltmeter
   b) ammeter
   c) megger
   d) wattmeter

3. Low insulation resistance generally indicates
   a) strong insulation
   b) presence of moisture or dirt
   c) high efficiency
   d) correct installation

4. BDV test is performed on
   a) transmission lines
   b) insulation oil
   c) batteries
   d) earthing rods

5. Polarization Index is measured over a time period of
   a) 1 second
   b) 1 minute and 10 minutes
   c) 10 seconds and 1 minute
   d) 5 minutes and 20 minutes

6. Drying of windings is carried out mainly to
   a) reduce weight
   b) increase copper loss
   c) remove moisture
   d) increase noise

7. Gradual loading of equipment helps mainly in
   a) increasing tariff
   b) preventing mechanical and electrical stress
   c) reducing voltage rating
   d) painting equipment

8. Which of the following is NOT a commissioning test?
   a) IR test
   b) PI test
   c) Painting inspection
   d) High-voltage test

9. Test report is prepared
   a) before testing
   b) during manufacturing
   c) after testing and commissioning
   d) only during breakdown

10. Test certificate certifies that the equipment is
    a) damaged
    b) unsafe
    c) fit for service
    d) under construction

11. Preventive maintenance is carried out
    a) only after failure
    b) at predetermined intervals
    c) only for new equipment
    d) only for small devices

12. Breakdown maintenance is applicable when
    a) equipment is working normally
    b) equipment is operating at full efficiency
    c) equipment has already failed
    d) commissioning is completed

13. High insulation resistance indicates
    a) poor insulation
    b) good insulation

c) overheating
d) short circuit

14. Gradual loading usually begins with
a) full load
b) half load
c) no-load condition
d) short-circuit test

15. Before commissioning, the first activity generally carried out is
a) dismantling
b) troubleshooting
c) visual inspection
d) painting

16. During commissioning, earthing is checked mainly for
a) color
b) insulation paint
c) mechanical strength
d) safety and fault current dissipation

17. In test documentation, calibration record is related to
a) test instruments
b) workers
c) buildings
d) cables only

18. Higher temperature of insulation usually results in
a) increased IR
b) reduced IR
c) no change in IR
d) zero IR

19. A common reason for transformer oil filtration is
a) increasing copper loss
b) removing moisture and impurities
c) decreasing core loss
d) reducing viscosity to zero

20. In commissioning activities, trial run is carried out to
a) change design
b) check practical behavior of equipment
c) repaint equipment
d) increase tariff charges

### 🎤 B. Short Answer / Viva Questions (10)

1. Define commissioning and state its main objectives.
2. Why is insulation resistance testing important before energizing equipment?
3. Explain why gradual loading is preferred instead of sudden full-load operation.
4. State any four causes of reduction in insulation resistance.
5. What is Polarization Index and what information does it provide?
6. Why is record keeping essential during testing and commissioning activities?
7. Distinguish between preventive and breakdown maintenance.
8. What precautions should be taken while performing high-voltage tests?
9. State the importance of test certificates in industrial practice.
10. Why is drying of winding required before commissioning stored or flood-affected equipment?

### 🎓 Final educator's note

Use this Mastery Check to:

- revise before exams
- prepare for viva and practicals
- self-evaluate after each topic
- identify weak areas for re-study

### 📚 1. AI Tools & Digital Learning Tools

These tools help you **visualize**, **simulate**, **practice**, and **generate explanations** for the topics in this unit.

### ✅ 1. ChatGPT / Gemini / Claude (AI Learning Assistant)

**Purpose / Use-case:**

- Ask questions, get explanations, summaries, examples, viva answers
- Create checklists, reports, troubleshooting flows

**How it helps this unit:**

- Explains commissioning steps
- Generates test procedures
- Creates maintenance schedules and troubleshooting charts
- Helps revise definitions and solve doubts instantly

✅ **2. PhET Interactive Simulations**

**Purpose / Use-case:**

- Virtual electrical experiments
- Understanding current, voltage, insulation, circuits, testing principles

**How it helps this unit:**

- Visualizes insulation behavior, leakage paths, safety grounding ideas
- Builds intuition about testing before real lab work
- Safe practice without equipment damage risk

✅ **3. Electrical 3-Phase & Motor Simulation Apps (Android/iOS)**

**Purpose / Use-case:**

- Visualize motor starting, loading, and performance
- Study commissioning behavior of machines

**How it helps this unit:**

- Shows effects of phase sequence, overload, imbalance
- Helps understand gradual loading, no-load vs full-load conditions
- Strengthens conceptual clarity for practical exams

✅ **4. PSIM / LTspice (basic circuit simulation)**

**Purpose / Use-case:**

- Simulate electrical circuits, testing setups, measurement processes
- Observe waveforms and responses

**How it helps this unit:**

- Understands testing circuits conceptually
- Reinforces safety without live HV exposure
- Supports mini-projects and reports

✅ **5. Virtual Labs (Government MHRD Initiative)**

**Purpose / Use-case:**

- Perform practical experiments virtually
- Practice testing and measurement procedures

**How it helps this unit:**

- IR measurement experiments
- Transformer testing
- Motor commissioning-related activities
- Excellent for students without full lab access

🎥 **2. Video Learning Repository**

*(Search using keywords provided — no URLs needed)*

| **Topic Name** | **Recommended Channel / Course / Lecturer Name** | **Search Keywords** |
|---|---|---|
| Basics of Commissioning & Testing | NPTEL – Electrical Engineering | NPTEL commissioning testing electrical equipment |
| Insulation Resistance & Polarization Index | All About Electrical Engineering / NPTEL | insulation resistance PI test explained |
| Transformer Oil Testing & BDV Test | GATE Academy / Electrical Lectures | transformer oil BDV test procedure |
| Commissioning of Power Transformer | NPTEL Power Systems Course | commissioning of power transformer step by step |
| Testing of Induction Motor | Learn Electrical Engineering / NPTEL Machines | induction motor testing commissioning |

| Topic Name | Recommended Channel / Course / Lecturer Name | Search Keywords |
| --- | --- | --- |
| Drying of Windings | Electrical Maintenance Training Channel | drying of winding electrical machine procedure |
| Gradual Loading of Equipment | Substation Operation Training Channel | gradual loading of electrical equipment explanation |
| HV Circuit Breaker Testing | EEP Academy / NPTEL Switchgear | high voltage circuit breaker testing commissioning |
| GIS Substation Working & Commissioning | NPTEL – Substation Engineering | GIS substation commissioning testing |
| Commissioning of Solar PV Plant | NPTEL Renewable Energy / Energy Literacy | solar plant commissioning procedure |
| Commissioning of Wind Power Plant | NPTEL Wind Energy Course | wind power plant commissioning steps |
| Safety in Commissioning & Testing | Electrical Safety Training Channel | electrical safety during commissioning testing |
| Test Reports and Certificates | Engineering Inspection & Testing Channel | test report test certificate electrical commissioning |
| Earthing and Ground Testing | NPTEL Power System Protection | earthing testing commissioning procedure |
| Troubleshooting of Electrical Equipment | Practical Electrical Training Channel | troubleshooting electrical machine commissioning |

## ✅ 1. Most Repeated / High-Probability Questions

*(Theory, definitions, explanations, and diagram-based)*

These reflect **typical board-style questions** that frequently appear.

**Short Questions – 2 to 4 Marks**

1. Define commissioning. State its objectives.
2. List the tests carried out before commissioning of power transformer.

3. Define insulation resistance and state its importance.
4. State properties of insulating oil.
5. Define Polarization Index. What does it indicate?
6. List the factors affecting insulation resistance.
7. State causes of deterioration of transformer insulating oil.
8. List methods of drying winding of electrical equipment.
9. State the purpose of oil filtration in transformers.
10. Define preventive maintenance and breakdown maintenance.
11. What is BDV test? Where is it used?
12. Write significance of test reports and test certificates.

**Long Questions – 7 Marks**

13. Explain **commissioning tests of power transformer** in detail.
14. Describe **tests before and after commissioning** of induction motor.
15. Explain **drying of winding procedure** with neat block diagram.
16. Explain **measurement of insulation resistance and PI** step-wise.
17. Explain **gradual loading** of newly installed electrical equipment.
18. Describe **commissioning and testing procedure of GIS substation equipment**.
19. Explain **standard procedure for commissioning of solar plant**.
20. Explain **standard procedure for commissioning of wind power plant**.

**Diagram / Flow-chart-based Questions**

21. Draw and explain **IR measurement setup using megger**.
22. Draw flowchart of **commissioning sequence of electrical machine**.
23. Draw labeled diagram of **transformer oil testing arrangement**.
24. Prepare a **typical test report format** for commissioning of equipment.

Tip: In board exams, **commissioning of transformer + IR/PI + oil testing** are the **highest frequency questions**.

## ✅ 2. Application & Logical Thinking Questions

*(Differentiates pass-level from distinction-level students)*

1. **A newly installed transformer shows low IR value.**
   – Explain step-by-step diagnostic procedure a commissioning engineer will follow.
2. **During motor commissioning, full-load is suddenly applied and tripping occurs.**
   – Analyze the reason and suggest preventive measures using gradual loading concept.
3. **A substation GIS breaker passes mechanical tests but fails during electrical test.**
   – Interpret the situation and list possible technical causes.
4. **Insulating oil passes BDV test but machine still shows poor PI value.**
   – Explain logically how both results can occur and what action should be taken.
5. **Write a logical commissioning workflow for domestic solar rooftop system**, including testing, documentation, and safety verification steps.

## Unit–3: Maintenance of Electrical Equipment

### 🌟 Teaching Philosophy

You will notice the plan integrates:

- ✔ **Professional expertise** (industry practices and standards)
- ✔ **Motivational coaching** (why topics matter for careers)
- ✔ **Approachable mentorship** (simple language + examples)
- ✔ **OBE focus** (CO mapped, skills & employability)
- ✔ **NEP-2020 spirit** (application, projects, field exposure)

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### 📚 UNIT–3 Structured Study Plan

***Maintenance of Electrical Equipment***

🔹 **Legend used**

- **Core Topic (C)** – must master
- **Supporting Topic (S)** – helps understanding

- **Application/Industry-Oriented Topic (A)** – job skills & practical use
- **Exam Weight** – ★ Low, ★★ Medium, ★★★ High
- **Practical Relevance** – 🛠 low, 🛠🛠 medium, 🛠🛠🛠 high

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✅ **Unit–3 Topic-wise & Hour-wise Teaching Plan (Total 10 Hours)**

| Sr | Topic & Subtopics (as per syllabus) | Category | Logical Position | Suggested Time (hrs) | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|---|
| 1 | **Need & functions of maintenance department** | C | Introductory foundation | 1.0 | ★★ | 🛠🛠 |
| 2 | **Reasons of electrical equipment failure due to poor maintenance** | C | After need awareness | 0.75 | ★★★ | 🛠🛠🛠 |
| 3 | **Preventive maintenance** – need, classification, activities, advantages & frequency | C | Core maintenance philosophy | 1.5 | ★★★ | 🛠🛠🛠 |
| 4 | **Breakdown maintenance** – concept, advantages, activities | S | Comparison with preventive | 0.75 | ★★ | 🛠🛠 |
| 5 | **Factors for preparing maintenance schedule** | S | Link to scheduling topics | 0.5 | ★★ | 🛠🛠 |
| 6 | **Maintenance schedule of transformer below & above 1000 kVA** | A | First equipment application | 1.25 | ★★★ | 🛠🛠🛠 |

| Sr | Topic & Subtopics (as per syllabus) | Category | Logical Position | Suggested Time (hrs) | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|---|
| 7 | **Maintenance schedule of induction motor, alternator in TPP, SF6 circuit breaker** | A | Multi-equipment competence | 1.25 | ★★★ | 🛠🛠🛠 |
| 8 | **Probable faults due to poor maintenance** in – transformer, IM, alternator, breaker, OH lines, battery, solar inverter | C + A | Fault linkage to maintenance | 1.0 | ★★★ | 🛠🛠🛠 |
| 9 | **Conditioning & monitoring** – need and advantages | C | Bridge to advanced condition monitoring | 0.5 | ★★ | 🛠🛠 |
| 10 | **Condition monitoring of transformer & IM** | A | Skill-based employability content | 0.75 | ★★★ | 🛠🛠🛠 |
| 11 | **Maintenance of domestic & industrial solar plant components & wind plant** | A (Green tech) | Advanced / modern application | 0.75 | ★★★ | 🛠🛠🛠 |

◆ **Total = 10 Hours**

🧭 **Logical Teaching Sequence**

You will begin with **why maintenance matters**, then build up to **methods**, then extend to **equipment-specific schedules and renewable systems**.

1. **Conceptual foundation**
    - maintenance need & role

- failure causes

2. **Types & philosophy**
   - preventive vs breakdown
   - scheduling principles
3. **Equipment-wise applications**
   - transformer
   - induction motor
   - alternator
   - circuit breaker
4. **Failure analysis**
   - probable faults
   - link with maintenance quality
5. **Modern maintenance approach**
   - condition monitoring
   - data-based assessment
6. **Future oriented systems**
   - solar plant maintenance
   - wind plant maintenance

This flow develops learning **from "KNOW → UNDERSTAND → APPLY → ANALYZE"** (OBE-compliant).

### 🎯 Core, Supporting & Application-Oriented Topic Classification

| **Type** | **Topics Included** |
|---|---|
| **Core Topics (C)** | Maintenance need, failure reasons, preventive & breakdown maintenance, faults due to poor maintenance, condition monitoring basics |

| Type | Topics Included |
|---|---|
| **Supporting Topics (S)** | Scheduling factors, classification & terminology |
| **Application-Oriented Topics (A)** | Equipment-wise maintenance schedules, solar plant & wind plant maintenance, SF6 breaker maintenance, condition monitoring of transformer & IM |

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### 📝 Exam & Practical Focus Guidance for Faculty & Students

| Topic Area | Exam Probability | Lab/Field Jobs Benefit |
|---|---|---|
| Preventive vs breakdown maintenance | Very High | Directly asked in interviews |
| Maintenance schedule preparation | Very High | Core industry documentation |
| Transformer & motor maintenance | Very High | Substation & plant jobs |
| Fault causes due to poor maintenance | Very High | Troubleshooting roles |
| SF6/Vacuum breaker maintenance | High | Switchgear industries |
| Solar & wind plant maintenance | Very High (new trend) | Green energy sector |
| Condition monitoring | High | Predictive maintenance jobs |

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### 🧩 Alignment with OBE & NEP-2020

This unit develops:

- ✔ **Cognitive skills:** explain, compare, analyze failures
- ✔ **Psychomotor skills:** prepare schedules, inspect systems
- ✔ **Affective skills:** safety, responsibility, eco-awareness
- ✔ **Employability:** substation & renewable maintenance

- ✔ **Multidisciplinary learning:** electrical + safety + environment

Learning outcomes targeted:

- CO3: Maintenance of equipment
- CO4: Troubleshooting skills
- CO5: Safety & reliability awareness

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💡 **Suggested Teaching–Learning Strategy (for lecturer)**

- 🔹 Start each topic with **industry scenario or failure case**
- 🔹 Use lab visits / substation photos / videos
- 🔹 Motivate students toward **roles like maintenance engineer, supervisor, technician**
- 🔹 Integrate **micro-projects & checklists**
- 🔹 Encourage AI tools for:
    - schedule generation
    - troubleshooting charts
    - checklists creation

**Unit 3 – Maintenance of Electrical Equipment**
**Topic 3.1 – Need & Functions of Maintenance Department**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a question:

👉 *"What happens if we never service our bike or scooter?"*
At first, it runs fine… then mileage drops… unusual noise starts… finally, one day it refuses to start.

**Electrical equipment behaves exactly the same way.**

Transformers, motors, circuit breakers, panels — all are like living systems.
They **age**, **heat up**, **vibrate**, **get dusty**, and **fail** if we ignore them.

A single failure in an industry can cause:

- production loss
- power shut down
- safety hazards
- expensive repairs

That is why every power plant, substation, and industry has a **Maintenance Department** — the "doctor" of electrical equipment.

Fun fact: In modern industries, the **maintenance budget is often higher than the installation cost** because reliability is more valuable than new purchase.

Today, we will understand **why maintenance is needed** and **what the maintenance department actually does.**

## 2. Core Concepts (≈ 40 minutes)

**➤ What is maintenance?**

Maintenance is a **systematic activity** carried out to **keep equipment in healthy operating condition**, prevent breakdowns, and restore normal working after faults.

Simple analogy:
Maintenance department = **hospital for machines**

**➤ Need for maintenance**

Maintenance is required to:

- avoid unexpected breakdown
- ensure safety of workers
- increase life of equipment
- reduce energy losses & overheating
- maintain efficiency & reliability
- comply with electrical standards and rules
- ensure continuous production and power supply

Imagine a transformer in a substation.
If its oil is not tested for BDV or moisture — it may fail and **blackout an entire area**.

➤ **Functions of maintenance department**

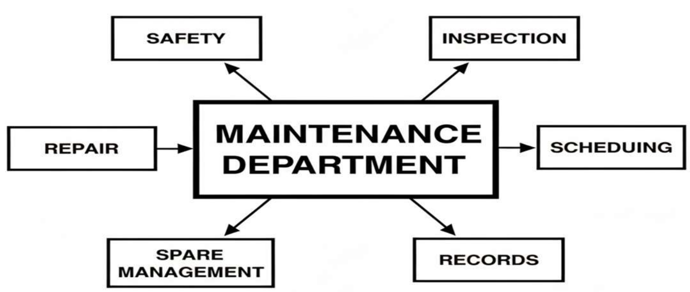
The maintenance department normally performs the following functions:

1. **Routine inspection**
    - visual checking, noise observation, temperature monitoring
2. **Preventive maintenance**
    - cleaning, lubrication, tightening of connections
    - periodic testing of insulation resistance, earthing, oil quality
3. **Predictive / condition monitoring**
    - vibration analysis
    - thermal scanning
    - oil testing
    - online monitoring systems
4. **Breakdown maintenance**
    - locating faults
    - repairing or replacing failed parts
    - restoring supply
5. **Maintenance planning and scheduling**
    - yearly/quarterly/monthly maintenance charts
    - shutdown planning
    - manpower and tool allocation
6. **Record keeping**
    - logbooks
    - test reports
    - service history
    - warranty and spare records
7. **Safety management**

- work permits
- earthing of equipment
- lockout–tagout procedures

8. **Inventory control**
    - spare parts
    - lubricants
    - tools & instruments
9. **Training of technicians**
    - safe working practices
    - equipment-specific knowledge

Visual suggestion: Draw a **simple block diagram** showing "Maintenance Department" in the center with arrows pointing to functions like *Inspection, Scheduling, Records, Safety, Repair, Spare Management.*




## 3. Real-World / Industry Applications (≈ 10 minutes)

- Power stations maintain **generators, alternators & switchgear**
- Substations maintain **transformers, CTs, PTs, breakers**
- Industries maintain **motors, drives, PLC panels**
- Renewable plants maintain **solar inverters, wind generators**

Case example:

A cement plant reported frequent motor burnouts.
Maintenance team found **loose terminals causing overheating**. After scheduled tightening and IR testing — failures **reduced to zero**. That is the power of maintenance.

## 4. Summary & Q&A (≈ 5 minutes)

**Quick revision points**

- Maintenance prevents failure and ensures safety
- It increases life and reliability of equipment
- Maintenance department functions include:
    - inspection
    - preventive and breakdown maintenance
    - record keeping
    - safety procedures
    - inventory control
    - condition monitoring

**Typical student doubts**

- "Why do new machines need maintenance?" → Aging starts from day one
- "Is preventive maintenance expensive?" → Breakdown is much more expensive
- "Who works in maintenance department?" → Diploma engineers are key staff

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### 🎯 Mentorship Note (Career Tip)

If you master **maintenance concepts**, you open doors to careers in:

- power plants
- transmission and distribution utilities
- large industries
- renewable energy plants
- electrical service companies

Maintenance engineers are highly valued because they **keep systems alive**.

Remember: *Anyone can install equipment — but only skilled engineers can keep it running safely and reliably.*

**Unit 3 – Maintenance of Electrical Equipment**
**Topic 3.2 – Reasons of electrical equipment failure due to poor maintenance**

## 1. Hook / Introduction (≈ 5 minutes)

Let me start with a small story.

A factory installed a brand-new 3-phase induction motor. It worked perfectly for 8 months. After that, it suddenly burned out. When engineers investigated, the reason was very simple:

👉 **dust accumulation + loose connections + no preventive maintenance**

The motor was healthy —
**maintenance was unhealthy.**

So here is today's question for you:

"Do machines die because they are old — or because they are neglected?"

Most failures in electrical equipment do not happen overnight. They **grow slowly inside the system** because of poor maintenance practices.

Today, we will learn the **main causes of failure** so that you, as future diploma engineers, can **prevent breakdown instead of repairing after failure.**

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## 2. Core Concepts (≈ 40 minutes)

➤ **Meaning of failure due to poor maintenance**

Failure here means:

- overheating
- insulation breakdown
- mechanical damage
- unexpected shutdown

- reduction in efficiency or life

Now let's understand the key reasons one by one.

## 1. Lack of periodic inspection

If equipment is not checked regularly:

- dust accumulates
- terminals loosen
- vibration increases
- unusual sound remains unnoticed

Example: Loose terminals in a motor cause **sparking + heat → insulation failure.**

## 2. Poor lubrication and cleaning

Rotating machines need lubrication.
Without it →

- bearing wear
- friction heating
- shaft misalignment

Analogy: Just like running a bicycle without oil on the chain.

## 3. Overheating and overloading

Overloading causes:

- copper losses ↑
- temperature ↑
- insulation strength ↓

Result → winding burnout in motors and transformers.

## 4. Moisture and contamination

Moisture enters through cracks or breathing holes.

Effects:

- reduction in insulation resistance
- corrosion of terminals
- oil deterioration

That is why IR test and BDV test are part of maintenance.

**5. Ignoring warning signals**

Machines “talk” to us through:

- noise
- smell
- temperature rise
- vibration
- change in current

When these are ignored, minor defects become major failures.

**6. Poor-quality repair and wrong spare parts**

Incorrect rewinding, improper insulation class, or local-quality spares → early failure.

**7. Lack of earthing and protection**

Improper earthing and defective protective devices lead to:

- electric shock hazards
- equipment burnout
- fire incidents

**8. Poor record keeping**

If maintenance history is not recorded:

- same fault repeats
- preventive actions are missed

## 3. Real-World / Industry Applications (≈ 10 minutes)

- In substations, failure of transformer often starts with **oil contamination**.
- In industries, motors fail due to **unbalanced voltages or loose terminals.**

- In solar plants, failure occurs due to **dirty panels and inverter cooling issues.**
- In wind turbines, poor lubrication causes **gearbox failure**.

Short anecdote:

A textile mill kept replacing burned motors again and again. Finally, an engineer tightened all connections and scheduled monthly IR testing. Breakdowns stopped. Machines were fine — **maintenance was corrected.**

## 4. Summary & Q&A (≈ 5 minutes)

**Key takeaways**

- Most failures are **avoidable**
- Major causes:
    - lack of inspection
    - poor lubrication
    - dust and moisture
    - overheating/overloading
    - ignoring warning signs
    - improper repair
    - poor earthing and protection
    - absence of maintenance records

**Typical student doubts**

- *“Can new equipment fail?”* → Yes, if maintenance is poor
- *“Is failure always electrical?”* → No, mechanical causes are common
- *“Is preventive maintenance costly?”* → Breakdown cost is always higher

🎯 **Mentorship Note (Career Tip)**

Industries value engineers who **prevent failures**, not just those who repair them.
If you master **failure causes and maintenance practices**, you will be ready for roles in:

- power plants
- substations

- manufacturing industries
- renewable energy plants
- electrical service companies

Remember:

**"A good maintenance engineer does not wait for breakdowns — he prevents them."**

**Unit 3 – Maintenance of Electrical Equipment**

**Topic 3.3 – Preventive Maintenance: Need, Classification, Activities, Advantages & Frequency**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple question:

👉 *"Do you service your bike or scooter only after it completely breaks down?"*
Of course not. You change oil, clean filters, and check brakes **before** failure happens.

That is called **preventive maintenance**.

Electrical equipment is no different. Transformers, motors, breakers, solar inverters and cables cannot speak… but they "warn" us through heat, vibration, smell, noise, and reduced performance.

A famous saying in industry is:

**"One hour of maintenance can save 100 hours of breakdown."**

Today we will learn how preventive maintenance **protects equipment, saves money, and ensures safety**.

## 2. Core Concepts (≈ 40 minutes)

➤ **What is preventive maintenance?**

Preventive maintenance is **planned, systematic maintenance carried out at regular intervals** to:

- reduce chances of failure
- detect problems early

- keep equipment in healthy working condition

**Analogy:** Just like regular health checkups for humans.

➤ **Need for preventive maintenance**

Preventive maintenance is necessary to:

- avoid unexpected shutdowns
- increase life of equipment
- maintain efficiency and reliability
- reduce repair cost
- improve safety of workers and installations
- comply with statutory rules and insurance norms

Without preventive maintenance, industries suffer **production loss and accidents**.

➤ **Classification of preventive maintenance**

Preventive maintenance can be classified into:

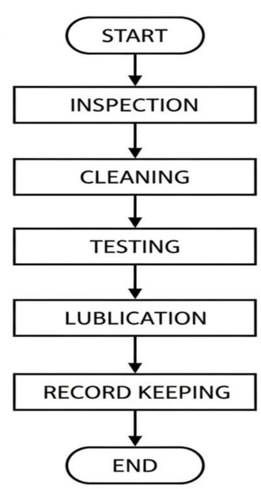
1. **Time-based preventive maintenance**
    - done after fixed time intervals
    - e.g., monthly IR testing, yearly oil filtration
2. **Condition-based maintenance**
    - performed based on equipment condition
    - judged by vibration, temperature, oil quality etc.
3. **Predictive maintenance**
    - uses instruments and sensors to predict failure in advance
    - e.g., thermal imaging, partial discharge testing
4. **Shutdown maintenance**
    - done during planned plant shutdown
    - major inspection and overhauling

➤ **Activities involved in preventive maintenance**

Common preventive maintenance activities include:

- cleaning dust and contaminants
- tightening electrical connections
- lubrication of bearings and moving parts
- inspection of insulation and terminals
- measuring insulation resistance (IR)
- transformer oil BDV testing and filtration
- checking cooling systems and ventilation
- testing protective relays and earthing
- load balancing and alignment checks

**Visual idea:** Draw a simple **flowchart**:
Inspection → Cleaning → Testing → Lubrication → Tightening → Record Keeping.




### ➤ Advantages of preventive maintenance

- reduction in breakdowns
- increased life of equipment
- improved reliability of power supply

- safer operation
- better production quality
- reduced repair and replacement cost
- less downtime
- improved energy efficiency

Fun fact: Airlines and railways operate safely mainly because of **strict preventive maintenance schedules**.

➤ **Frequency of preventive maintenance**

Frequency depends on:

- type of equipment
- environmental conditions
- load and duty cycle
- manufacturer's recommendations

Typical guidelines:

- **Daily:** visual check, noise/vibration observation
- **Monthly:** IR test, terminal tightening
- **Quarterly:** lubrication, relay testing
- **Yearly:** major overhauling, oil filtration, alignment check

## 3. Real-World / Industry Applications (≈ 10 minutes)

- Power plants follow **annual shutdown maintenance**
- Substations perform **periodic transformer oil testing**
- Industries carry out **motor bearing lubrication schedules**
- Solar plants clean panels **weekly or monthly**, check inverter cooling
- Wind turbines follow **gearbox oil replacement schedules**

Short anecdote:
A pharmaceutical plant faced frequent power trips. After regular preventive maintenance of

switchgear and earthing, tripping reduced drastically. **Prevention proved cheaper than cure.**

## 4. Summary & Q&A (≈ 5 minutes)

**Key takeaways**

- Preventive maintenance = maintenance **before** failure
- It is **planned, periodic and systematic**
- Types: time-based, condition-based, predictive, shutdown
- Activities: inspection, cleaning, lubrication, testing, record keeping
- Advantages: higher reliability, safety, economy and longer life
- Frequency depends on duty, environment and manufacturer guidelines

**Typical student doubts**

- *"Is preventive maintenance expensive?"* → Breakdown cost is much higher
- *"Do new machines need it?"* → Yes, aging starts from first operation
- *"Is predictive maintenance same as preventive?"* → It is **advanced preventive maintenance** using monitoring tools

🎯 **Mentorship Note (Career Tip)**

Industries today demand **maintenance engineers who prevent breakdowns, not just repair them**.
Mastering preventive maintenance prepares you for careers in:

- substations and utility companies
- power plants
- manufacturing industries
- renewable energy plants
- electrical testing and service firms

Preventive maintenance knowledge also strengthens your **project work, internships, and interviews**.

Remember: **"A smart engineer does not fight breakdowns — he prevents them."**

**Unit 3 – Maintenance of Electrical Equipment**

**Topics 3.4 & 3.5 – Breakdown Maintenance: Concept, Advantages, Activities & Factors for Preparing Maintenance Schedule**

## 1. Hook / Introduction (≈ 5 minutes)

Think of your mobile phone.

👉 You charge it only when the battery becomes **0%**.
👉 You repair it only when the screen **breaks**.

That approach is called **"use until it fails"**.

Now imagine this happening to:

- a power transformer in a substation
- an induction motor in a factory
- a hospital power backup system

Failure here is not just inconvenience — it can mean **production loss, financial loss, and safety risk**.

Today we will discuss:

✔ what breakdown maintenance is
✔ when it is useful
✔ what activities are involved
✔ and how engineers prepare **maintenance schedules** wisely

This topic connects directly with your future role as **maintenance supervisor/engineer**.

## 2. Core Concepts (≈ 40 minutes)

### ➤ Concept of Breakdown Maintenance

Breakdown maintenance is maintenance carried out **after the equipment fails**.

It is also called:

- corrective maintenance
- run-to-failure strategy

Example analogy: We call a doctor **after** we fall sick.

Breakdown occurs due to:

- insulation failure
- mechanical wear
- overheating
- loose connections
- wrong operation

Here, repair is done **to restore normal working condition**.

**➤ Advantages of Breakdown Maintenance**

Although failure sounds bad, breakdown maintenance has some advantages:

- No expenditure until failure actually occurs
- Simple planning — no periodic maintenance charts required
- Suitable for **non-critical equipment** (fans, small pumps, lights)
- Useful when maintenance cost is higher than replacement cost
- Effective for equipment with **very low failure probability**

**Fun fact:** Many low-cost domestic appliances are economically maintained using **breakdown strategy**.

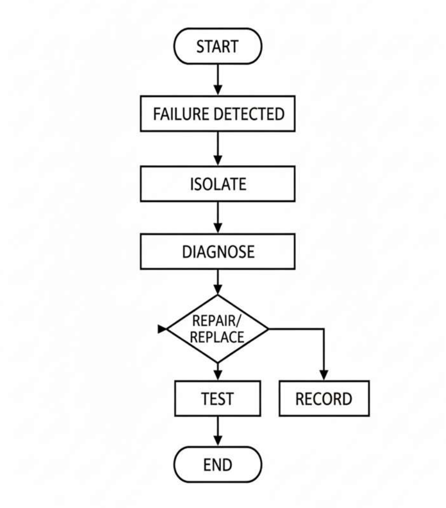
**➤ Activities involved in Breakdown Maintenance**

When failure occurs, the maintenance team performs:

1. **Fault diagnosis**
    - Identify cause: electrical, mechanical, or environmental
2. **Isolation**
    - switch OFF supply
    - apply earthing & safety procedures
3. **Repair or replacement**
    - rewind, refit, replace or reconnect components

4. **Testing**
    - insulation resistance test
    - no-load and full-load trials
5. **Root cause analysis**
    - why did it fail? prevent repeat occurrence
6. **Record keeping**
    - failure history and repair details logged

**Visual description:** Draw a flowchart
Failure detected → Isolate → Diagnose → Repair/Replace → Test → Record.




➤ **Factors for Preparing Maintenance Schedule (Topic 3.5)**

Even though breakdown maintenance exists, industries rely more on **planned schedules**. While framing maintenance schedule, engineers consider:

- type of equipment (motor, transformer, breaker, inverter)
- criticality to production or power supply
- environmental conditions (dust, humidity, temperature)
- loading pattern and duty cycle
- past failure history and test results

- manufacturer's recommendation
- availability of spares and manpower
- shutdown opportunities
- safety regulations and statutory requirements
- cost versus risk of failure

Result: a **daily / monthly / yearly maintenance chart** is prepared.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- In a **cement plant**, breakdown of a kiln-drive motor stops entire production.
- In **IT data centers**, unplanned breakdown of UPS causes server downtime.
- In **substations**, breakdown of circuit breaker risks public safety.
- In **renewable plants**, inverter breakdown interrupts power export.

Therefore industries classify equipment into:

- **critical** → preventive/predictive maintenance
- **non-critical** → breakdown maintenance acceptable

Short anecdote: A factory used breakdown maintenance for exhaust fans, but preventive maintenance for 2 MW motors — because **risk level is different**.

## 4. Summary & Q&A (≈ 5 minutes)

**Key takeaways**

- Breakdown maintenance = repair **after** failure
- Suitable for non-critical, low-cost equipment
- Activities include fault finding, isolation, repair, testing, recording
- Maintenance schedule depends on:
    - criticality, environment, loading
    - manufacturer's advice
    - safety rules and shutdown planning

**Typical student doubts**

- "Is breakdown maintenance bad?" → Not always; depends on criticality
- "Why maintain new equipment?" → Aging starts from first operation
- "Who prepares schedule?" → Maintenance engineer with team inputs

🎯 **Mentorship Note (Career Tip)**

Engineers who can **decide the right maintenance strategy** are highly valued. Understanding breakdown maintenance and schedule planning helps you in:

- substation O&M
- industrial maintenance departments
- renewable energy plant operations
- utility and service companies

Remember:

**"Smart engineers don't just repair machines — they design systems so that failures rarely happen."**

**Unit 3 – Maintenance of Electrical Equipment**
**Topic 3.6 – Maintenance Schedule of Transformer Below & Above 1000 kVA**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a question:

👉 *"Which electrical equipment works silently, continuously, and is trusted by everyone — yet is extremely expensive to repair?"*

Answer: **The transformer.**

Transformers sit quietly in substations, industries, hospitals, residential colonies and renewable plants. They do not have rotating parts, so students often think:

"Transformer maintenance is not important."

But one transformer failure can lead to:

- power interruption to thousands of consumers
- fire or oil explosion risk

- heavy replacement cost
- long outage time

So today, we will learn **how to prepare maintenance schedules** for transformers **below 1000 kVA and above 1000 kVA**, as followed in real industry and electricity utilities.

## 2. Core Concepts (≈ 40 minutes)

**➤ Why schedule maintenance of transformers?**

Transformers face:

- heating and cooling cycles
- insulation aging
- moisture entry
- dust contamination
- vibration and oil deterioration

Scheduled maintenance prevents:

- insulation breakdown
- winding failure
- bushing flashover
- oil leakage and fire accidents

**➤ Difference: Below 1000 kVA vs Above 1000 kVA**

| **Below 1000 kVA** | **Above 1000 kVA** |
|---|---|
| Generally distribution transformers | Power / large distribution transformers |
| Simpler construction | More complex auxiliaries (OLTC, radiators, fans) |
| Mostly natural air/oil cooling | Forced oil/air cooling, monitoring systems |
| Less instrumentation | Advanced protection and online monitoring |

Hence **large transformers require more frequent and detailed maintenance**.

**➤ Maintenance Schedule – Below 1000 kVA**

**Daily / Weekly**

- visual inspection for oil leakage
- temperature rise observation
- check noise and vibration
- ensure tightness of earthing connections

**Monthly**

- cleaning of bushings and terminals
- tightening of connections
- oil level indication check

**Half-yearly / Yearly**

- insulation resistance (IR) test
- transformer turns ratio (TTR) test
- BDV test of oil sample
- check breather silica gel color and replace if pink / moist
- check for corrosion of tank and repainting if needed

**Occasional**

- oil filtration when BDV value is low
- repair of gasket leakage
- thermographic scanning (hot-spot detection)

➤ **Maintenance Schedule – Above 1000 kVA**

For higher-capacity units, more detailed inspection is needed.

**Daily**

- winding and oil temperature indicator readings
- cooling fan and pump operation status
- load and voltage monitoring

**Monthly**

- OLTC operation check (if provided)
- relay functioning test
- cooling system inspection
- bushing cleaning

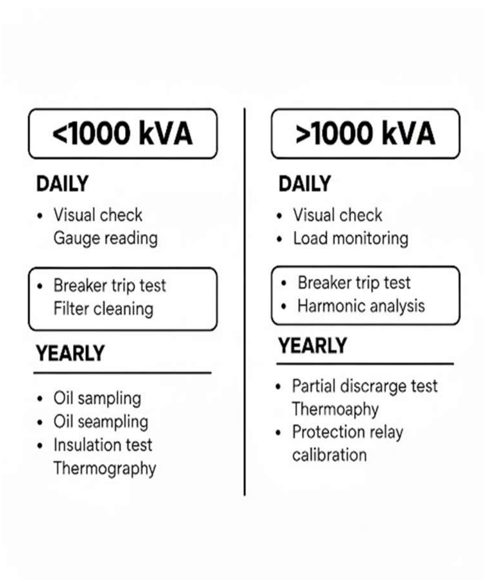
**Quarterly**

- DGA (Dissolved Gas Analysis) of transformer oil
- dielectric dissipation factor / tan-delta testing of insulation
- check radiator valves, conservator diaphragm/bladder

**Yearly**

- complete shutdown inspection
- IR and polarization index test
- TTR and short-circuit impedance measurement
- oil filtration / dehydration if required
- mechanical tightening and core/coil inspection (if opened)

**Visual suggestion:** Draw a **table or flowchart** with two columns:
"< 1000 kVA" and "> 1000 kVA" and list maintenance activities at **Daily / Monthly / Yearly** intervals.



## 3. Real-World / Industry Applications (≈ 10 minutes)

- Electricity boards follow strict transformer maintenance schedules to **avoid feeder failure**
- Industries maintain large power transformers feeding **plant substations**
- Renewable solar parks maintain inverter-duty transformers
- Railway traction substations maintain **high-voltage power transformers**

Short anecdote:

A 5 MVA transformer tripped repeatedly. DGA revealed **excess acetylene gas**, indicating arcing. Early detection prevented catastrophic failure — **maintenance saved crores of rupees.**

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Transformers require **scheduled maintenance**
- Below 1000 kVA → simpler, less frequent checks
- Above 1000 kVA → advanced testing and online monitoring
- Important tests: IR, BDV, TTR, DGA, PI
- Maintenance prevents failure, fire risk, and long power outages

**Typical Student Doubts**

- *"Why test oil?"* → Oil provides insulation and cooling
- *"Do dry-type transformers need oil tests?"* → No, but insulation and temperature checks are needed
- *"Why are large transformers more critical?"* → Higher cost, higher power responsibility

🎯 **Mentorship Note (Career Tip)**

Knowledge of transformer maintenance is highly valued in:

- power utilities
- transmission and distribution companies
- industries and substations

- renewable power plants

Transformers are the **heart of the power system** — and maintenance engineers are the **cardiologists**.

Master this topic to succeed in **O&M jobs, substation supervision, and protection testing careers.**

**"A reliable power system is not built by installing transformers — it is built by maintaining them."**

**Unit 3 – Maintenance of Electrical Equipment**

**Topic 3.7 – Maintenance Schedule of Induction Motor, Alternator in TPP, and $SF_6$ Circuit Breaker**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with three quick questions:

👉 What drives almost every machine in an industry? — **Induction motor**
👉 What generates bulk electrical power in thermal power plants? — **Alternator**
👉 What protects the entire power system during faults? — **Circuit breaker**

Now imagine any one of these failing suddenly.

- Production stops
- Power generation stops
- Safety of equipment and humans is threatened

This is why **scheduled maintenance** of these three devices is absolutely essential. Today's lecture will guide you through **what to check, when to check, and why to check**.

## 2. Core Concepts (≈ 40 minutes)

**A) Maintenance Schedule of Induction Motor**

Induction motors are rugged but face problems such as overheating, bearing wear, unbalanced supply, and insulation aging.

**Daily / Weekly**

- observe noise, vibration, smell
- check motor body temperature

- verify terminal tightness and earthing
- clean external dust

**Monthly**

- insulation resistance (IR) measurement
- check ventilation/opening for air circulation
- alignment of motor and coupled load

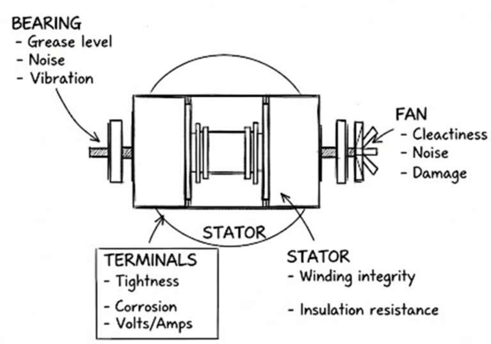
**Quarterly / Half-yearly**

- bearing lubrication or grease replacement
- check rotor/stator air gap
- tighten mounting bolts and base foundation

**Yearly**

- winding resistance test
- complete overhauling if required
- rewinding decision if insulation weak

**Visual idea:** Draw a simple motor diagram marking **bearings, terminals, fan, stator** and list checks near each part.



**B) Maintenance Schedule of Alternator in Thermal Power Plant (TPP)**

Alternators operate at **high voltage and high power**, so maintenance is more detailed.

**Daily**

- temperature and winding thermometer readings
- output voltage, current, and frequency monitoring
- unusual sound from stator/rotor

**Monthly**

- brush condition and slip ring cleaning (if brush-type rotor)
- cooling water/air system checking
- vibration level monitoring

**Quarterly**

- insulation resistance and polarization index tests
- excitation system inspection
- tightness of stator winding overhang

**Yearly / Shutdown**

- rotor withdrawal and inspection (if necessary)
- complete cleaning and varnishing
- protection relays and AVR testing

Analogy: Alternator maintenance is like **heart check-up** in a thermal power plant.

**C) Maintenance Schedule of $SF_6$ Circuit Breaker**

$SF_6$ circuit breakers use **sulphur hexafluoride gas** for arc quenching. They are common in high-voltage substations.

**Routine Inspection**

- gas pressure reading in gauge
- operation counter check
- leakage from valves and seals

**Monthly / Quarterly**

- condition of operating mechanism
- auxiliary contacts test
- heater and control circuit inspection

**Yearly**

- contact resistance measurement
- dielectric test
- $SF_6$ gas quality test and refilling if necessary

Important note: $SF_6$ is a strong greenhouse gas. Hence **leakage control** is very important.

**Visual suggestion:** Draw a simple block diagram showing:
"Tank – Contacts – Operating Mechanism – Gas Cylinder – Pressure Gauge."


## 3. Real-World / Industry Applications (≈ 10 minutes)

- Induction motors run **pumps, compressors, conveyors, fans**
- Alternators in TPP feed **national grid**
- $SF_6$ breakers isolate **faulty lines or transformers** within milliseconds

Short anecdote:

In a power plant, unnoticed bearing heating in an induction motor led to shaft seizure. After structured maintenance scheduling, failures dropped drastically. The lesson: **machines do not fail suddenly — warning signs are ignored.**

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Induction motors, alternators, and $SF_6$ breakers need **planned maintenance schedules**
- Checks are divided into **daily, monthly, yearly** intervals
- Focus areas:
    - motors → bearings, insulation, alignment
    - alternators → cooling, excitation, vibration
    - $SF_6$ breakers → gas pressure, contacts, mechanism

**Typical Student Doubts**

- *Why test IR repeatedly?* → insulation degrades with heat and moisture
- *Why monitor vibration?* → indicates misalignment or bearing failure
- *Why care about $SF_6$ leakage?* → safety + environmental regulations

🎯 **Mentorship Note (Career Tip)**

Mastering maintenance scheduling prepares you for careers in:

- power plants (generation)
- substations and switchyards (transmission & distribution)
- large industrial maintenance departments
- testing & commissioning companies

Employers look for engineers who **keep systems running**, not just those who can start them.

**"Maintenance engineers are the guardians of reliability."**

**Unit 3 – Maintenance of Electrical Equipment**
**Topic 3.8 – Probable Faults Due to Poor Maintenance in Transformer, Induction Motor, Alternator, Circuit Breaker, Overhead Lines, Battery, and Solar Inverter**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple thought:

👉 *"Machines rarely fail suddenly. They usually give warnings — we fail to listen."*

A transformer does not burst in one second.
An induction motor does not burn instantly.
A battery doesn't die overnight.

**Faults grow slowly because of poor maintenance.**

Just like ignoring fever may lead to serious illness, ignoring minor warnings in electrical equipment leads to **major breakdowns, blackouts, fires, and financial loss**.

Today we will identify **probable faults caused specifically by poor maintenance** so that as future engineers, you can **prevent them before they occur**.

## 2. Core Concepts (≈ 40 minutes)

We will move device-by-device and connect fault → cause linkage.

◆ **Transformer**

**Probable faults due to poor maintenance**

- insulation breakdown of windings
- oil deterioration and low BDV
- bushing flashover and cracking
- overheating of core and coils
- oil leakage and fire hazard
- moisture ingress in oil

**Root maintenance causes**

- not testing oil, not replacing silica gel
- loose connections, lack of cleaning
- ignoring abnormal sound/vibration

◆ **Induction Motor (IM)**

**Probable faults**

- winding burnout
- bearing failure and shaft seizure

- unbalanced current and overheating
- rotor bar breakage
- reduced torque and efficiency

**Maintenance causes**

- poor lubrication
- dust blocking cooling path
- loose terminal connections
- wrong alignment with load

Analogy: running a bike without lubricating chain.

- **Alternator**

**Probable faults**

- stator winding insulation failure
- rotor earth fault
- heating due to blocked cooling ducts
- vibration and mechanical looseness
- AVR malfunction

**Maintenance causes**

- poor cleaning
- lack of vibration monitoring
- incorrect excitation checks

- **Circuit Breaker ($SF_6$ / Vacuum / Oil)**

**Probable faults**

- failure to trip during fault
- contact welding and erosion
- gas pressure drop ($SF_6$)
- oil carbonization (oil CB)

**Maintenance causes**

- skipping contact resistance testing
- ignoring gas leakage
- infrequent mechanism lubrication

◆ **Overhead (OH) Lines**

**Probable faults**

- snapping of conductor
- excessive sag
- flashover due to bird droppings and pollution
- insulator puncture

**Maintenance causes**

- lack of patrolling and tightening
- improper tree clearances
- poor replacement of damaged insulators

◆ **Battery**

**Probable faults**

- sulfation of plates
- reduced backup capacity
- terminal corrosion
- electrolyte level drop

**Maintenance causes**

- irregular topping up
- not cleaning terminals
- overcharging or deep discharging

◆ **Solar Inverter**

**Probable faults**

- overheating and frequent tripping
- MPPT failure
- low output due to dusty panels
- fan failure and component burnout

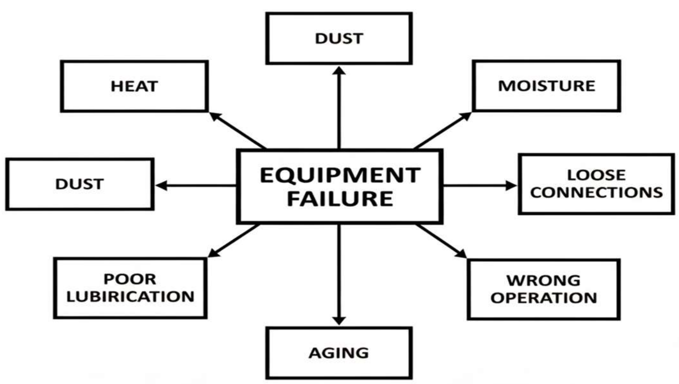
**Maintenance causes**

- inadequate cooling
- dust accumulation
- loose DC connections
- not updating firmware (in smart systems)

✏️ **Suggested Visual**

Draw a **fault tree diagram**:

Central box: *EQUIPMENT FAILURE*
Branches labeled: *Heat, Dust, Moisture, Loose Connections, Poor Lubrication, Aging, Wrong Operation.*




## 3. Real-World / Industry Applications (≈ 10 minutes)

- Utilities face transformer explosions due to **ignored oil testing**
- Industries lose lakhs due to **burned motors from loose terminals**

- Data centers crash because **battery banks are poorly maintained**
- Solar plants lose output because **panels remain dusty**

Short anecdote:

A factory replaced three motors in one year.
The real cause? — **loose terminals and poor ventilation.**
After proper maintenance scheduling, zero motors failed the next year.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Poor maintenance = source of most electrical faults
- Typical faults:
    - transformer → insulation/oil/bushing problems
    - IM → bearing/winding/overheating faults
    - alternator → vibration/excitation/insulation faults
    - breaker → contact/gas/mechanism faults
    - OH lines → snapping/flashover/insulator faults
    - battery → sulfation/corrosion/low backup
    - solar inverter → overheating/low power/tripping

**Typical Student Doubts**

- *Can new equipment fail?* → Yes, if neglected
- *Is dust really dangerous?* → Causes heating & flashover
- *Are mechanical faults common?* → Very common in motors and alternators

🎯 **Mentorship Note (Career Tip)**

Engineers who understand **faults + causes** become excellent:

- maintenance engineers
- substation supervisors
- plant operation engineers

- renewable O&M professionals

Your strength is not only operating machines —**your real value is preventing them from failing.**

**"Great engineers don't just repair faults — they stop faults from being born."**

**Unit 3 – Maintenance of Electrical Equipment**
**Topic 3.9 – Conditioning & Monitoring: Need, Advantages and Condition Monitoring of Transformer & Induction Motor**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a question:

👉 *Do you prefer a health check-up that warns you before illness… or treatment after you fall sick?*

Most of us prefer **early detection**.

Electrical equipment is just like the human body. It **breathes, heats, vibrates, ages and weakens** over time. If we can *monitor* it continuously, we can detect problems **before breakdown**.

This is exactly what **condition monitoring** does.

Fun fact: In modern smart substations, transformers themselves "send messages" to engineers through sensors and SCADA systems!

Today we will learn:

- what conditioning & monitoring means
- why it is needed
- major advantages
- and **how transformers and induction motors are monitored in practice**

## 2. Core Concepts (≈ 40 minutes)

🔹 **What is conditioning & monitoring?**

**Conditioning** means:
taking actions to keep equipment in healthy condition
(cleaning, drying, filtration, tightening, lubrication, etc.)

**Condition monitoring** means:
assessing **current health condition** of equipment using measurements such as:

- temperature
- vibration
- insulation resistance
- oil quality
- sound and smell
- electrical performance parameters

Simple analogy:
Condition monitoring = **regular medical check-up**
Conditioning = **treatment and lifestyle care**

◆ **Need for condition monitoring**

Condition monitoring is needed because:

- equipment ages due to heat, dust, moisture
- unexpected breakdown is costly
- safety of people and system is critical
- modern industries run **24×7** – shutdown is difficult
- early detection prevents catastrophic failures

Instead of "break first, repair later", industries follow **"Predict and prevent"**.

◆ **Advantages of condition monitoring**

- reduced breakdowns and outages
- enhanced reliability of supply
- extended equipment life
- improved safety
- reduced repair and replacement cost
- better planning of shutdowns
- supports predictive maintenance

One hour of monitoring may save **millions of rupees** in failure loss.

🛠 **Condition Monitoring of Transformer**

Transformers are critical assets. Condition monitoring focuses mainly on **insulation, oil and temperature**.

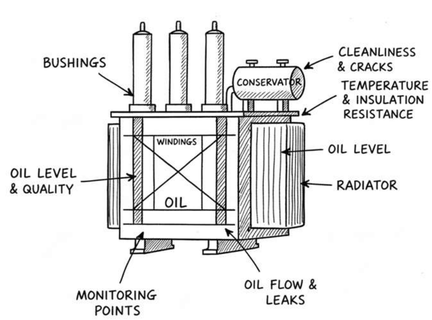
**Key methods**

- **Oil BDV test** – checks dielectric strength
- **DGA (Dissolved Gas Analysis)** – detects arcing/overheating by gas content
- **IR and PI test** – measure insulation resistance & health
- **Winding temperature monitoring** – hot spot indication
- **Bushing monitoring** – partial discharge / leakage inspection
- **Thermography** – infrared imaging of hot connections

**Conditioning actions**

- oil filtration/dehydration
- tightening loose connections
- drying insulation
- replacing silica gel in breather

**Suggested visual:**
Draw a transformer and mark *oil, bushings, windings, conservator, radiator*, with arrows showing "monitoring points".



🛠 **Condition Monitoring of Induction Motor (IM)**

Induction motors experience **mechanical and electrical stresses**.

**Key monitoring parameters**

- vibration level
- bearing temperature
- stator and rotor current
- insulation resistance
- air-gap uniformity
- noise pattern

**Techniques used**

- vibration analysis
- thermography of bearings and terminals
- motor current signature analysis (MCSA)
- IR and winding resistance testing

**Conditioning actions**

- lubrication of bearings
- realignment and tightening
- cleaning ventilation ducts
- re-insulation or rewinding if needed

Analogy: Ignoring vibration in motors is like **ignoring chest pain** — the problem grows silently.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- Power utilities install **online transformer monitoring panels**
- Industries monitor **motor vibration** to avoid production halts
- Thermal power plants perform **round-the-clock alternator monitoring**
- Renewable plants monitor **solar inverters and transformer heating**

Short anecdote:
A 10 MVA transformer showed rising acetylene in DGA. Engineers acted early and prevented explosion. Monitoring **saved the substation**.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Conditioning = improving equipment health
- Condition monitoring = checking health continuously
- Needed for safety, reliability and economy
- Transformers monitored by **DGA, BDV, IR, thermography**
- Motors monitored by **vibration, temperature, current, IR**

**Typical Student Doubts**

- *Is condition monitoring costly?* → Cheaper than breakdown
- *Do small motors need monitoring?* → Yes, at basic level
- *Does new equipment need monitoring?* → Aging starts from day one

🎯 **Mentorship Note (Career Tip)**

Engineers skilled in **condition monitoring and predictive maintenance** are in high demand in:

- power utilities and substations
- thermal and renewable power plants
- large industries and refineries

This topic directly relates to careers in **O&M, diagnostics, testing and reliability engineering**.

**"Future engineers will not only run machines — they will listen to machines."**

**Unit 3 – Maintenance of Electrical Equipment**
**Topic 3.10 – Maintenance of Domestic & Industrial Solar Plant Components and Wind Plant**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple question:

👉 *"If sunlight is free, why doesn't every solar plant always give its full power output?"*

The answer is simple: **because of poor maintenance.**

Dust on panels, loose cables, poor cooling of inverters, degraded batteries — all reduce energy generation.
Similarly, wind turbines stand tall and look strong, but inside they consist of **gearboxes, generators, blades, bearings, brakes and control systems** that need regular care.

Fun fact: A thin layer of dust on a solar panel can reduce output by **20–30%**.

Today, we will understand **what to maintain, how often, and why** for:

- domestic solar plants (rooftop systems)
- industrial solar plants (MW-scale)
- wind power plants (WTGs)

## 2. Core Concepts (≈ 40 minutes)

**A) Solar Power Plant – Components to Maintain**

Whether domestic or industrial, a solar PV system mainly consists of:

- solar PV modules
- supporting structures
- DC cables and connectors
- junction boxes / combiner boxes
- inverters (string/central)
- batteries (in hybrid/off-grid systems)
- protection devices
- earthing and lightning protection

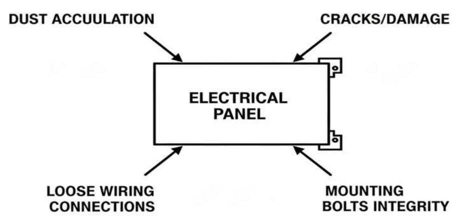
🔹 **Maintenance of Solar PV Modules**

Common activities:

- regular cleaning to remove dust, bird droppings, leaves
- checking for cracks, hotspots, discoloration
- tightening mounting structures and bolts

- ensuring tilt angle and direction are unchanged

**Visual suggestion:** Draw a simple rectangle panel with arrows marking *dust, cracks, wiring and mounting bolts.*




◆ **Maintenance of DC Cabling and Junction Boxes**

- check tightness of MC-4 connectors
- inspect insulation and UV damage
- verify polarity and continuity
- remove water entry or insects from boxes

Poor maintenance causes **heating, fire, or power loss**.

◆ **Maintenance of Inverters**

Inverters are the “brain” of the solar system.

Maintenance includes:

- cooling fan and heat-sink cleaning
- checking display/alarm messages
- firmware updates (for smart inverters)
- tightness of AC/DC terminals
- checking earthing and surge protection

Overheating and dust are the **main enemies** of inverters.

◆ **Maintenance of Battery Bank (off-grid / hybrid)**

- electrolyte level check (for flooded batteries)
- terminal cleaning with petroleum jelly
- equalization charging
- ventilation to avoid gas accumulation
- avoiding deep discharge

**B) Wind Power Plant – Key Maintenance Components**

Wind turbines include:

- blades and hub
- gearbox and generator
- yaw and pitch control mechanism
- tower and nacelle
- braking system
- power electronics and transformer

**Routine maintenance includes:**

- blade inspection for cracks, erosion, lightning marks
- gearbox oil level and leakage check
- bearing lubrication
- vibration and noise monitoring
- brake system inspection
- tightening of tower bolts

Condition monitoring systems continuously observe **vibration, temperature, oil quality and power output**.

Analogy: Wind turbine is like an **airplane on a tower** — highly engineered and safety-critical.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- Rooftop solar systems in homes/schools need **regular cleaning**
- Industrial solar parks employ **O&M teams** for washing robots and thermography

- Wind farms schedule **preventive maintenance during low-wind seasons**
- SCADA systems monitor output and alarms from remote control rooms

Short anecdote:
One solar plant increased generation by **25%** simply by regular panel cleaning — no new equipment added. Maintenance itself generated power!

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Renewable energy systems **also need maintenance**
- Solar plant maintenance includes:
  - panel cleaning
  - cable tightening
  - inverter cooling and alarms
  - battery checks (where used)
- Wind plant maintenance focuses on:
  - blades, bearings, gearbox, generator, tower bolts
  - lubrication and vibration monitoring

**Typical Student Doubts**

- *"Does rain clean solar panels automatically?"* → Not fully; sticky dirt remains
- *"Are wind turbines maintenance-free?"* → No, they are mechanically intensive
- *"Why are inverters sensitive?"* → Electronics + heat + dust

**🎯 Mentorship Note (Career Tip)**

India is one of the fastest-growing **renewable-energy markets**.
Engineers trained in **solar and wind O&M (operation & maintenance)** are in very high demand.

Mastering this topic will help you grow in:

- solar plant installation & O&M companies
- wind farm maintenance teams

- electrical utility renewable divisions
- startups in rooftop solar services

**"The future of power is renewable — and the future of jobs is maintenance of renewable systems."**

**Unit 3: Maintenance of Electrical Equipment**

✅ **A. Low-Level Prompts (10 prompts – Remember & Understand)**

*Focus: definitions, basic ideas, and simple explanations*

1. **"Explain in very simple language what 'maintenance of electrical equipment' means and why it is important."**
2. **"Give short definitions of preventive maintenance, breakdown maintenance, and condition monitoring with simple examples."**
3. **"Explain the basic parts of a transformer, induction motor, and circuit breaker in easy words for diploma students."**
4. **"List the common causes of failure of electrical equipment due to poor maintenance and explain each in two–three lines."**
5. **"Explain what preventive maintenance is, using everyday-life examples like vehicles or home appliances."**
6. **"Write short notes on insulation resistance, overheating, moisture, and vibration in electrical equipment."**
7. **"Explain the difference between maintenance, repair, and troubleshooting in simple words."**
8. **"Summarize Unit–3 'Maintenance of Electrical Equipment' in bullet points for quick revision."**
9. **"Explain why regular inspection and cleaning are important for electrical machines in simple language."**
10. **"Explain what a maintenance schedule is and why industries prepare it, using easy examples."**

🟡 **B. Moderate-Level Prompts (10 prompts – Apply & Analyze)**

*Focus: comparing, applying concepts, and solving practical-type questions*

11. **"Compare preventive maintenance and breakdown maintenance with examples of where each type is suitable."**

12. **“Given a situation where a motor becomes very hot and noisy, explain the possible causes and steps a technician should take.”**
13. **“Explain how poor maintenance can cause faults in transformer, induction motor, and battery, using real-life examples.”**
14. **“Describe how you would prepare a simple maintenance schedule for a small workshop containing motors and electrical panels.”**
15. **“Explain step-by-step how an electrician should inspect electrical equipment safely before working on it.”**
16. **“Analyze why overheating happens in electrical machines and suggest practical preventive actions.”**
17. **“Explain how condition monitoring helps prevent major failures in electrical equipment with two case examples.”**
18. **“Compare maintenance requirements of domestic electrical systems and industrial electrical systems.”**
19. **“Explain why electrical safety, earthing, and proper tools are important during maintenance activities.”**
20. **“Explain how environmental factors like dust, moisture, and temperature affect the life of electrical equipment.”**

🔵 **C. High-Level Prompts (5 prompts – Design & Create)**

*Focus: design thinking, workflows, schedules, predictive ideas*

21. **“Design a maintenance checklist for a small electrical workshop containing motors, wiring, and a distribution panel.”**
22. **“Create a step-by-step workflow for diagnosing faults in electrical equipment starting from visual inspection to final repair.”**
23. **“Prepare a model maintenance schedule (daily, monthly, yearly) for electrical machines used in an industrial plant.”**
24. **“Design a simple condition monitoring plan for critical electrical equipment focusing on safety, reliability, and cost.”**
25. **“Create an examination-style case study where failure occurs due to poor maintenance, and then provide the analysis and solution.”**

✨ **How students should use this toolkit**

- Copy–paste any prompt
- Read the AI response
- Ask follow-up questions like:
    - "Explain more simply."
    - "Give an example."
    - "Make it exam-oriented."

Encourage them to:

- convert answers into **notes**
- draw **diagrams based on descriptions**
- practice **viva questions based on the replies**

🎯 **Mentor's Message to Students**

Using AI wisely does **not replace learning**—it **accelerates** your learning if you ask good questions.

👉 Strong maintenance engineers are built through:

- understanding concepts
- practicing real problems
- asking "why" and "how"

Use these prompts like **your personal tutor, lab assistant, and revision partner**.

**Unit 3: Maintenance of Electrical Equipment**
Designed for **Diploma Electrical Engineering** students (conceptual + exam focused, OBE aligned)

✅ **1. Key Definitions / Glossary (15 Important Terms)**

1. **Maintenance** – Planned activities carried out to keep equipment in safe and efficient working condition.
2. **Preventive Maintenance** – Regular maintenance done before failure occurs to prevent breakdown.

3. **Breakdown Maintenance** – Repair or replacement performed after equipment has actually failed.
4. **Condition Monitoring** – Continuous observation of equipment health using parameters like temperature, vibration, and insulation resistance.
5. **Insulation Resistance** – Resistance offered by insulating material to leakage current between conductors and earth.
6. **Overheating** – Excessive rise in temperature of equipment due to overloading, poor cooling, or loose connections.
7. **BDV (Breakdown Voltage) of Oil** – The minimum voltage at which insulation oil breaks down and allows current to flow through it.
8. **DGA (Dissolved Gas Analysis)** – Test used to analyze gases dissolved in transformer oil to detect internal faults.
9. **Commissioning** – Process of testing and putting new electrical equipment into service.
10. **Earthing** – Connection of electrical equipment to earth to provide a safe path for fault current.
11. **Fault** – Abnormal condition in electrical equipment or system that prevents normal operation.
12. **Circuit Breaker** – Switching device used to interrupt current during fault conditions.
13. **Overloading** – Operation of equipment beyond its rated capacity causing heating and possible damage.
14. **Shutdown Maintenance** – Maintenance carried out when the system or plant is intentionally stopped.
15. **Troubleshooting** – Systematic process of finding and correcting faults in electrical equipment.

## ✅ 2. FAQ & Assessment Section

### 🔹 A. Multiple Choice Questions (MCQs) — 20 Questions

1. The main purpose of preventive maintenance is to
A) increase breakdowns
B) repair damaged equipment
C) prevent failure before it occurs
D) reduce insulation resistance

2. Breakdown maintenance is carried out
   A) during installation
   B) before failure
   C) during normal operation
   D) after failure occurs

3. Which test is commonly used to check transformer oil quality?
   A) Megger test
   B) BDV test
   C) Speed test
   D) Polarity test

4. Condition monitoring mainly aims at
   A) increasing losses
   B) predicting equipment health
   C) designing new equipment
   D) reducing voltage

5. Overheating in electrical machines is mainly caused by
   A) underloading
   B) proper ventilation
   C) overloading and poor cooling
   D) high power factor

6. Loose electrical connections usually result in
   A) less heat
   B) high efficiency
   C) sparking and temperature rise
   D) increased insulation resistance

7. DGA test is related to
   A) batteries
   B) motors
   C) transformer oil
   D) overhead lines

8. Which maintenance type requires minimum planning?
   A) Preventive
   B) Predictive
   C) Breakdown
   D) Condition-based

9. Insulation resistance is generally measured using
   A) wattmeter
   B) megger

C) voltmeter
D) ammeter

10. The life of electrical equipment increases mainly due to
A) overload
B) lack of maintenance
C) proper maintenance
D) short-circuit

11. Which of the following is *not* an effect of poor maintenance?
A) higher reliability
B) unexpected failure
C) overheating
D) safety risk

12. Earthing is provided mainly to
A) increase voltage
B) protect from electric shock
C) increase current
D) reduce power factor

13. Which parameter is important in motor maintenance?
A) rotor diameter
B) bearing lubrication
C) painting color
D) shaft material only

14. Scheduled maintenance depends on
A) availability of manpower
B) criticality of equipment
C) environmental condition
D) all of the above

15. Which of the following indicates transformer internal fault?
A) low gas in OLTC
B) change in DGA pattern
C) higher power factor
D) less noise

16. Visual inspection helps to detect
A) internal winding resistance
B) hidden short circuit
C) oil leakage, rusting, loose parts
D) excitation voltage

17. Batteries fail mainly due to
    A) proper charging
    B) low temperature
    C) sulphation and poor maintenance
    D) good ventilation

18. In condition monitoring, vibration analysis is mainly used for
    A) transformers
    B) induction motors
    C) relays
    D) batteries

19. Overhead line failure is commonly caused by
    A) correct sag
    B) broken conductor or insulator
    C) proper clearance
    D) good weather

20. Which one is an advantage of preventive maintenance?
    A) increased breakdown cost
    B) reduced reliability
    C) longer equipment life
    D) high accident rate

- **B. Short Answer / Viva Questions (10 Questions)**

1. Why is preventive maintenance preferred over breakdown maintenance in critical equipment?

2. Explain the term "condition monitoring" with one practical example.

3. State two common causes of overheating in electrical machines and how they can be prevented.

4. Why is BDV testing of transformer oil necessary?

5. What is the role of earthing in protecting both humans and equipment?

6. List four common symptoms that indicate poor maintenance of induction motors.

7. Explain why record keeping is important in maintenance activities.

8. What are the consequences of ignoring small faults in electrical equipment?

9. Why is lubrication important in rotating machines?

10. Distinguish between inspection and troubleshooting in maintenance work

**Unit–3: Maintenance of Electrical Equipment**
Diploma Electrical Engineering — Self-learning • Revision • Visualization • Practice

## ✅ 1. AI Tools & Digital Learning Tools (3–5 recommended)

These tools help students **visualize, simulate, practice, and generate explanations** related to maintenance concepts.

### 🔹 1) Interactive AI Tutor (Chat-based AI assistants)

**Purpose / Use-case:**

- Ask questions, get summaries, create notes, solve doubts
- Generate revision points, viva questions, check answers

**How it helps this unit:**

- Explains preventive vs breakdown maintenance
- Creates maintenance schedules/checklists
- Gives examples of equipment faults and remedies
- Helps in **exam preparation and viva practice**

### 🔹 2) Online Electrical Machine Simulators

**Purpose / Use-case:**

- Visualize working of transformers and motors
- Observe effect of faults and loading
- Test concepts safely without real hardware

**How it helps this unit:**

- Shows impact of overheating, vibration, and insulation failure
- Helps understand **maintenance importance through performance changes**
- Builds intuition about machine behaviour

Search keywords students can use:

"Electrical machines virtual lab simulator" "transformer and motor simulation online lab"

◆ **3) Circuit Simulation Tools**

**Purpose / Use-case:**

- Simulate basic electrical protection circuits
- Visualize switches, fuses, relays, breakers behavior

**How it helps this unit:**

- Demonstrates **breaker tripping** during fault
- Shows overload and short-circuit conditions
- Connects maintenance topics with protection systems

Search keywords:

“online circuit simulator for electrical engineering” “virtual electrical lab circuit breaker simulation”

◆ **4) Maintenance Management Templates (Digital planners)**

**Purpose / Use-case:**

- Create **maintenance schedules, checklists and logs**
- Track servicing activity

**How it helps this unit:**

- Students learn to design:
    - daily / monthly equipment checklists
    - inspection records
    - shutdown maintenance plans

Search keywords:

“maintenance schedule template electrical equipment” “equipment maintenance checklist pdf”

◆ **5) Concept Visualization Platforms**

**Purpose / Use-case:**

- Animated explanations of motors, transformers, wind and solar systems

**How it helps this unit:**

- Helps **slow learners** see working instead of only reading
- Improves retention of:
    - lubrication systems
    - cooling systems
    - condition monitoring methods

Search keywords:

"electrical machine animation working" "transformer maintenance animation"

### 🎥 2. Video Learning Repository (Recommended Video Resources)

Students can search using keywords — **no links required**
Focus: concept clarity • practical orientation • exam readiness

| **Topic Name** | **Recommended Channel / Course / Lecturer Name** | **Search Keywords** |
|---|---|---|
| Introduction to Maintenance of Electrical Equipment | NPTEL – Electrical Engineering | "NPTEL maintenance of electrical equipment introduction" |
| Preventive vs Breakdown Maintenance | NPTEL / SWAYAM – Industrial Maintenance | "NPTEL preventive and breakdown maintenance lecture" |
| Maintenance of Transformers | NPTEL – Prof. B.G. Fernandes or similar | "NPTEL transformer maintenance and testing" |
| Maintenance of Induction Motors | NPTEL – Electrical Machines Course | "NPTEL induction motor maintenance lecture" |
| Condition Monitoring Basics | NPTEL – Condition Based Maintenance | "NPTEL condition monitoring of electrical machines" |
| Transformer Oil Testing & DGA | NPTEL – Power Equipment Diagnostics | "NPTEL dissolved gas analysis transformer oil" |
| Maintenance of Circuit Breakers | NPTEL – Switchgear and Protection | "NPTEL maintenance of circuit breakers lecture" |

| Topic Name | Recommended Channel / Course / Lecturer Name | Search Keywords |
|---|---|---|
| Maintenance of Overhead Lines | NPTEL – Power System Operation & Maintenance | “NPTEL overhead line maintenance” |
| Solar Power Plant Maintenance | Energy Literacy / Government Renewable Portals | “Solar plant maintenance training video diploma level” |
| Wind Power Plant Maintenance | MNRE / NPTEL Renewable Energy Systems | “Wind turbine maintenance training NPTEL” |

**Unit–3: Maintenance of Electrical Equipment**
Diploma Electrical Engineering – based on **standard technical board patterns and question trends**

### ✅ 1. MOST REPEATED / HIGH-PROBABILITY QUESTIONS

*(Likely to appear as 3-, 4-, or 7-mark questions)*

#### 🔹 A. Core definitions & short theory questions

1. Define preventive maintenance and state its advantages.
2. Define breakdown maintenance and list the activities involved.
3. Define condition monitoring and state its need in industries.
4. List causes of failure of electrical equipment due to poor maintenance.
5. State the functions of a maintenance department in an industry.
6. Write short note on maintenance schedule of transformer.
7. List factors affecting the life of electrical equipment.
8. Explain the term “overheating” and state its causes in electrical machines.
9. Define earthing and state its importance during maintenance work.
10. Define troubleshooting and explain its importance in maintenance.

#### 🔹 B. Explanatory / descriptive questions

11. Explain the need, functions and objectives of maintenance in electrical systems.

12. Explain preventive maintenance: classification, activities and advantages.
13. Explain breakdown maintenance and steps followed after failure occurs.
14. Explain reasons of failure of electrical equipment due to poor maintenance.
15. Explain condition monitoring: need, advantages and methods.
16. Explain the maintenance schedule of transformer below 1000 kVA.
17. Explain maintenance schedule of induction motor.
18. Explain maintenance of alternator used in power plants.
19. Explain maintenance schedule of overhead lines.
20. Explain the procedure of maintenance of circuit breakers.

🔹 **C. Diagram / schedule / flow-based questions**

21. Draw and explain a **maintenance schedule chart** for transformer.
22. Draw flowchart of steps followed during breakdown maintenance.
23. Draw layout of a maintenance department and explain its functions.
24. Draw a checklist format used in preventive maintenance.
25. Draw a flowchart for troubleshooting an electrical machine.

🟡 **2. APPLICATION & LOGICAL THINKING QUESTIONS**

*(These differentiate average answers from distinction-level answers)*

1. A 3-phase induction motor starts producing abnormal noise and vibration. – Identify probable causes and suggest preventive maintenance actions.
2. A transformer shows rapid rise in temperature and oil discoloration. – Analyze the situation and list condition-monitoring tests to be performed.
3. An industry faces frequent unexpected shutdowns of equipment. – Prepare a strategy choosing between preventive and breakdown maintenance and justify your choice.
4. Equipment installed in a dusty and humid environment fails frequently. – Explain environmental impact and redesign the maintenance schedule accordingly.
5. A plant manager wants to reduce maintenance cost without compromising reliability.– Propose a maintenance policy and logically defend it.

**Unit–4: Troubleshooting of Electrical Equipment**
Diploma – Electrical Engineering

This plan is based **strictly on the attached GTU–COGC-2021 syllabus** and is suitable for:

- faculty lesson planning
- student self-study
- AI-assisted content generation
- OBE & NEP-2020 aligned learning

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### ✅ Structured Study Plan – Unit 4 (Total Time: 8 Hours)

**➤ Topics taken strictly from syllabus section Unit–IV: Troubleshooting of Electrical Equipment**

| Sr. No. | Syllabus Topic (Exact as Given) | Logical Sequence & Sub-Coverage | Time Allocation (hours) | Core / Supporting / Application Topic | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|---|
| 1 | **Causes of faults in electrical equipment (Internal and External)** | Types of faults, internal vs external causes, symptom observation, effect on performance | 1.5 | **Core** | Very High – definitions & short notes frequently asked | Strong – foundation for all troubleshooting |
| 2 | **Instruments and tools for troubleshooting** | Multimeter, megger, test lamp, clamp meter, IR tester, safety tools, selection & care | 1.0 | **Supporting** | High – frequently asked list-type question | Essential for laboratory & field work |
| 3 | **Common troubles in electrical equipment –** DC machines, AC machines, | Typical symptoms, causes, stepwise approach to fault identification | 2.0 | **Core + Application** | Very High – repeated as long answer questions | Directly used in machine labs and industries |

| Sr. No. | Syllabus Topic (Exact as Given) | Logical Sequence & Sub-Coverage | Time Allocation (hours) | Core / Supporting / Application Topic | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|---|
| | transformers, circuit breakers, underground cables, electrical installation | | | | | |
| 4 | **Need of troubleshooting chart** | Importance of systematic approach, diagnosis flow, documentation culture | 0.5 | Supporting | Medium | Helpful for maintenance records |
| 5 | **Troubleshooting charts** for DC machine; 1-phase and 3-phase transformer | Tabular fault–cause–remedy, structured method | 1.0 | **Application-Oriented** | Very High – table/diagram questions repeat | Used during practical & viva |
| 6 | **Troubleshooting charts** for synchronous motor, induction motor, alternator (TPP) | Starting failure, overheating, vibration, noise, unbalanced load | 1.0 | **Application-Oriented** | High | Industrial relevance – power plants |
| 7 | **Troubleshooting charts for $SF_6$ & vacuum circuit breaker** | Failure to trip/close, gas pressure issues, mechanical | 0.5 | Application-Oriented | Medium–High | Substation & switchgear labs |

| Sr. No. | Syllabus Topic (Exact as Given) | Logical Sequence & Sub-Coverage | Time Allocation (hours) | Core / Supporting / Application Topic | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|---|
| | | jamming, contact wear | | | | |
| 8 | **Troubleshooting of domestic appliances –** iron, fan, washing machine, air cooler | Simple fault analysis, safety precaution, user-level diagnosis | 0.5 | Application & Life-skill | High for viva & practical exams | Highly relevant to real-life |
| 9 | **Common causes of faults & troubleshooting in solar plant and wind plant** | Inverter issues, panel mismatch, cable faults, wind turbine mechanical/electrical faults | 0.5 | Application-Oriented / Emerging Area | Increasing importance | Renewable industry relevance |

✓ **Total time = 8 hours**

🎯 **Logical Learning Flow (Intro → Concept → Application)**

1. **Begin with fault causes**
   – builds conceptual foundation
2. **Introduce required tools & instruments**
   – enables "how to troubleshoot safely"
3. **Study common troubles in major equipment**
   – connects theory to machines already studied in earlier units
4. **Learn charts and systematic troubleshooting**
   – develops engineering thinking and documentation mindset
5. **Apply to advanced systems**
   – circuit breakers, power-plant machines

6. **Extend to domestic & renewable systems**
   – aligns with NEP-2020 & green energy orientation

## ⭐ Identification of Topic Types

### ✓ Core Topics (must master)

- Causes of faults – internal & external
- Common troubles in:
    - DC machines
    - AC machines
    - transformers
- Troubleshooting charts
- Instruments for troubleshooting

### ✓ Supporting Topics

- Need for troubleshooting charts
- Safety tools and practices

### ✓ Application-Oriented Topics

- Faults in:
    - circuit breakers
    - underground cables
    - electrical installations
- Domestic appliance troubleshooting
- Renewable system troubleshooting (solar & wind)

## 🏆 Exam & Viva Orientation

- **Very high probability**
    - causes of faults
    - troubleshooting charts
    - common troubles in machines

- **Common 7-mark questions**
  - “Prepare troubleshooting chart for induction motor / transformer”
  - “Explain internal & external causes of faults”
- **Frequent viva questions**
  - selection of troubleshooting instruments
  - symptom analysis (noise, heat, smell, vibration)

**Unit 4 – Troubleshooting of Electrical Equipment**
**Topic 4.1 – Causes of Faults in Electrical Equipment (Internal and External)**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a question:

👉 *“Do electrical faults happen suddenly, or do they grow slowly over time?”*

Most students think faults happen suddenly — a spark, a bang, smoke, or tripping of supply. Reality is different.

Faults usually **start small**:

- a loose nut
- a little dust
- slight overheating
- ignored unusual sound

and gradually become **big failures**.

Just like **health problems begin with small symptoms**, electrical equipment also “gives signals” before breaking down.

Today we will learn the **root causes of faults** so that you can **predict and prevent breakdowns**, just like a good doctor prevents disease instead of only treating it.

## 2. Core Concepts (≈ 40 minutes)

🔹 **What is a “fault”?**

A fault is **any abnormal condition** that:

- disturbs normal operation
- reduces performance
- may damage equipment
- may cause safety hazards

Examples: short-circuit, insulation failure, overheating, vibration, excessive noise.

### 🔹 Classification of Causes of Faults

Fault causes are divided into two main groups:

- **Internal causes** – inside the equipment
- **External causes** – outside the equipment (environment, supply, operation)

We now study both in detail.

### ✅ Internal Causes of Faults

These are faults **originating within equipment components**.

1. **Insulation failure**
   - due to aging, heat, moisture, mechanical stress
   - results in short circuit or leakage current
2. **Loose connections**
   - causes sparking, temperature rise, burning of terminals
3. **Winding faults**
   - turn-to-turn short circuit in machines and transformers
4. **Mechanical wear**
   - worn bearings, misalignment, increased vibration
5. **Poor cooling system**
   - blocked ducts, fan failure → overheating
6. **Manufacturing defects**
   - poor quality material, improper assembly

7. **Oil deterioration (in transformers)**
    - decrease in BDV leading to breakdown

**Analogy:** Internal causes are like **diseases inside the body**—not easily visible but dangerous.

✅ **External Causes of Faults**

These are due to **outside influences**.

1. **Overloading**
    - operating above rated current → insulation damage and heating
2. **Environmental conditions**
    - dust, moisture, chemicals, salt, pollution → corrosion and flashover
3. **Poor maintenance**
    - no cleaning, no lubrication, no inspection
4. **Improper operation**
    - wrong starting method, repeated switching, unbalanced supply
5. **Power quality issues**
    - voltage dips/swells, harmonics, unbalance
6. **Lightning and switching surges**
    - high transient voltage causing insulation breakdown
7. **Mechanical shocks and vibration**
    - during transport or installation

**Analogy:** External causes are like **bad weather affecting health** even if the person is strong.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- In industries, loose terminals cause **motor burnouts**
- In substations, moisture leads to **transformer failure**
- In renewable plants, dust reduces **solar inverter life**
- In domestic wiring, poor earthing causes **shock risk**

Short anecdote:

A new motor failed within two months. Investigation showed: **loose connections + dust inside cooling path**. The motor was fine — **maintenance was poor**.

This is why companies invest in **preventive maintenance and condition monitoring**.

## 4. Summary & Q&A (≈ 5 minutes)

**Key Takeaways**

- Fault = abnormal condition affecting normal operation
- Two main causes:
    - **Internal:** insulation, winding, loose parts, oil quality
    - **External:** loading, environment, maintenance, power quality

**Typical Student Doubts**

- *Can new equipment fail?* → Yes, due to poor installation or manufacturing defect
- *Is dust really dangerous?* → Yes, causes heating and flashover
- *Is overheating electrical or mechanical?* → Both—bearings or overload may cause it

🎯 **Mentorship Note (Career Tip)**

Troubleshooting is the **signature skill of a good electrical engineer**.
When you understand fault causes, you can:

- diagnose breakdowns confidently
- work in industries, substations, power plants
- become a maintenance or service engineer

**"Machines don't fail without reason. Engineers who find the reason become leaders in the field."**

**Unit 4 – Troubleshooting of Electrical Equipment**
**Topic 4.2 – Instruments and Tools for Troubleshooting**

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple question:

👉 *"Can a doctor treat a patient without a stethoscope or thermometer?"*
The answer is obvious — **No.**

In the same way, an electrical engineer **cannot troubleshoot without proper instruments and tools.**

Sometimes the fault is visible — burnt smell, smoke, broken wire.
But most of the time, faults are **invisible**:

- leakage current
- low insulation resistance
- loose terminals inside panels
- unbalanced current in phases

To "see" these invisible problems, we use **testing instruments**.
Today's class will introduce the **essential toolkit of a troubleshooting engineer.**

## 2. Core Concepts (≈ 40 minutes)

🔹 **What is a troubleshooting instrument?**

A troubleshooting instrument is a device used to:

- test electrical quantities
- locate faults
- verify safety conditions
- confirm whether equipment is healthy or not

We will study the most important instruments, one by one.

✅ **1) Test Lamp**

- simplest tool
- used for quick continuity and supply presence check
- helpful in basic installation troubleshooting

**Analogy:** Just like a doctor checks pulse first, electricians check supply first.

✅ **2) Multimeter (Digital or Analog)**

Measures:

- voltage (AC/DC)
- current
- resistance
- continuity

Uses:

- checking open circuit or short circuit
- polarity testing
- battery condition check
- electronic board troubleshooting

### ✅ 3) Clamp Meter (Tong Tester)

Measures **current without breaking the circuit**.

Used for:

- load current measurement
- overload detection
- unbalanced 3-phase current checking

Fun fact: It works using **magnetic field around conductor**.

### ✅ 4) Megger (Insulation Resistance Tester)

Measures **high resistance values** in mega-ohms.

Applications:

- insulation condition of cables
- transformer windings
- motor windings

Low IR value indicates:

- moisture presence
- insulation aging
- possibility of shock hazard

### ✅ 5) Earth Tester

Used to measure **earth resistance**.

Important because:

- good earthing protects people and equipment
- high earth resistance leads to shock danger

### ✅ 6) Line Tester / Neon Tester

- pen-type tool
- checks presence of phase (live) wire

Important for **safety before touching conductors**.

### ✅ 7) Thermal Scanner (Infrared Thermometer/Thermography)

Used to detect **hot spots** in:

- panels
- busbars
- transformer connections
- bearings

It helps identify **loose connections and overload** without opening equipment.

### 🧰 Essential Hand Tools for Troubleshooting

- insulated pliers
- screwdrivers
- wire stripper
- spanner set
- crimping tool
- hacksaw and file
- insulation tape

And the most important tool of all:

👉 **Safety tools** — gloves, shoes, helmet & lockout–tagout kit.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- Multimeter used daily by technicians in workshops
- Clamp meter used in industries to check **motor loading**
- Megger testing is compulsory before commissioning cables
- Thermography is routine in substations for **hot-spot detection**
- Earth tester used during **earthing pit testing**
- Domestic electricians rely on test lamps and neon testers

Short anecdote:

In one plant, cables were heating repeatedly. Visual inspection showed nothing. Thermal scanning revealed a **loose lug causing hot spot**.

Right tool → right diagnosis → problem solved.

## 4. Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways**

- Troubleshooting needs **correct tools + correct method**
- Essential instruments:
    - test lamp
    - multimeter
    - clamp meter
    - megger
    - earth tester
    - thermal scanner
- Essential hand tools:
    - pliers, screwdrivers, crimpers, spanners
- Safety tools are **non-negotiable**

❓ **Typical Student Doubts**

- *Which tool is used first?* → Test lamp / line tester

- *Why not measure insulation with multimeter?* → Range is too small
- *Can clamp meter measure voltage?* → Some models yes, but primarily current

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🎯 **Mentorship Note (Career Tip)**

Industries hire engineers who can **diagnose faults confidently and safely.**
Mastering troubleshooting tools prepares you for:

- maintenance departments
- service centers
- power plants & substations
- renewable energy O&M

**"A great engineer is not the one who owns many tools — but the one who knows exactly which tool to use, when, and why."**

**Unit 4 – Troubleshooting of Electrical Equipment**
**Topic 4.3 – Common Troubles in Electrical Equipment**
(DC machines, AC machines, transformers, circuit breakers, underground cables, electrical installation)

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## 1. Hook / Introduction (≈ 5 minutes)

Let us begin with a simple thought:

👉 *"Does electrical equipment fail suddenly… or does it give warning signs first?"*

Most equipment **does not fail suddenly**.
It **whispers before it screams**— unusual sound, smell, heating, vibration, or poor performance.
A good technician learns to **listen to these signs**.

Just as doctors diagnose fever, cough, and pain, electrical engineers diagnose:

- sparking
- overheating
- loss of output

- tripping
- insulation failure

Today, we will learn the **usual troubles in commonly used electrical equipment** and how to recognize them. This knowledge makes you confident in labs, workshops, industries, and power plants.

## 2. Core Concepts (≈ 40 minutes)

We will study equipment one by one.

◆ **DC Machines (DC Motors & Generators)**

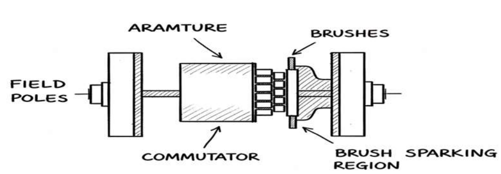
**Common troubles**

- sparking at brushes
- excessive heating
- uneven commutation
- reduced speed or torque
- noise and vibration

**Reasons**

- worn-out brushes
- incorrect brush position
- armature winding faults
- overloading
- poor lubrication of bearings

**Visual:** Draw a simple DC motor showing *armature, commutator, brushes, field poles* and mark *brush sparking region*.



- **AC Machines – Induction Motors & Alternators**

**Typical faults in Induction Motors**

- motor not starting
- overheating
- single phasing
- low starting torque
- abnormal noise

**Causes**

- blown fuse or supply failure
- phase loss
- rotor bar breakage
- overloading
- misalignment

**Alternator troubles**

- voltage fluctuation
- frequency variation
- overheating of stator or rotor
- bearing faults

**Causes**

- faulty excitation
- uneven loading
- cooling failure

- **Transformers**

**Common troubles**

- excessive humming noise

- oil leakage
- overheating
- reduced insulation resistance
- winding failure

**Reasons**

- loose laminations
- moisture ingress in oil
- overload or short circuit
- poor earthing

- **Circuit Breakers**

**Common troubles**

- failure to trip
- nuisance tripping
- contact welding
- abnormal heating

**Causes**

- mechanism jamming
- weak spring tension
- worn contacts
- incorrect settings

- **Underground Cables**

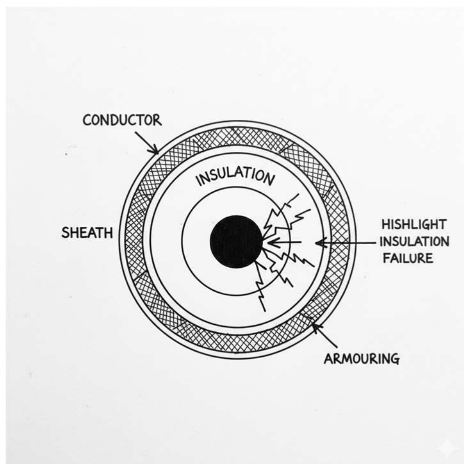
**Typical faults**

- short circuit
- open circuit
- earth fault
- insulation breakdown

**Causes**

- mechanical damage during digging
- moisture entry
- aging of insulation
- overloading and heating

**Visual:** Draw a cable cross section showing *conductor, insulation, sheath, armouring* and highlight insulation failure.




◆ **Electrical Installations (Domestic & Industrial)**

**Common troubles**

- frequent fuse blowing
- shock hazards
- flickering lights
- tripping of MCBs
- loose connections and heating at switches

**Reasons**

- overloading circuits
- damaged insulation
- poor earthing

- wrong wiring practices

## 3. Real-World / Industry Applications (≈ 10 minutes)

- Brush sparking observed in DC machines of cranes and traction motors
- Single phasing commonly occurs in workshop induction motors
- Transformer failures due to oil moisture in rainy seasons
- Breaker tripping saves large industries from major accidents
- Underground cable faults are frequent during metro, road or pipeline construction
- Domestic installations often fail due to loose terminals and cheap accessories

**Short anecdote**

In one factory, lights used to flicker every evening. Investigation showed **loose neutral connection** at the main distribution panel. Small fault—big disturbance. Troubleshooting saved productivity.

## 4. Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways**

- Every equipment type has **typical faults and warning signs**
- DC machines → brush sparking, heating, commutation problems
- AC machines → single phasing, noise, overloading
- Transformers → oil leakage, insulation failure
- Circuit breakers → nuisance tripping or failure to trip
- Underground cables → earth fault, short circuit
- Installations → shock hazard, loose connections, repeated fuse blowing

❓ **Common Student Questions**

- *Why do motors make noise when overloaded?*
- *How does moisture reduce insulation resistance?*
- *Why do circuit breakers trip even without visible fault?*
- *Which fault is most dangerous—short circuit or earth fault?*

🎯 **Mentorship Note (Career Tip)**

Industries **value engineers who can identify faults quickly** and prevent downtime. Mastering troubleshooting of common equipment prepares you for roles in:

- operation & maintenance
- power utilities
- manufacturing plants
- service and repair sectors

**"Troubleshooting skill is not magic; it is systematic observation, patience, and practice."**

**Unit 4 – Troubleshooting of Electrical Equipment**

**Topic 4.4 – Need of Troubleshooting Chart and Troubleshooting Charts for DC Machine; 1-phase & 3-phase Transformer**

## 1. Hook / Introduction (≈ 5 minutes)

Let us start with a simple thought experiment:

👉 *Imagine entering a large workshop where a motor has stopped suddenly.*
*Ten people give ten different opinions. Which one will you follow?*

Confusion wastes time. Wrong actions increase damage.

That is why industries do not rely only on memory. They use **troubleshooting charts**—simple, logical step-by-step guides that help technicians:

- identify symptoms
- relate them to possible causes
- take correct corrective action

Just like doctors use **diagnosis flowcharts**, electrical engineers use **troubleshooting charts**. They **convert experience into a visual guide** that even a beginner can follow safely.

## 2. Core Concepts (≈ 40 minutes)

🔹 **What is a troubleshooting chart?**

A troubleshooting chart is a structured table or flowchart that shows:

- **symptom / fault observed**
- **probable causes**
- **checks to perform**
- **remedies / corrective action**

It reduces guesswork and supports **systematic troubleshooting**.

◆ **Why do we need troubleshooting charts?**

- saves time and downtime
- prevents repeated mistakes
- improves safety
- supports training of new technicians
- ensures standard maintenance practice
- useful for exam viva and laboratory work

**Analogy:** It is like Google Maps for fault finding — it shows *correct path* instead of random searching.

◆ **Troubleshooting Chart – DC Machine**

**Typical symptoms include:**

- excessive sparking at brushes
- abnormal heating
- low or fluctuating output
- noise and vibration

**A simple chart structure you can draw in notebook:**

Draw a **three-column table** titled *"DC Machine Troubleshooting Chart"*:

1. **Fault observed** – e.g., heavy sparking at commutator
2. **Probable cause** – worn brushes / wrong brush angle / dirt / overload
3. **Remedy** – replace brushes, set neutral plane, clean commutator, reduce load

Similarly include:

- motor not starting → blown fuse / open circuit / field failure
- overheating → overloading / poor ventilation / bearing problem

🔸 **Troubleshooting Chart – 1-Phase Transformer**

Common symptoms:

- humming noise
- overheating
- low secondary voltage
- oil leakage

**Chart example you can copy in notebook:**

- **Fault:** Low output voltage
  **Cause:** loose connections / winding short / overload
  **Remedy:** tighten terminals, insulation test, reduce load
- **Fault:** Excessive noise
  **Cause:** loose core laminations
  **Remedy:** tighten bolts / varnish core

🔸 **Troubleshooting Chart – 3-Phase Transformer**

Extra issues due to three-phase system include:

- unbalanced load
- phase failure
- overheating of one limb
- differential protection tripping

**Flowchart description**

Draw a **diamond-shape decision flowchart**:

- Start → "Is load balanced?"
  - If NO → balance load
  - If YES → "Check oil level and temperature"

- If abnormal → test oil, insulation, cooling fan
- If normal → check winding resistance and protection settings

This helps students visualize **stepwise decision-making**.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- large factories keep laminated troubleshooting charts near panels
- power substations display transformer fault charts
- service centers use standard checklists for motors and transformers
- reduces dependency on senior engineers
- helps audits and ISO documentation

**Short anecdote**

In one plant, the maintenance team was replacing motors repeatedly. A simple troubleshooting chart later revealed **single-phasing due to loose terminal** as the real cause. The chart saved motors and money.

## 4. Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways**

- troubleshooting charts = **systematic fault-finding maps**
- avoid guesswork and confusion
- include: fault → cause → check → remedy
- charts studied today:
    - DC machine
    - 1-phase transformer
    - 3-phase transformer

❓ **Likely student doubts**

- *Is troubleshooting chart same as maintenance schedule?* → No
- *Do we always get single cause for fault?* → Not always
- *Can charts be used for viva answers?* → Yes, very useful

🎯 **Mentorship Note (Career Tip)**

Industries prefer engineers who are **organized troubleshooters, not trial-and-error electricians.**
Learning troubleshooting charts builds skills for:

- power utilities
- repair workshops
- O&M departments
- testing and commissioning work

**"Tools diagnose equipment, but charts guide your mind. Master both — and you become a real problem-solver."**

**Unit 4 – Troubleshooting of Electrical Equipment**
**Topic 4.5 – Troubleshooting Charts for:**

- **Synchronous motor**
- **Induction motor**
- **Alternator (Thermal Power Plant – TPP)**

## 1. Hook / Introduction (≈5 minutes)

Let me start with a real-life situation:

👉 *A large pump in a power plant suddenly stops. Production loss per minute is in lakhs of rupees. What will an engineer do first?*

Guesswork is dangerous.
Trial-and-error wastes time.

Professionals use **troubleshooting charts**—structured, logical guides to move from **symptom → cause → remedy**.

Today, we learn troubleshooting charts for three major machines:

- synchronous motor
- induction motor
- alternator used in thermal power plants

These are the **heart of industries and power generation systems**. Learning to troubleshoot them makes you industry-ready.

## 2. Core Concepts (≈40 minutes)

🔹 **What is a troubleshooting chart?**

A troubleshooting chart is usually drawn as:

- a **table** (Fault | Probable Cause | Remedy), or
- a **flowchart** (Yes/No decision blocks)

It ensures:

- systematic fault finding
- safe sequence of testing
- minimum downtime

🔸 **Troubleshooting Chart – Synchronous Motor**

**Typical faults / symptoms**

- motor fails to start
- hunting (speed oscillation)
- loss of synchronism
- overheating of stator or rotor
- excessive vibration

**Probable causes**

- no DC excitation
- open field winding
- wrong phase sequence
- mechanical misalignment
- unbalanced supply

**Remedies**

- check excitation system and brushes
- correct phase sequence
- ensure proper load gradually

- align shaft and coupling

**Visual to draw:**
Table with three columns titled **"Synchronous Motor Troubleshooting Chart"** linking *fault → cause → remedy*.

**SYNCHINROUS MOTOR TROUBLESHOODING CHART**

| FAULT | CAUSE | REMEDY |
|---|---|---|
| Motor failes to start | No field excitation<br>Low stator vollage<br>Overolad, Verify oy<br>Open circuit in stator | Check exciter/field circuit<br>Reduce load<br>Inspect windings/comections |
| Motor ottreheats | High ambient temp<br>Blocked ventilation<br>Bearing failure | Impfy powe cooling<br>Clean air ducts<br>Replace bearings |
| Excessive vibration | Misaligument<br>Unbanced rotor<br>Foundation issues | Align motor/load<br>Balance rotor<br>Reinfore foundation |
| Low power factor | Under-excited field<br>Lightly loaded motor<br>motor | Increase field current, Add capacitors/reduce load<br>load |
| Loss of syncchinization<br>Sudden load change<br>Field failure | Voltage dip<br>Sudden load change<br>Field failure | Increase field current,<br>Manage load<br>Inspect field circuit |

## 🔸 Troubleshooting Chart – Induction Motor

**Common symptoms**

- motor not starting
- low speed / low torque
- overheating
- abnormal noise
- single phasing

**Probable causes**

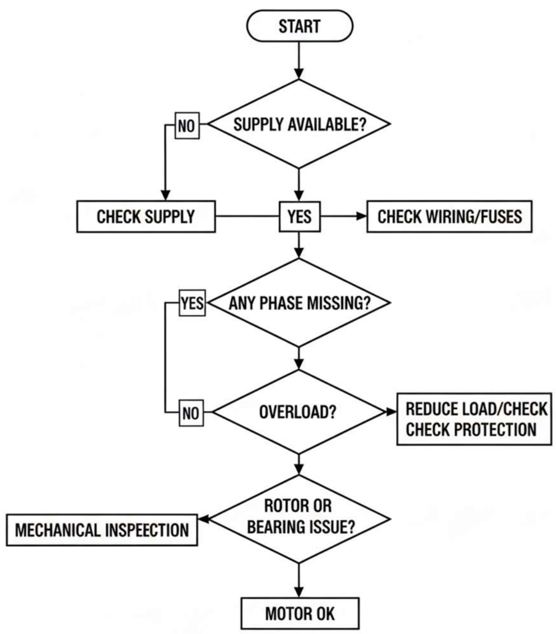
- blown fuses / loose supply
- rotor bar breakage
- overload

- blocked ventilation
- phase failure

**Remedies**

- check supply and protection
- test winding resistance and insulation
- reduce load
- clean ventilation path
- install single-phasing preventer

**Visual idea:**
Draw a **decision flowchart**:
Start → “Supply available?” → “Any phase missing?” → “Overload?” → “Rotor or bearing issue?”




🔸 **Troubleshooting Chart – Alternator (TPP – Thermal Power Plant)**

Alternators in TPP are **large turbo-alternators**, so faults are critical.

**Typical symptoms**

- voltage not building up
- frequency fluctuation
- overheating of stator/rotor
- vibration and noise
- protection tripping

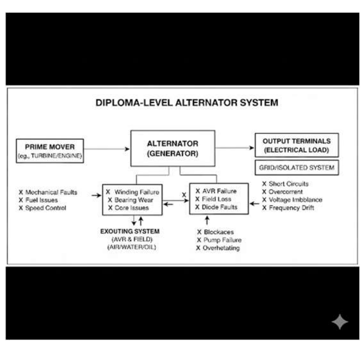
**Probable causes**

- loss of excitation
- turbine speed variation
- shorted turns in winding
- cooling failure (hydrogen/air/oil)
- unbalanced load

**Remedies**

- restore excitation
- check governor control
- inspect winding temperature sensors
- verify cooling pumps/fans
- balance the load and check protections

**Visual to describe:**
Sketch alternator block diagram showing **prime mover–alternator–excitation–cooling system–output terminals** and indicate points where problems occur.



## 3. Real-World / Industry Applications (≈10 minutes)

- Cement plants, refineries, and steel plants rely on synchronous motors for **power factor improvement and heavy drives**
- Induction motors run **fans, pumps, compressors, conveyors** everywhere
- Alternators in TPP generate **bulk electricity for national grids**

In industry, laminated troubleshooting charts are displayed:

- near MCC panels
- turbine control rooms
- maintenance workshops

**Short anecdote**

At a thermal power plant, alternator voltage was collapsing frequently. The troubleshooting chart guided engineers to check **excitation slip-ring carbon dust**—a small issue preventing voltage buildup. Chart → Correct diagnosis → Reliable generation.

## 4. Summary & Q&A (≈5 minutes)

🔑 **Key Takeaways**

- Troubleshooting charts give **clear, systematic fault-finding paths**
- Synchronous motor → excitation and synchronism issues
- Induction motor → starting, overheating, single-phasing issues
- Alternator (TPP) → excitation, cooling, load balance, turbine speed issues

❓ **Common student doubts**

- *Why does synchronous motor need DC excitation?*
- *How can single phasing damage an induction motor?*
- *Why does alternator frequency depend on turbine speed?*

🎯 **Mentorship Note (Career Tip)**

Power plants, industries, and service companies look for engineers who can **think logically under pressure**.
Master these charts and you can handle:

- maintenance jobs

- commissioning work
- diagnostic services
- plant operation profiles

**“Troubleshooting is not guessing; it is intelligent, step-by-step thinking. That ability makes you a professional engineer.”**

**Unit 4 – Troubleshooting of Electrical Equipment**
**Topic 4.6 – Troubleshooting Charts for $SF_6$ & Vacuum Circuit Breaker (VCB)**

## 1. Hook / Introduction (≈ 5 minutes)

Let us begin with a powerful thought:

👉 *Protection equipment must work perfectly the first time — because it is needed only when something goes wrong.*

Circuit breakers are like **airbags in cars**.
We may not use them every day, but **they must operate instantly during faults** to save:

- equipment
- human life
- power system stability

Today we focus on two modern high-voltage breakers:

- **$SF_6$ circuit breaker**
- **Vacuum circuit breaker (VCB)**

Both are widely used in **substations, industries, and power plants**.
To keep them reliable, we require **clear troubleshooting charts** that guide us from symptom → probable cause → remedy.

## 2. Core Concepts (≈ 40 minutes)

🔹 **Review: What do circuit breakers do?**

- detect fault current
- interrupt arc quickly
- isolate faulty section

In $SF_6$ breakers, **sulphur hexafluoride gas** is the arc extinguishing medium.
In VCBs, **high vacuum** inside interrupter bottles extinguishes the arc.

◆ **Troubleshooting Chart – $SF_6$ Circuit Breaker**

**Common symptoms / fault conditions**

- breaker fails to close
- breaker fails to open
- gas leakage indication ON
- abnormal gas pressure
- frequent tripping
- noisy or sluggish operation

**Probable causes**

- low $SF_6$ gas pressure
- hydraulic/pneumatic mechanism failure
- control circuit fault
- moisture contamination
- worn contacts
- auxiliary switch malfunction

**Remedies**

- refill gas to rated pressure after leak test
- check compressors, valves and operating mechanism
- verify trip/close coils and control wiring
- replace worn-out contacts
- perform dew-point/moisture test

**Visual description to draw in notebook**

Sketch a **box diagram** showing:

- interrupter chamber

- $SF_6$ gas tank
- operating mechanism
- pressure gauge
- alarm contacts

Mark points where **leakage and sensor alarms** occur.

### 🔸 Troubleshooting Chart – Vacuum Circuit Breaker (VCB)

**Typical symptoms**

- breaker does not close
- breaker trips as soon as it closes
- contact wear indication high
- abnormal heating
- mechanical jamming

**Probable causes**

- spring charging mechanism failure
- auxiliary supply loss
- interlock problem
- loss of vacuum in interrupter
- misalignment of operating rods

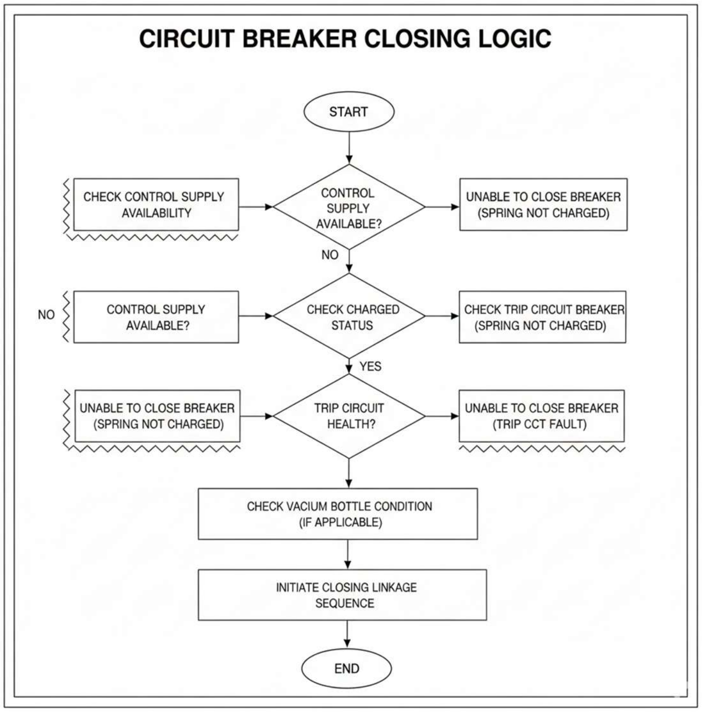
**Remedies**

- charge mechanism manually/electrically
- restore control supply
- reset interlocks after fault clearing
- perform vacuum integrity test
- realign drive linkage and lubricate moving parts

**Flowchart visual description**

Draw a **Yes/No decision flowchart**:

Start → “Is control supply available?”
→ “Spring charged?”
→ “Trip circuit healthy?”
→ “Check vacuum bottle condition”
→ “Check mechanical linkage”




This trains students in **logical troubleshooting sequence**.

## 3. Real-World / Industry Applications (≈ 10 minutes)

- $SF_6$ breakers used in **400 kV and 220 kV substations**
- VCBs widely used in **11 kV & 33 kV switchgear panels** in industries
- Power plants use both types for **generator, transformer and bus protection**

Typical applications include:

- steel plants
- cement factories
- metro rail traction
- renewable energy evacuation switchyards

**Short anecdote**

At an industrial substation, an $SF_6$ breaker frequently showed "low gas pressure alarm." Technicians followed the troubleshooting chart — leak soap test → flange gasket replaced → alarm cleared. Correct method avoided an expensive outage.

## 4. Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways**

- breakers are critical safety devices
- $SF_6$ breaker uses **gas insulation and arc extinction**
- VCB uses **high vacuum in interrupter bottle**
- troubleshooting charts reduce guesswork and downtime
- always check:
    - control supply
    - operating mechanism
    - pressure/vacuum level
    - interlocks and contacts

❓ **Typical student questions**

- *Why is $SF_6$ preferred in high-voltage breakers?*
- *How do we detect loss of vacuum in VCB?*
- *What causes nuisance tripping?*
- *Why are interlocks so important?*

🎯 **Mentorship Note (Career Tip)**

Substations, utilities and power plants need engineers who can **maintain and troubleshoot protection equipment** with confidence.
Mastering $SF_6$ and VCB troubleshooting opens doors to:

- power transmission companies
- switchgear manufacturing firms
- maintenance contractors

- testing and commissioning careers

**“Protection makes power systems safe. Learning to troubleshoot protection equipment makes *you* invaluable to the industry.”**

**Unit 4 – Troubleshooting of Electrical Equipment**
**Topic 4.7– Troubleshooting of Domestic Appliances & Renewable Energy Systems**
(iron, fan, washing machine, air cooler, solar plant, wind plant)

## 1. Hook / Introduction (≈ 5 minutes)

Let me begin with a simple question:

👉 *“How many of you have seen a ceiling fan stop working or an iron not heating at home?”*

Most of us have — and usually someone says, *“It has a loose connection.”*
But is every fault due to loose connection? **No.** Good engineers **don’t guess; they diagnose.**

Troubleshooting skills make you the *go-to problem solver*:

- at home
- during laboratory practicals
- in industries and power plants

Today’s class connects **daily-life appliances** with **renewable energy systems** so you can see the same principles applied from home to megawatt-scale plants.

## 2. Core Concepts (≈ 40 minutes)

🔹 **General troubleshooting approach (for any appliance)**

1. Observe the **symptom**
2. Ensure **power supply availability**
3. Check **connections and switches**
4. Identify **mechanical vs electrical** fault
5. Test components systematically
6. Apply safe remedy

*(Analogy: Like a doctor takes temperature, pulse, and history before treatment.)*

◆ **Electric Iron**

**Common faults**

- iron not heating
- overheating/burning clothes
- shock while touching body

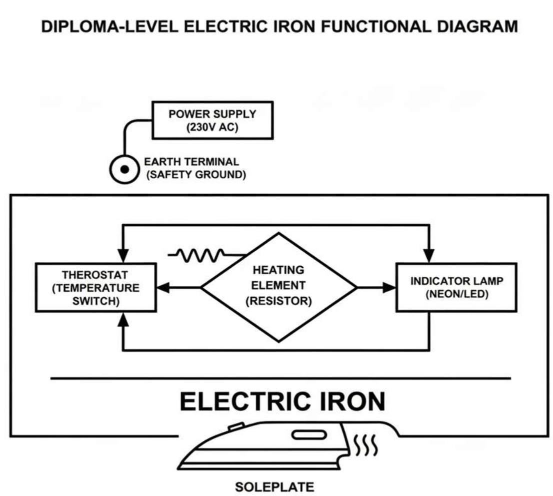
**Probable causes**

- open heating element
- faulty thermostat
- damaged insulation or earth wire

**Remedies**

- continuity test of element
- thermostat replacement
- proper earthing and insulation

**Visual:** Draw iron showing **element, thermostat, indicator lamp, earth terminal**.




◆ **Ceiling / Table Fan**

**Common troubles**

- fan not starting
- low speed
- noise or vibration

**Causes**

- capacitor failure
- worn bearings
- winding open/short

**Remedies**

- replace capacitor
- lubricate bearings
- rewind/replace motor

**Fun fact:** A failed capacitor makes fan **"hum but not run."**

🔶 **Washing Machine**

**Typical faults**

- drum not rotating
- water not draining
- excessive vibration

**Causes**

- motor or belt failure
- clogged drain pump
- unbalanced load

**Remedies**

- check motor & drive belt
- clean/replace drain pump
- distribute clothes evenly

🔶 **Air Cooler**

**Common faults**

- low cooling
- pump not working
- foul smell

**Causes**

- low water level
- pump failure
- dirty pads/stagnant water

**Remedies**

- refill tank
- repair/replace pump
- clean/replace pads and ensure airflow

◆ **Solar Power Plant – common faults & troubleshooting**

**Typical problems**

- low power output
- inverter tripping
- battery not charging

**Causes**

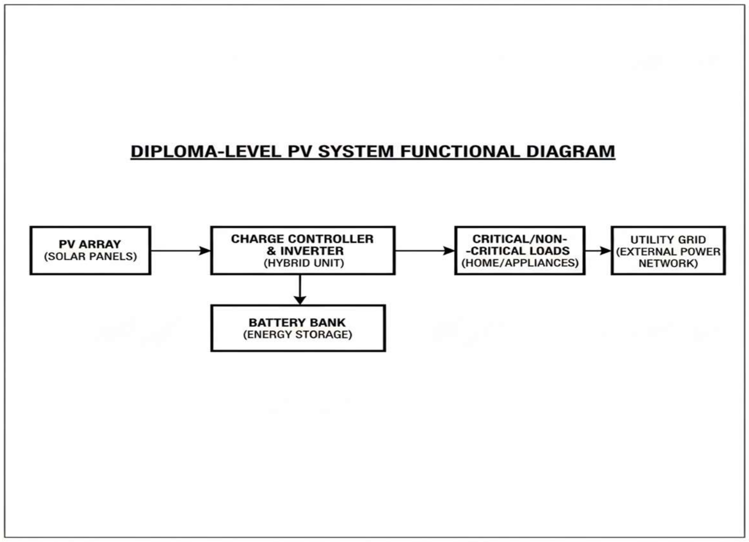
- dust shading on panels
- loose DC connections
- battery sulfation
- MPPT/inverter settings error

**Remedies**

- panel cleaning & tilt correction
- tighten connectors and check fuses
- battery maintenance/equalization

- verify inverter parameters

**Visual:** Block diagram—**PV array → charge controller/inverter → battery → load/grid**.




◆ **Wind Power Plant – common faults & troubleshooting**

**Typical problems**

- turbine not starting
- low generation
- abnormal noise/vibration

**Causes**

- low wind speed
- gearbox/bearing issues
- pitch control or yaw failure

**Remedies**

- verify anemometer reading
- inspect gearbox lubrication
- check control systems and braking units

## 3. Real-World / Industry Applications (≈ 10 minutes)

- technicians repair **fans, irons, pumps, inverters** daily

- O&M teams in solar parks regularly clean panels and check earthing
- wind farm engineers monitor **vibration and SCADA alarms**
- structured troubleshooting prevents long downtime and revenue loss

Short anecdote:

A large rooftop solar plant produced only 60% output. Students suspected inverter fault. Actually, **dust on panels** reduced irradiance. Simple cleaning raised output instantly — small action, big effect.

## 4. Summary & Q&A (≈ 5 minutes)

🔑 **Key Takeaways**

- Follow systematic troubleshooting steps
- Iron → element & thermostat faults
- Fan → capacitor, bearing, winding faults
- Washing machine → motor, pump, balance issues
- Air cooler → pump, pads, airflow
- Solar plant → dust, loose connections, inverter/battery issues
- Wind plant → wind availability, gearbox, control failures

❓ **Typical student doubts**

- *Why does fan hum when capacitor fails?*
- *How does thermostat control iron temperature?*
- *Why do panels lose output due to dust?*
- *What is the role of yaw control in wind turbines?*

🎯 **Mentorship Note (Career Tip)**

Troubleshooting skills make you **employable immediately**—from homes to renewable energy plants.
If you master fault-finding:

- service centres
- maintenance departments

- solar/wind O&M companies
- electrical workshops

will value you highly.

**"Every fault is a lesson. Great engineers don't panic—they diagnose, repair, and improve the system."**

🎓 **STUDENT AI TOOLKIT**

**Unit–4: Troubleshooting of Electrical Equipment**

🟢 **A. LOW-LEVEL PROMPTS**

**(Remember & understand – 10 Prompts)**

1. **"Explain the meaning of troubleshooting in simple terms, suitable for a Diploma Engineering student, with one practical example."**
2. **"List the common causes of faults in electrical equipment and explain each cause in one or two simple lines."**
3. **"Differentiate between internal faults and external faults using a simple table and easy language."**
4. **"Explain why faults occur in electrical equipment even when proper installation is done."**
5. **"Describe the basic steps involved in troubleshooting any engineering system in a logical sequence."**
6. **"Explain the role of test instruments in troubleshooting and why measurement is important before repair."**
7. **"What are the common symptoms that indicate a fault in an electrical system? Explain briefly."**
8. **"Explain the term 'troubleshooting chart' and state its purpose in maintenance work."**
9. **"Summarize the importance of troubleshooting for safety, reliability, and equipment life."**
10. **"Create a short, exam-ready note on 'Common troubles in electrical equipment' in simple bullet points."**

🟡 **B. MODERATE-LEVEL PROMPTS**

**(Apply & Analyze – 10 Prompts)**

11. **"Given a situation where equipment is not operating properly, explain how you would identify whether the fault is electrical or mechanical."**
12. **"Compare troubleshooting with the hit-and-trial method and explain why systematic troubleshooting is preferred."**
13. **"Analyze a case where an electrical system trips frequently and explain possible causes and checking steps."**
14. **"Explain how improper maintenance can lead to repeated faults, using cause-and-effect reasoning."**
15. **"Apply the concept of troubleshooting charts to explain how faults can be diagnosed step by step."**
16. **"Differentiate between symptoms, causes, and remedies in troubleshooting with suitable examples."**
17. **"Explain how environmental conditions can affect equipment performance and cause faults."**
18. **"Analyze a situation where equipment overheats and suggest logical troubleshooting steps."**
19. **"Explain how troubleshooting skills help in reducing downtime and improving system efficiency."**
20. **"Write an answer suitable for a 5-mark exam question on 'Common troubleshooting approach for engineering equipment'."**

🔵 **C. HIGH-LEVEL PROMPTS**

**(Design & Create – 5 Prompts)**

21. **"Design a general troubleshooting workflow that can be applied to any engineering equipment, from fault detection to final verification."**
22. **"Create a generic troubleshooting chart format showing symptoms, possible causes, checks, and corrective actions."**
23. **"Develop a logical decision-making process for troubleshooting that minimizes time, cost, and safety risks."**
24. **"Design a step-by-step troubleshooting strategy for a complex system that shows clear thinking and exam-level presentation."**

25. **“Create a model answer explaining how systematic troubleshooting reflects professional engineering practice and ethical responsibility.”**

✅ **MASTERY CHECK**

**Unit–4: Troubleshooting of Electrical Equipment**

## 1️⃣ KEY DEFINITIONS / GLOSSARY

*(Top 15 exam-frequent technical terms – simple, one-line definitions)*

1. **Troubleshooting** – A systematic process of identifying, analyzing, and correcting faults in equipment.
2. **Fault** – Any abnormal condition that prevents equipment from operating correctly.
3. **Internal Fault** – A fault that occurs within the equipment due to insulation failure, winding damage, or component defect.
4. **External Fault** – A fault caused by external factors such as supply issues, overloading, or environmental conditions.
5. **Symptom** – A visible or measurable sign indicating the presence of a fault.
6. **Cause** – The actual reason responsible for the occurrence of a fault.
7. **Remedy** – The corrective action taken to eliminate a fault.
8. **Troubleshooting Chart** – A structured table that links symptoms, causes, and remedies for quick fault diagnosis.
9. **Diagnostic Tool** – An instrument used to detect, measure, or confirm a fault condition.
10. **Overheating** – Excessive rise in temperature of equipment beyond safe operating limits.
11. **Overloading** – Operation of equipment beyond its rated capacity causing stress and faults.
12. **Insulation Failure** – Breakdown of insulating material leading to leakage current or short circuit.
13. **Short Circuit** – An unintended low-resistance path causing excessive current flow.

14. **Preventive Action** – Measures taken in advance to avoid the occurrence of faults.
15. **Systematic Approach** – A logical, step-by-step method used for effective troubleshooting.

## 2️⃣ FAQ & ASSESSMENT SECTION

### A. MULTIPLE CHOICE QUESTIONS (MCQs)

*(20 Questions – Conceptual, understanding & basic application)*

**Q1.** Troubleshooting mainly aims to:
A. Replace equipment
B. Increase equipment size
C. Identify and correct faults
D. Change system design

**Q2.** Which of the following is an internal fault?
A. Loose supply cable
B. Moisture in surroundings
C. Winding insulation damage
D. Voltage fluctuation

**Q3.** A visible sign indicating a fault is called:
A. Cause
B. Remedy
C. Symptom
D. Error

**Q4.** Which factor can cause external faults?
A. Component ageing
B. Insulation breakdown
C. Overloading
D. Manufacturing defect

**Q5.** The main advantage of a troubleshooting chart is:
A. Reduces equipment size
B. Saves time and improves accuracy
C. Increases current rating
D. Eliminates maintenance

**Q6.** Which condition usually results from overloading?
A. Reduced voltage
B. Overheating
C. Noise reduction
D. Improved efficiency

**Q7.** Which approach is best for fault finding?
A. Random checking
B. Hit-and-trial method
C. Systematic approach
D. Immediate replacement

**Q8.** A fault due to environmental factors is classified as:
A. Internal fault
B. Mechanical fault
C. External fault
D. Design fault

**Q9.** Which item helps in fault detection?
A. Lubricant
B. Diagnostic tool
C. Insulation tape
D. Nameplate

**Q10.** Insulation failure mainly leads to:
A. Open circuit
B. Short circuit
C. Low speed
D. Noise

**Q11.** Which step comes first in troubleshooting?
A. Repair
B. Replacement
C. Fault identification
D. Documentation

**Q12.** Repeated faults usually indicate:
A. Proper maintenance
B. Incorrect troubleshooting
C. Poor preventive action
D. Correct operation

**Q13.** Which factor reduces equipment life?
A. Correct loading
B. Regular maintenance
C. Overheating
D. Proper ventilation

**Q14.** Troubleshooting charts mainly contain:
A. Cost details
B. Wiring diagrams only

C. Symptoms, causes, and remedies
D. Manufacturer details

**Q15.** A systematic troubleshooting method mainly improves:
A. Equipment weight
B. Safety and reliability
C. Voltage level
D. Energy consumption

**Q16.** Which is a symptom of a fault?
A. Loose connection
B. Burnt insulation
C. Excessive noise
D. Moisture

**Q17.** Which practice helps prevent faults?
A. Overloading
B. Preventive action
C. Random repair
D. Ignoring symptoms

**Q18.** External faults are mostly related to:
A. Internal components
B. Environmental and supply conditions
C. Design error
D. Manufacturing process

**Q19.** A short circuit mainly causes:
A. Low current
B. Excessive current
C. Low temperature
D. Reduced losses

**Q20.** Troubleshooting skill is most important for:
A. Equipment painting
B. Maintenance and service work
C. Equipment transportation
D. Store management

**B. SHORT ANSWER / VIVA QUESTIONS**

*(10 Questions – Reasoning & conceptual understanding)*

1. What is troubleshooting and why is it important in electrical maintenance?

2. Differentiate between internal faults and external faults.
3. What is the role of symptoms in fault diagnosis?
4. Why is a systematic approach preferred over hit-and-trial troubleshooting?
5. Explain the importance of troubleshooting charts.
6. How does overloading affect electrical equipment?
7. State any two common causes of insulation failure.
8. Why should faults be identified before repair or replacement?
9. How does preventive action help in reducing breakdowns?
10. Explain how troubleshooting improves safety and equipment reliability.

📚 **DIGITAL RESOURCE LIBRARY**

**Unit–4: Troubleshooting of Electrical Equipment**

1️⃣ **AI TOOLS & DIGITAL LEARNING TOOLS**

*(For understanding, visualization, analysis, and exam preparation)*

These tools **do not replace teachers**—they help you **practice thinking like a troubleshooter**.

🔹 **Tool 1: AI Learning Assistant (ChatGPT / Gemini / Copilot)**

**Purpose / Use-case**

- Concept explanation, doubt solving, exam answer practice

**How it helps in this unit**

- Explains **faults, symptoms, causes, and remedies** in simple language
- Helps create **troubleshooting charts and step-by-step logic**
- Useful for **viva preparation and revision summaries**

🔹 **Tool 2: Virtual Electrical Lab Platforms (General Virtual Labs)**

**Purpose / Use-case**

- Simulate electrical systems and observe fault behavior

**How it helps in this unit**

- Helps visualize **what happens when faults occur**
- Supports understanding of **cause–effect relationships**
- Useful for students with **limited lab access**

🔹 **Tool 3: Concept Visualization Tools (Whiteboard / Diagram Tools)**

**Purpose / Use-case**

- Drawing flowcharts, fault trees, and troubleshooting steps

**How it helps in this unit**

- Enables students to **draw troubleshooting workflows**
- Improves **diagram-based answers in exams**
- Helps in converting theory into **logical steps**

🔹 **Tool 4: Digital MCQ & Quiz Practice Platforms**

**Purpose / Use-case**

- Self-assessment and quick revision

**How it helps in this unit**

- Strengthens **conceptual clarity**
- Helps identify **weak areas before exams**
- Useful for **CA tests and GTU-style MCQs**

🔹 **Tool 5: Note-Summarization & Flashcard Tools**

**Purpose / Use-case**

- Quick revision and memory reinforcement

**How it helps in this unit**

- Converts long topics into **short fault–cause–remedy points**
- Ideal for **last-day exam preparation**
- Supports **active recall learning**

**2️⃣ VIDEO LEARNING REPOSITORY**

*(Diploma-level | Exam-oriented | Easy to search)*

👉 **Tip for students:**

Copy the **Search Keywords exactly** into YouTube / SWAYAM / NPTEL for best results.

### 🎥 Recommended Video Resources Table

| **Topic Name** | **Recommended Channel / Course / Lecturer Name** | **Search Keywords** |
|---|---|---|
| Introduction to Troubleshooting | Basic Electrical Engineering Channels | "electrical troubleshooting basics diploma" |
| Internal and External Faults | Polytechnic / ITI Electrical Lectures | "internal external faults electrical equipment" |
| Systematic Troubleshooting Method | Engineering Maintenance Lectures | "systematic troubleshooting electrical engineering" |
| Troubleshooting Charts Explained | Electrical Maintenance Education | "troubleshooting chart electrical equipment" |
| Common Electrical Faults & Symptoms | Diploma Electrical Concepts | "common electrical faults and symptoms" |
| Use of Instruments in Troubleshooting | Basic Electrical Measurement Channels | "electrical troubleshooting instruments multimeter megger" |
| Overheating and Overloading Faults | Electrical Machines Lectures | "overheating overloading electrical equipment" |
| Domestic Appliance Troubleshooting | Polytechnic Practical Channels | "domestic electrical appliance troubleshooting diploma" |
| Circuit Breaker Faults (Conceptual) | Power System Basics Channels | "circuit breaker common faults troubleshooting" |
| Maintenance vs Troubleshooting | Maintenance Engineering Lectures | "maintenance vs troubleshooting electrical" |
| Safety During Troubleshooting | Electrical Safety Education | "electrical safety during troubleshooting" |

| **Topic Name** | **Recommended Channel / Course / Lecturer Name** | **Search Keywords** |
|---|---|---|
| Exam-Oriented Troubleshooting Questions | Diploma Exam Preparation Channels | "troubleshooting electrical exam questions diploma" |

🎯 **Alignment with OBE & NEP-2020**

- ✓ **Skill-oriented learning** (fault diagnosis & reasoning)
- ✓ **Self-paced and digital learning support**
- ✓ Encourages **critical thinking over rote learning**
- ✓ Supports **employability and service readiness**

🌟 **Mentor's Guidance for Students**

"Do not just *watch* videos—
**pause, predict the fault, then check the explanation.**
That is real troubleshooting practice."

📘 **PREDICTED QUESTION BANK**

**Unit–4: Troubleshooting of Electrical Equipment**

*(Diploma Engineering – Electrical Engineering)*

1️⃣ **MOST REPEATED / HIGH-PROBABILITY QUESTIONS**

*(Theory-oriented | Definitions | Explanatory | Chart-based)*

🔹 **A. Very High Probability (Asked Almost Every Year)**

1. **What is troubleshooting? Write the systematic steps involved in troubleshooting.**
   *(3 marks / short theory)*
2. **State and explain the external causes of faults in electrical equipment.**
   *(3 marks)*

3. **List the instruments/tools required for troubleshooting electrical equipment.**
   *(3 marks)*
4. **Explain the need of a troubleshooting chart. State its advantages.**
   *(4 marks)*
5. **Prepare a troubleshooting chart for D.C. motor.**
   *(7 marks – chart based)*
6. **Prepare a troubleshooting chart for transformer.**
   *(7 marks – chart based)*

- **B. High Probability (Frequently Appearing Variants)**

7. **Explain troubleshooting chart of circuit breaker for any four faults.**
   *(4 marks)*
8. **Prepare a troubleshooting chart for ceiling fan.**
   *(4 marks)*
9. **Prepare a troubleshooting chart for tube light / fluorescent lamp.**
   *(7 marks)*
10. **List the equipment required for troubleshooting and explain any four.**
    *(4 marks)*
11. **Explain common causes of faults in solar plant.**
    *(4 marks)*
12. **Prepare troubleshooting chart for solar plant.**
    *(3 or 7 marks)*

- **C. Conceptual / Explanation-Based (Moderate Probability)**

13. **Differentiate between internal faults and external faults.**
    *(Short answer / 3–4 marks)*
14. **Explain mechanical, electrical, and magnetic faults occurring in electrical equipment.**
    *(7 marks – descriptive)*
15. **Explain causes of sparking on brushes of D.C. motor and steps to solve it.**
    *(3 marks)*
16. **Why is systematic troubleshooting preferred over hit-and-trial method?**
    *(Short answer / viva oriented)*

17. **Explain the role of instruments in troubleshooting work.**
    *(4 marks)*

◆ **D. Examiner's Favourite "OR-Type" Questions**

18. **Prepare troubleshooting chart for electric iron.**
    *(7 marks)*
19. **Why circuit breaker does not open? Explain causes and remedies.**
    *(3 marks)*
20. **Explain troubleshooting chart for domestic electrical appliance (any one).**
    *(7 marks)*

**2 APPLICATION & LOGICAL THINKING QUESTIONS**

*(5 Questions – High-Scoring & Distinction Level)*

These questions **separate average answers from top-rank answers**.

1. **An electrical system trips repeatedly after short intervals. Explain how you will systematically troubleshoot the problem using logical steps.**
2. **An equipment shows abnormal heating and noise during operation. Identify possible causes and explain how troubleshooting charts help in diagnosis.**
3. **Explain how improper maintenance can increase the frequency of faults and complicate troubleshooting.**
4. **A domestic electrical appliance is not working even though supply is available. Explain a logical troubleshooting approach without replacing components blindly.**
5. **Explain how troubleshooting charts improve safety, reduce downtime, and support preventive maintenance practices.**

## 📘 STUDY PLAN

**Unit–5: Electrical Accidents and Safety**

**Total Teaching Hours: 6 Hours**
**Exam Weightage: 14 Marks**

### 📊 Topic-Wise Detailed Study Plan

| Sr. No. | Syllabus Topic (Strictly as per GTU) | Topic Nature* | Suggested Hours | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|
| 1 | **Major causes of electrical accidents** | Core | 1.0 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐ |
| 2 | **Consequences of electrical accidents** | Core | 0.5 | ⭐⭐⭐ | ⭐⭐⭐⭐ |
| 3 | **Factors affecting severity of electrical shock** | Core | 0.5 | ⭐⭐⭐ | ⭐⭐⭐⭐ |
| 4 | **Preventive steps against electrical accidents** | Core | 0.5 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐⭐ |
| 5 | **Necessity of earthing** | Core | 0.5 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐⭐ |
| 6 | **Factors affecting earth resistance** | Supporting | 0.5 | ⭐⭐⭐ | ⭐⭐⭐⭐ |
| 7 | **Advantages and types of earth electrodes** | Supporting | 0.5 | ⭐⭐⭐ | ⭐⭐⭐ |
| 8 | **Methods of earthing: Plate, Pipe, Coil & Chemical earthing** | Core | 1.0 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐⭐ |
| 9 | **Measurement of earth resistance** (Voltmeter-ammeter, Earth tester, Ohm meter, Earth loop tester) | Application | 0.75 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐⭐ |

| Sr. No. | Syllabus Topic (Strictly as per GTU) | Topic Nature* | Suggested Hours | Exam Importance | Practical Relevance |
|---|---|---|---|---|---|
| 10 | **Earthing procedures** (Building, domestic, industrial, substation, generating station, overhead line) | Application | 0.75 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐⭐ |
| 11 | **Procedure for shutting down substation and power lines** | Core | 0.5 | ⭐⭐⭐ | ⭐⭐⭐⭐ |
| 12 | **Certificates: Requisition for shutdown, Permit to work, Line clear certificate** | Supporting | 0.5 | ⭐⭐⭐ | ⭐⭐⭐ |
| 13 | **Fire extinguishers – fixed installations & portable devices** | Core | 0.5 | ⭐⭐⭐⭐ | ⭐⭐⭐⭐⭐ |

🎯 **Exam Orientation (Based on GTU Question Paper Pattern)**

- **Total Marks from Unit–5:** 14
- **Common Question Types:**
    - Causes & prevention (3–4 marks)
    - Earthing methods (7 marks)
    - Measurement of earth resistance (4 marks)
    - Fire extinguisher operation (3 marks)

🧠 **Outcome-Based Education (OBE) Alignment**

| Unit Outcome (CO-5 Related) | Learning Emphasis |
|---|---|
| Identify electrical hazards | Awareness & safety culture |
| Apply earthing methods | Practical skill & protection |
| Measure earth resistance | Instrument handling & interpretation |

**Unit Outcome (CO-5 Related) Learning Emphasis**

Follow safety procedures        Industry readiness

## 📘 Unit–5: Electrical Accidents and Safety

### Topic 5.1: Major Causes of Electrical Accidents

### 1️⃣ Hook / Introduction (≈ 5 Minutes)

*"Imagine this—one loose wire, one moment of carelessness, and an engineer's career or even life can change forever."*

Electrical accidents are **sudden, silent, and often fatal**, yet most of them are **100% preventable**. As future electrical engineers and technicians, you will work daily with live systems—machines, panels, tools, and power lines. Understanding **why electrical accidents happen** is not just for passing exams; it is about **going home safely every day**.

Before we begin, ask yourself:

*Is electricity dangerous by nature—or dangerous because of human mistakes?*

Today, we will answer this question by learning the **major causes of electrical accidents**.

### 2️⃣ Core Concepts (≈ 40 Minutes)

Electrical accidents occur due to **technical faults, human errors, or unsafe environments**. Let us study the major causes one by one.

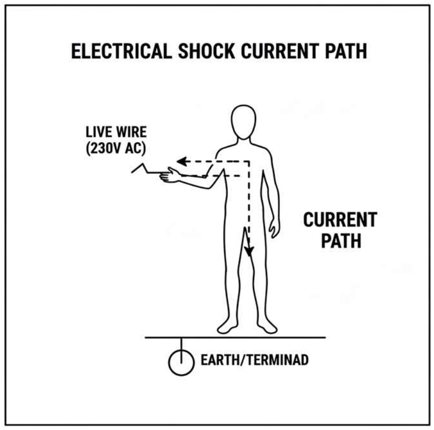
#### 🔹 1. Direct Contact with Live Parts

This is the **most common cause** of electrical accidents.
It occurs when a person directly touches a **live conductor or terminal** due to:

- Exposed wires
- Damaged insulation
- Open terminals without covers

⚡ *Result:* Severe electric shock or electrocution.

**Visual to draw:**
Simple diagram showing a person touching a live wire with current path through the body to earth




### 🔹 2. Improper or No Earthing

Earthing provides a **safe path for fault current**.
Accidents occur when:

- Equipment is not earthed
- Earthing resistance is high
- Earth connection is broken

Without earthing, **metal body becomes live** during fault conditions.

**Exam Tip:**
“Poor earthing” is a **very high-probability exam answer**.

### 🔹 3. Use of Defective or Substandard Equipment

Old, damaged, or low-quality tools and appliances can cause:

- Insulation failure
- Short circuits
- Leakage current

Examples:

- Cracked plugs
- Broken switches
- Damaged cables

**Fun Fact:**
Most domestic electrical accidents happen due to **cheap or repaired appliances**.

◆ **4. Overloading of Electrical Circuits**

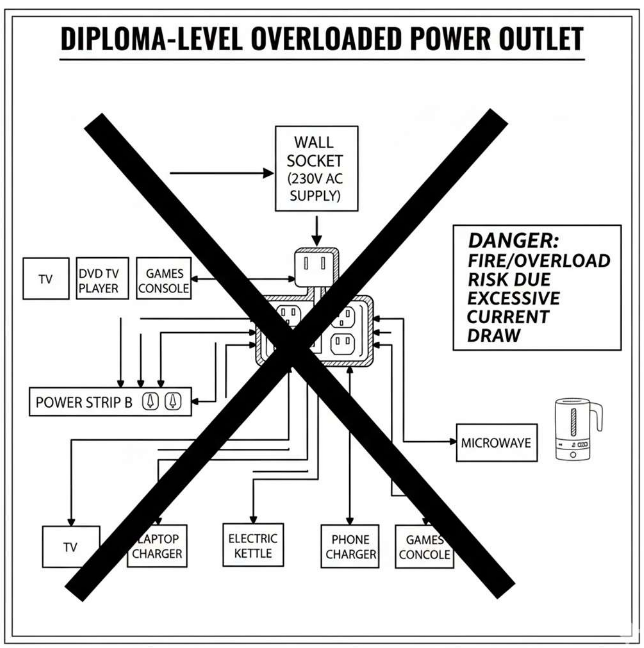
Overloading occurs when:

- Too many loads are connected to one circuit
- Equipment operates beyond rated capacity

This leads to:

- Overheating
- Insulation damage
- Fire hazards

**Visual to draw:**
Single socket with multiple appliances connected using adapters.




◆ **5. Lack of Safety Awareness and Training**

Many accidents happen due to:

- Working without switching OFF supply

- Ignoring safety rules
- Overconfidence

Remember:

*Electricity does not forgive mistakes.*

### 🔹 6. Wet or Damp Conditions

Water reduces body resistance.
Accidents commonly occur:

- In bathrooms
- During rainy season
- In damp industrial areas

Even low voltage can be **fatal in wet conditions**.

### 🔹 7. Poor Maintenance and Housekeeping

Loose connections, dust, corrosion, and oil leakage increase accident risk.

## 3️⃣ Real-World / Industry Applications (≈ 10 Minutes)

In industries:

- Most accidents occur during **maintenance work**
- Shutdown procedures are ignored to save time
- Earthing continuity is not checked regularly

In substations and power plants:

- Safety permits and lock-out systems are compulsory
- Accidents are reduced where **standard operating procedures (SOPs)** are followed

In homes:

- Accidents increase during **monsoon season**
- Improper extensions and wet hands are common causes

## 4️⃣ Summary & Q&A (≈ 5 Minutes)

### ✅ Key Takeaways:

- Electrical accidents are **preventable**
- Major causes include:
    - Direct contact with live parts
    - Poor earthing
    - Overloading
    - Defective equipment
    - Human negligence
- Safety awareness is as important as technical knowledge

🤔 **Common Student Doubt:**

**"Sir, why do accidents occur even at low voltage?"**
👉 Because **current through the body**, not voltage alone, causes injury—especially in wet conditions.

🎓 **Mentorship Note (Career Guidance)**

*A skilled engineer is respected for knowledge, but a wise engineer is valued for safety.*

Mastering electrical safety:

- Makes you **industry-ready**
- Builds trust as a **responsible technician**
- Protects your **career, coworkers, and life**

📘 **Unit–5: Electrical Accidents and Safety**

**Topic 5.2: Consequences of Electrical Accidents & Factors Affecting Severity of Electrical Shock**

1️⃣ **Hook / Introduction (≈ 5 Minutes)**

*"Two people touch the same electrical source—one survives with a mild shock, the other does not. Why?"*

This question brings us to an important truth in electrical safety:
👉 **Not all electric shocks have the same effect.**

In the previous lecture, we learned **why electrical accidents occur**.
Today, we will understand:

- **What happens after an electrical accident**, and
- **What factors decide how severe an electric shock will be**

This knowledge helps engineers **predict danger**, **design safer systems**, and **take correct emergency actions**.

2️⃣ **Core Concepts (≈ 40 Minutes)**

🔹 **Part A: Consequences of Electrical Accidents**

Electrical accidents can affect **humans, equipment, and surroundings**.

## 1. Electric Shock

Electric shock occurs when current passes through the human body.

Possible effects:

- Tingling sensation
- Muscle contraction (cannot release conductor)
- Severe pain

⚡ *Important:* Even a small current can be dangerous if it passes through vital organs.

## 2. Electrical Burns

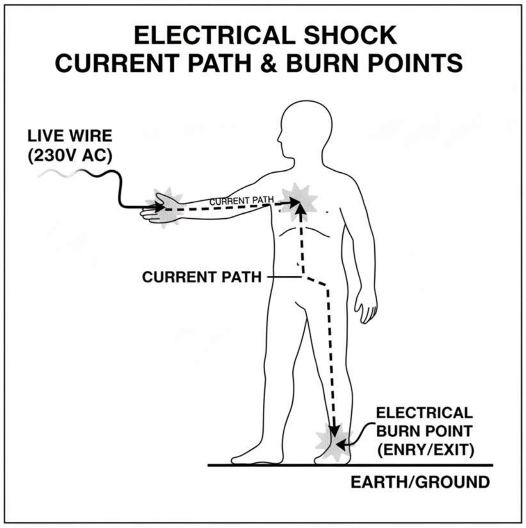
Burns are caused by:

- Heat due to current flow
- Arc flash
- Contact with hot conductors

Types:

- Skin burns
- Deep tissue burns

**Visual to draw:**
Diagram showing current entering hand and exiting foot, with burn points.




## 3. Ventricular Fibrillation (Heart Failure)

This is the **most dangerous consequence**.

- Heart rhythm becomes irregular
- Blood circulation stops
- Can cause instant death

**Exam Highlight:**
Most deaths from electric shock are due to **heart failure**, not burns.

## 4. Respiratory Failure

Electric shock can paralyze:

- Chest muscles
- Nervous control of breathing

Result: Person stops breathing even if heart is working.

**5. Secondary Accidents**

Electrical shock may cause:

- Falling from height
- Dropping tools
- Fire or explosion

◆ **Part B: Factors Affecting Severity of Electrical Shock**

## 1. Magnitude of Current

Severity depends on **current through the body**, not voltage alone.

- 1 mA → slight shock
- 10 mA → painful, loss of muscle control
- 50 mA → fatal

## 2. Duration of Current Flow

Longer contact time = **more damage**

Quick release reduces severity.

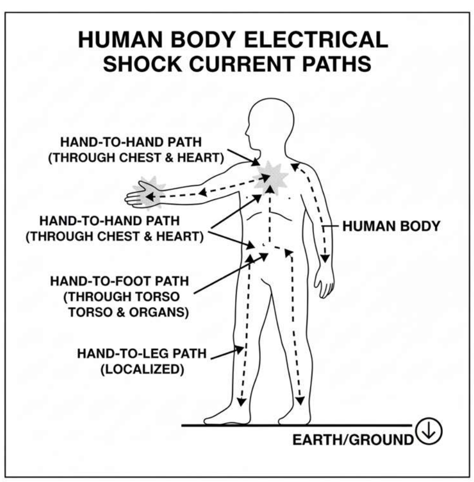
## 3. Path of Current Through Body

Most dangerous paths:

- Hand to hand
- Hand to foot

These paths pass through **heart and lungs**.

**Visual to draw:**
Human body diagram with current paths marked.



## 4. Body Resistance

Body resistance decreases when:

- Skin is wet
- Person is sweating
- Barefoot on ground

Wet skin = **higher danger**.

**5. Type and Frequency of Current**

- AC is more dangerous than DC
- AC causes muscle locking

**Fun Fact:**
AC at power frequency is more likely to cause heart fibrillation.

**6. Environmental Conditions**

- Wet floors
- Metal surroundings
- Poor insulation

All increase accident severity.

**3️⃣ Real-World / Industry Applications (≈ 10 Minutes)**

In industries:

- Workers wear **insulated gloves and shoes** to increase body resistance
- Lock-out/tag-out systems reduce shock duration

In homes:

- Accidents increase during **monsoon**
- Bathrooms require special safety devices

In substations:

- Workers follow **minimum approach distance** rules
- Emergency rescue training is mandatory

4️⃣ **Summary & Q&A (≈ 5 Minutes)**

✅ **Key Takeaways:**

- Electrical accidents can cause shock, burns, heart failure, and death
- Shock severity depends on:
    - Current magnitude
    - Time duration
    - Current path
    - Body resistance
    - Environmental conditions

🤔 **Common Student Doubt:**

**"Why is AC more dangerous than DC?"**
👉 Because AC causes continuous muscle contraction, preventing release.

🎓 **Mentorship Note (Career Guidance)**

*Safety knowledge is silent—but its impact is lifelong.*

Understanding shock severity:

- Helps you design **safer electrical systems**
- Improves **emergency response decisions**
- Builds confidence in **industrial and field jobs**

🔑 **A successful engineer is not one who never makes mistakes—but one who understands risks and controls them.**

📘 **Unit–5: Electrical Accidents and Safety**

**Topic 5.3: Preventive Steps Against Electrical Accidents & Necessity of Earthing**

1️⃣ **Hook / Introduction (≈ 5 Minutes)**

*"Why do birds sit safely on high-voltage lines, while humans cannot?"*

This simple question leads us to two powerful ideas:

- **Prevention is better than cure**
- **Earthing saves lives**

In earlier topics, we studied **causes and consequences** of electrical accidents. Today, we focus on **how accidents can be prevented** and **why earthing is the most important safety protection in electrical systems**.

Remember:

*An engineer who ignores safety designs danger—not only for others, but for himself.*

2️⃣ **Core Concepts (≈ 40 Minutes)**

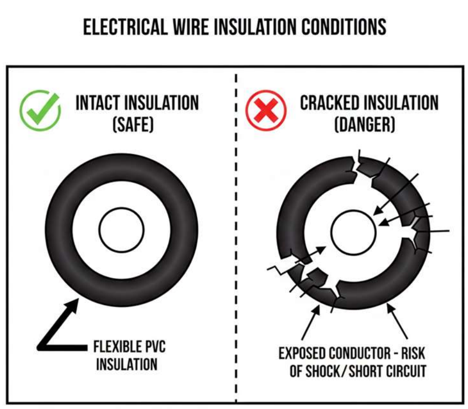
🔹 **Part A: Preventive Steps Against Electrical Accidents**

Preventive steps are actions taken **before an accident occurs**.

## 1. Proper Insulation of Conductors

- All live parts must be **fully insulated**
- Damaged insulation should be **replaced immediately**
- Use correct insulation grade for voltage level

**Visual to draw:**
Wire showing intact insulation vs cracked insulation.



## 2. Switching OFF Supply Before Work

- Always isolate supply before maintenance
- Use lock-out/tag-out practices
- Display "MEN AT WORK" boards

**Golden Rule:**
*Never trust a switch—test before touch.*

## 3. Use of Protective Devices

Protective devices reduce accident risk:

- Fuses and circuit breakers
- Earth leakage protection devices

They **disconnect supply automatically** during faults.

## 4. Use of Personal Protective Equipment (PPE)

Examples:

- Insulated gloves
- Safety shoes
- Helmets

PPE increases **body resistance**, reducing shock severity.

**5. Avoid Wet Conditions**

- Do not operate electrical equipment with wet hands
- Keep floors dry
- Special care during rainy season

**6. Regular Maintenance and Inspection**

- Tighten loose connections
- Replace worn-out components
- Check earthing periodically

**Fun Fact:**
Over 70% of electrical accidents occur due to **poor maintenance**.

- **Part B: Necessity of Earthing**

Earthing is the **backbone of electrical safety**.

**What is Earthing?**

Earthing is the process of **connecting non-current carrying metal parts of equipment to the earth**.

**Why is Earthing Necessary?**

1. **Protects Human Life**
   Fault current flows safely to earth instead of through the body.

2. **Prevents Electric Shock**
   Keeps equipment body at earth potential.

3. **Protects Equipment**
   Reduces damage during short circuits and lightning.

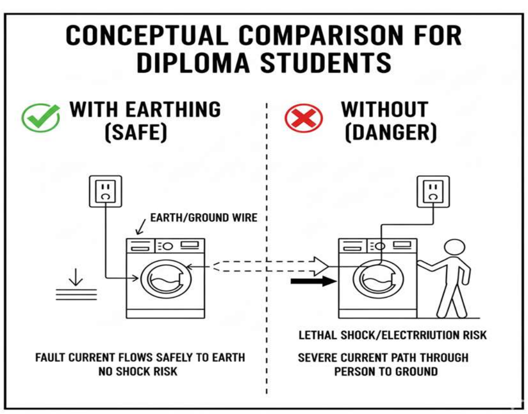
4. **Ensures Proper Operation of Protective Devices**
   Fault current helps fuses and breakers operate quickly.

**Example to Understand Earthing**

Imagine a metal-bodied appliance:

- Without earthing → body becomes live → shock
- With earthing → fault current flows to ground → supply trips

**Visual to draw:**
Two diagrams of an appliance—one with earthing, one without.



### 3️⃣ Real-World / Industry Applications (≈ 10 Minutes)

In industries:

- Earthing is compulsory for all machines
- Separate earthing provided for power, neutral, and lightning

In homes:

- Earthing protects users from faulty appliances
- Required in bathrooms and kitchens

In substations:

- Earthing grids protect workers and equipment
- Step and touch voltage are controlled

### 4️⃣ Summary & Q&A (≈ 5 Minutes)

### ✅ Key Takeaways:

- Electrical accidents can be prevented by:
    - Proper insulation
    - Switching off supply
    - Using protective devices
    - PPE and maintenance
- Earthing is essential for:
    - Human safety
    - Equipment protection
    - Reliable system operation

### 😲 Common Student Doubt:

**"If earthing is present, why accidents still occur?"**
👉 Because earthing must be **proper and low resistance** to be effective.

### 🎓 Mentorship Note (Career Guidance)

*In industry, your safety habits define your professionalism.*

Mastering accident prevention and earthing:

- Builds trust as a **responsible engineer**
- Helps in **projects, site work, and maintenance jobs**
- Makes you valuable in **power plants, industries, and service roles**

🔑 **Remember:**
*Good engineers make systems work.*
*Great engineers make systems safe.*

---

## 📘 Unit–5: Electrical Accidents and Safety

**Topic 5.4: Factors Affecting Earth Resistance & Advantages and Types of Earth Electrodes**

---

### 1️⃣ Hook / Introduction (≈ 5 Minutes)

*"Two electrical installations look identical—but one is safe and the other is dangerous. What makes the difference?"*

The answer is often **earthing quality**.
Earthing is not just about connecting a wire to the ground; it is about achieving **low earth resistance**. Today's lecture explains:

- **What affects earth resistance**, and
- **Why different types of earth electrodes are used**

This topic is **highly exam-oriented** and **extremely important for real-life safety**.

---

### 2️⃣ Core Concepts (≈ 40 Minutes)

#### 🔹 Part A: Factors Affecting Earth Resistance

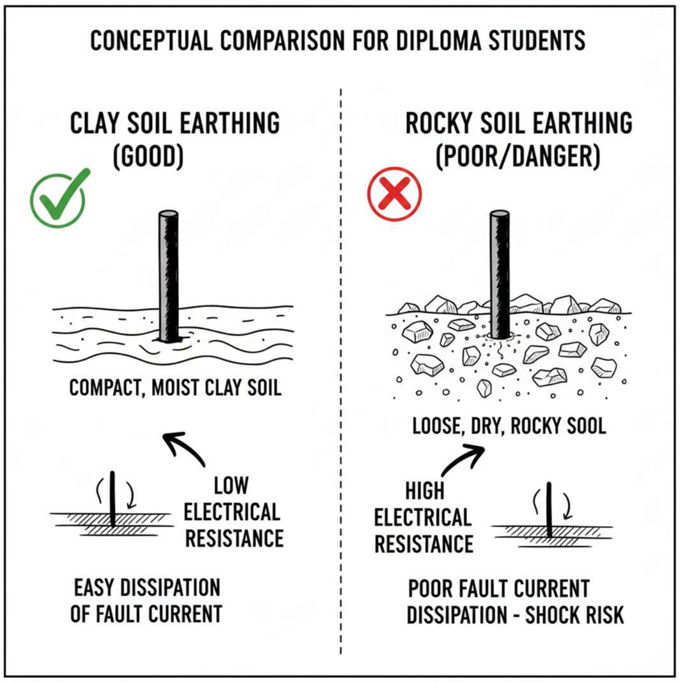
**Earth resistance** is the resistance offered by the earth electrode and surrounding soil to the flow of fault current.

---

## 1. Soil Resistivity

- Different soils have different resistivity:
  - Clay → low resistance
  - Sandy or rocky soil → high resistance

**Visual to draw:**
Comparison diagram of clay soil vs rocky soil earthing.




## 2. Moisture Content of Soil

- Moist soil → **lower earth resistance**
- Dry soil → **higher earth resistance**

This is why earthing performance reduces in **summer**.

---

## 3. Depth of Earth Electrode

- Greater depth → more contact with moist soil
- Leads to **lower resistance**

**Exam Tip:**
Depth of electrode is a **very common short-answer question**.

---

## 4. Size and Shape of Earth Electrode

- Larger surface area → lower resistance
- Plates, pipes, and coils provide different contact areas

---

**5. Temperature of Soil**

- Higher temperature → lower resistance
- Frozen or dry soil → high resistance

---

**6. Chemical Treatment of Soil**

- Adding salt, charcoal, or chemicals reduces soil resistance
- Used in **chemical earthing**

---

◆ **Part B: Advantages of Proper Earthing**

1. **Safety of Human Life**
   Provides safe path for fault current.
2. **Protection of Equipment**
   Reduces damage due to short circuit or lightning.
3. **Reliable Operation of Protective Devices**
   Enables fast operation of fuses and breakers.
4. **Stable System Voltage**
   Maintains system reference potential.

---

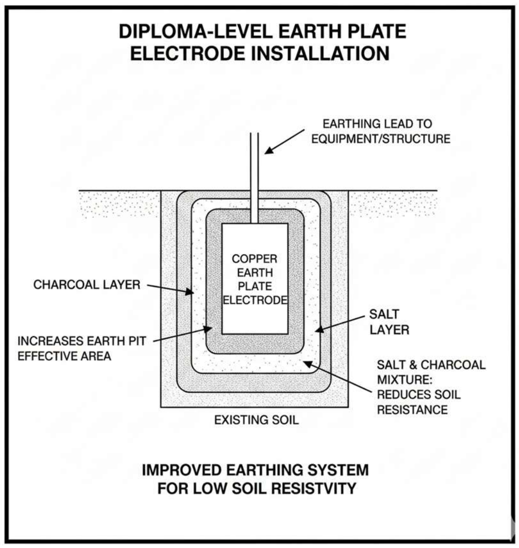
◆ **Part C: Types of Earth Electrodes**

Earth electrodes are conductors buried in soil to make contact with earth.

## 1. Plate Earthing

- Uses copper or GI plate
- Buried vertically with charcoal and salt

**Visual to draw:**
Plate electrode surrounded by salt and charcoal layers.




## 2. Pipe Earthing

- GI pipe placed vertically in ground
- Most common and economical
- Suitable for domestic and industrial use

## 3. Rod Earthing

- Copper or GI rod driven into ground
- Used where space is limited

## 4. Strip or Wire Earthing

- Copper or GI strip buried horizontally
- Used in large installations and substations

---

### 3️⃣ Real-World / Industry Applications (≈ 10 Minutes)

In residential buildings:

- Pipe earthing is most common
- Regular watering is needed in summer

In industries:

- Separate earthing for equipment and lightning
- Earth resistance is measured periodically

In substations:

- Earthing grids are designed to control step and touch voltages

---

### 4️⃣ Summary & Q&A (≈ 5 Minutes)

✅ **Key Takeaways:**

- Earth resistance depends on:
    - Soil type
    - Moisture
    - Depth and size of electrode
- Proper earthing ensures:
    - Safety
    - Equipment protection
- Different electrodes are selected based on:

- Soil condition
- Space
- Application

🤔 **Common Student Doubt:**

**“Why do we add salt and charcoal in earthing?”**
👉 To reduce soil resistivity and improve conductivity.

---

### 🎓 Mentorship Note (Career Guidance)

*Good earthing design shows good engineering judgment.*

Understanding earth resistance and electrode types:

- Helps in **site work and installations**
- Improves performance in **practical exams and interviews**
- Builds foundation for **power systems and safety engineering**

🔑 **Remember:**
*An invisible system like earthing often provides the strongest protection.*

---

## 📘 Unit–5: Electrical Accidents and Safety

### Topic 5.5: Methods of Earthing – Plate, Pipe, Coil & Chemical Earthing

---

### 1️⃣ Hook / Introduction (≈ 5 Minutes)

*“If earthing is the backbone of electrical safety, then earthing methods are the bones that hold the system together.”*

In previous lectures, we learned **why earthing is necessary** and **what affects earth resistance**.
Today, we focus on **how earthing is actually done in practice**.

Different locations and soil conditions require **different earthing methods**. Choosing the correct method is an important responsibility of an electrical engineer.

---

## 2 Core Concepts (≈ 40 Minutes)

### ◆ What is a Method of Earthing?

A **method of earthing** refers to the **way an earth electrode is installed in the ground** to achieve low resistance and safe dissipation of fault current.

Let us study the four commonly used methods.

---

### ◆ 1. Plate Earthing

**Construction:**

- A copper or GI plate is buried vertically in the ground.
- Plate size is generally large to provide more contact area.
- Surrounding soil is treated with **charcoal and salt**.
- A watering pipe is provided to maintain moisture.

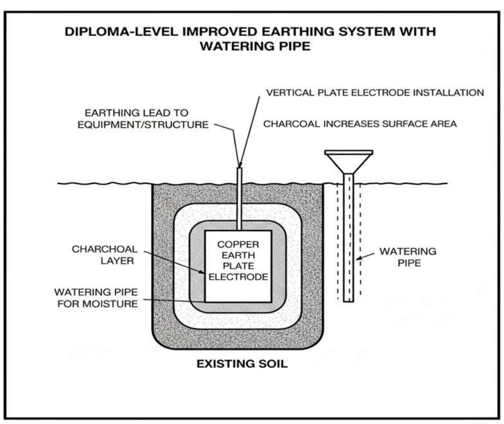
**Advantages:**

- Reliable and effective
- Long service life

**Disadvantages:**

- Costly
- Requires more space

**Visual to draw:**
Vertical plate surrounded by alternate layers of charcoal and salt with watering pipe.



**Exam Tip:**
Plate earthing is a **very common 7-mark question**.

---

### ◆ 2. Pipe Earthing

**Construction:**

- A GI pipe with holes is buried vertically.
- Pipe length is usually more than plate earthing depth.
- Charcoal and salt are added around the pipe.

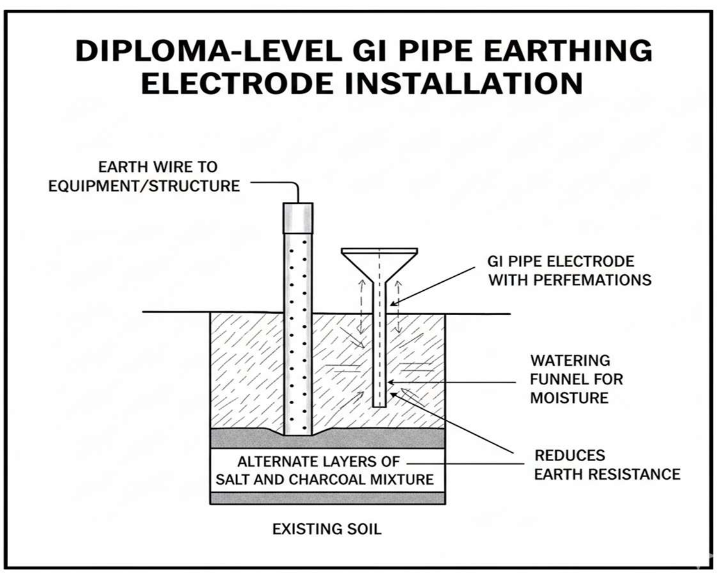
**Advantages:**

- Economical
- Low earth resistance
- Most commonly used method

**Applications:**

- Residential buildings
- Small industries

**Visual to draw:**
GI pipe with perforations, watering arrangement, and earth wire connection.



### 3. Coil (Strip/Wire) Earthing

**Construction:**

- Copper or GI strip/wire laid horizontally in trenches.
- Connected to equipment body at multiple points.

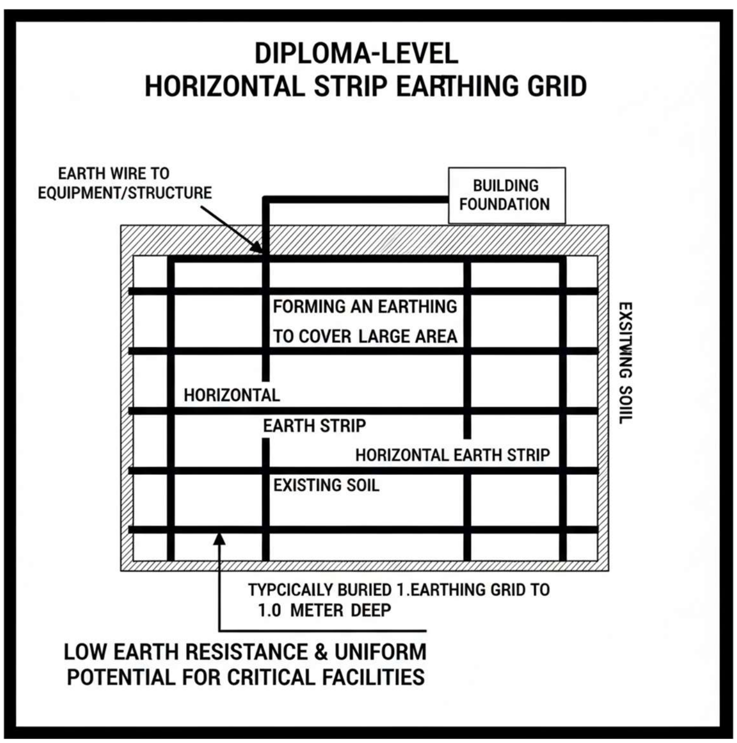
**Advantages:**

- Suitable for large installations
- Provides uniform earthing

**Applications:**

- Substations
- Power plants
- Transmission yards

**Visual to draw:**
Horizontal strip buried in ground forming an earthing grid.



### 🔸 4. Chemical Earthing

**Construction:**

- Special electrode with chemical compounds.
- Chemicals maintain low soil resistivity permanently.
- Requires less maintenance.

**Advantages:**

- Stable earth resistance
- Effective in rocky or dry soil
- Long life

**Disadvantages:**

- Higher initial cost

**Fun Fact:**
Chemical earthing is widely used in **modern data centers and solar plants**.

## 3️⃣ Real-World / Industry Applications (≈ 10 Minutes)

In homes:

- **Pipe earthing** is most commonly used.

In industries:

- Combination of **pipe and strip earthing** ensures safety.

In substations:

- **Grid or coil earthing** is used to control step and touch voltage.

In modern installations:

- **Chemical earthing** ensures stable performance with minimal maintenance.

---

## 4️⃣ Summary & Q&A (≈ 5 Minutes)

### ✅ Key Takeaways:

- Earthing methods differ based on:
    - Soil condition
    - Space availability
    - Type of installation
- Plate earthing → Reliable but costly
- Pipe earthing → Economical and widely used
- Coil earthing → Large installations
- Chemical earthing → Modern and maintenance-free

🤔 **Common Student Doubt:**

**"Which earthing method is best?"**
👉 There is no single best method; **selection depends on application and soil condition**.

---

### 🎓 Mentorship Note (Career Guidance)

*An engineer who understands earthing is trusted with safety-critical responsibilities.*

Mastering earthing methods helps you:

- Score high in **theory and practical exams**
- Perform confidently in **site and maintenance jobs**
- Build a strong base for **power systems and safety engineering**

🔑 **Remember:**
*Good earthing may never be seen—but its absence is always felt.*

---

## 📘 Unit–5: Electrical Accidents and Safety

### Topic 5.6: Measurement of Earth Resistance

*(Voltmeter–Ammeter Method, Earth Tester, Ohm Meter, Earth Loop Tester)*

---

### 1️⃣ Hook / Introduction (≈ 5 Minutes)

*"You installed perfect earthing—but how do you prove it is safe?"*

This question highlights an important truth:
👉 **Earthing is useful only when its resistance is low and verified.**

Many electrical accidents occur not because earthing is absent, but because **earth resistance is too high** and nobody measures it. Today's lecture focuses on **how engineers measure earth resistance using different methods**.

This topic is **highly practical**, **frequently asked in exams**, and **essential for field engineers**.

---

### 2️⃣ Core Concepts (≈ 40 Minutes)

#### 🔹 What is Earth Resistance Measurement?

Earth resistance measurement determines **how easily fault current can flow from equipment to the earth**.
Lower resistance = **higher safety**.

---

#### 🔸 1. Voltmeter–Ammeter Method

**Principle:**

- Based on **Ohm's Law**
- Earth resistance = Voltage / Current

**Procedure:**

- An auxiliary electrode is placed in the ground.
- AC supply is applied.
- Voltage and current are measured.

**Advantages:**

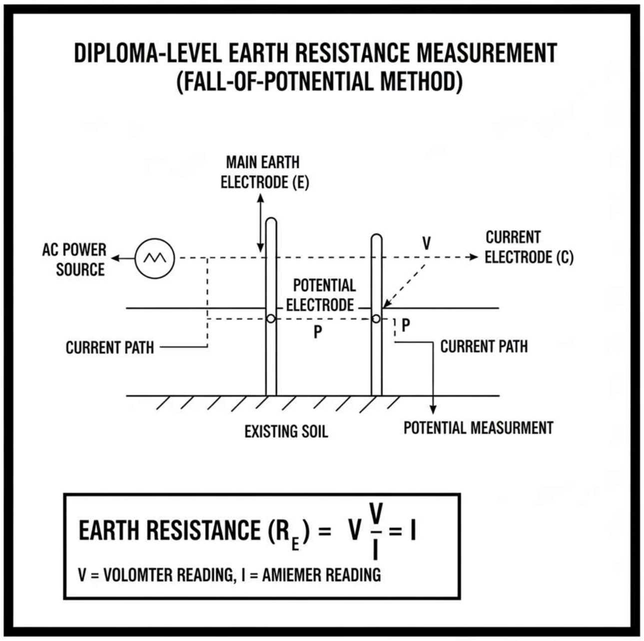
- Simple method
- Uses basic instruments

**Limitations:**

- Less accurate

- Not suitable for large installations

**Visual to draw:**
Earth electrode, auxiliary electrode, voltmeter across earth, ammeter in series.




**Exam Tip:**
Mention **formula clearly** to score full marks.

◆ **2. Earth Tester Method**

**Principle:**

- Uses **three-point or four-point method**
- Measures resistance directly

**Procedure:**

- Main earth electrode connected
- Two auxiliary electrodes placed at fixed distances
- Tester gives direct reading

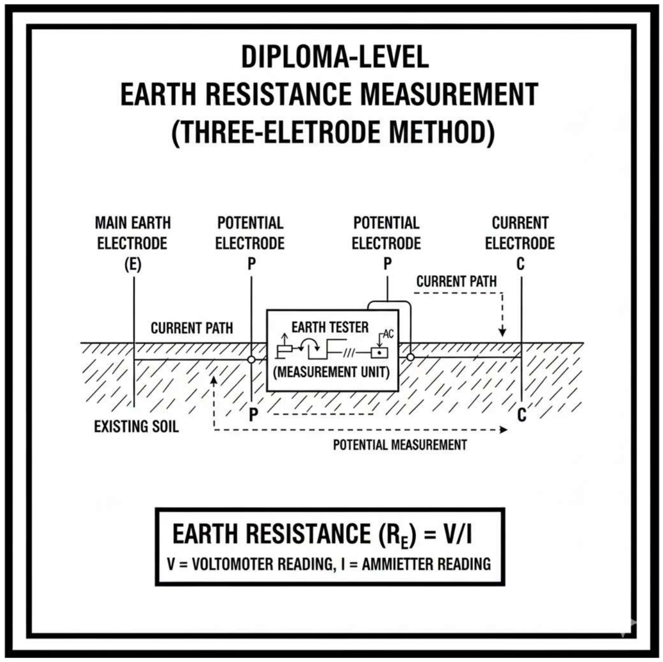
**Advantages:**

- Accurate
- Most commonly used method

**Applications:**

- Industrial installations
- Substations

**Visual to draw:**
Three electrodes in straight line connected to earth tester.

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◆ **3. Ohm Meter Method**

**Principle:**

- Measures resistance between earth and reference electrode

**Features:**

- Simple and portable
- Used for rough checking

**Limitations:**

- Not very accurate
- Not suitable for large earthing systems

**Fun Fact:**
Ohm meter testing is mainly used for **quick inspection**, not certification.

## 🔸 4. Earth Loop Tester Method

**Principle:**

- Measures earth resistance without disconnecting the earth
- Uses existing earth loop

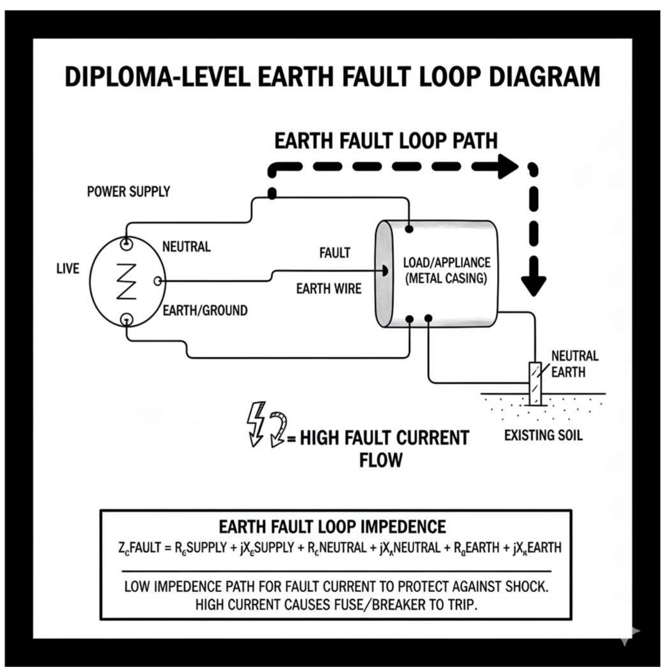
**Advantages:**

- No disconnection required
- Safe and fast

**Applications:**

- Live installations
- Domestic and commercial buildings

**Visual to draw:**
Earth loop formed through supply neutral and earth conductor.




## 3️⃣ Real-World / Industry Applications (≈ 10 Minutes)

In residential buildings:

- Earth resistance checked during wiring inspection

In industries:

- Earth testers used periodically
- Results recorded for safety audits

In substations:

- Earth grid resistance tested regularly
- Critical for step and touch voltage control

In modern systems:

- Earth loop testers used for live testing without shutdown

---

**4️⃣ Summary & Q&A (≈ 5 Minutes)**

✅ **Key Takeaways:**

- Measuring earth resistance is **mandatory for safety**
- Common methods:
  - Voltmeter–ammeter → basic
  - Earth tester → accurate & common
  - Ohm meter → quick checking
  - Earth loop tester → live testing
- Lower earth resistance ensures:
  - Faster fault clearance
  - Reduced shock risk

🤔 **Common Student Doubt:**

**“What is acceptable earth resistance value?”**
👉 Generally **less than 5 ohms** (lower is better).

---

### 🎓 Mentorship Note (Career Guidance)

*Field engineers are judged by measurements—not assumptions.*

Understanding earth resistance measurement:

- Builds confidence in **site work and maintenance**
- Helps in **practical exams and viva**
- Prepares you for roles in **power plants, substations, and industries**

🔑 **Remember:**
*You cannot see earthing—but you must always measure it.*

## 📘 Unit–5: Electrical Accidents and Safety

**Topic 5.7: Earthing Procedures & Shutdown Procedures of Substation and Power Lines**

---

### 1️⃣ Hook / Introduction (≈ 5 Minutes)

*"Many electrical accidents do not happen because of lack of knowledge, but because correct procedures are not followed."*

Imagine a technician starts work assuming a line is dead—but it is still live. This single mistake can be fatal.

Today's topic focuses on **two life-saving aspects** of electrical safety:

1. **Correct earthing procedures for different installations**, and
2. **Proper shutdown procedures before working on substations or power lines**

This knowledge transforms a student into a **safe and responsible engineer**.

---

### 2️⃣ Core Concepts (≈ 40 Minutes)

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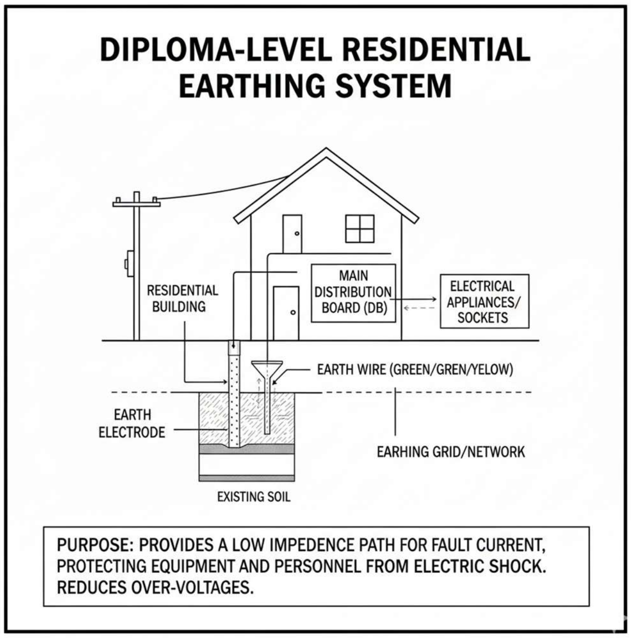
#### 🔹 Part A: Earthing Procedures

Earthing procedure means **how earthing is practically implemented and connected** in different systems.

◆ **1. Earthing of Buildings**

- Main earth electrode installed near the building
- All metallic parts (panels, conduits, lift frames) connected to earth
- Separate earth for lightning protection

**Visual to draw:**
Building with earth pit connected to distribution board.




◆ **2. Domestic Earthing**

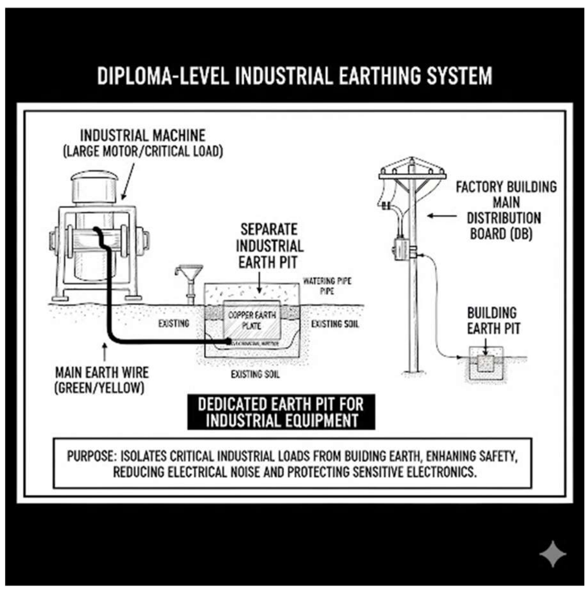
- Pipe earthing commonly used
- Earthing connected to:
    - Switchboard earth terminal
    - Metal body of appliances
- Essential for bathrooms and kitchens

**Key Point:**
Every socket must have a **proper earth connection**.

### ◆ 3. Industrial Earthing

- Multiple earthing points used
- Separate earthing for:
  - Equipment body
  - Neutral
  - Lightning arresters
- Earth resistance checked periodically

**Visual to draw:**
Industrial machine connected to separate earth pit.

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### ◆ 4. Substation Earthing

- Earthing grid or mat laid underground
- All equipment bodies connected to grid
- Controls **step voltage and touch voltage**

**Exam Highlight:**
Substation earthing is a **very important descriptive question**.

◆ **5. Generating Station Earthing**

- Heavy fault currents expected
- Multiple earth electrodes used
- Neutral earthing is critical

**Purpose:**
Protects generators, turbines, and personnel.

---

◆ **6. Earthing of Overhead Lines**

- Poles earthed at regular intervals
- Lightning arresters earthed
- Prevents damage during lightning and line faults

---

◆ **Part B: Procedure for Shutting Down Substation and Power Lines**

Before any maintenance work, **shutdown is compulsory**.

---

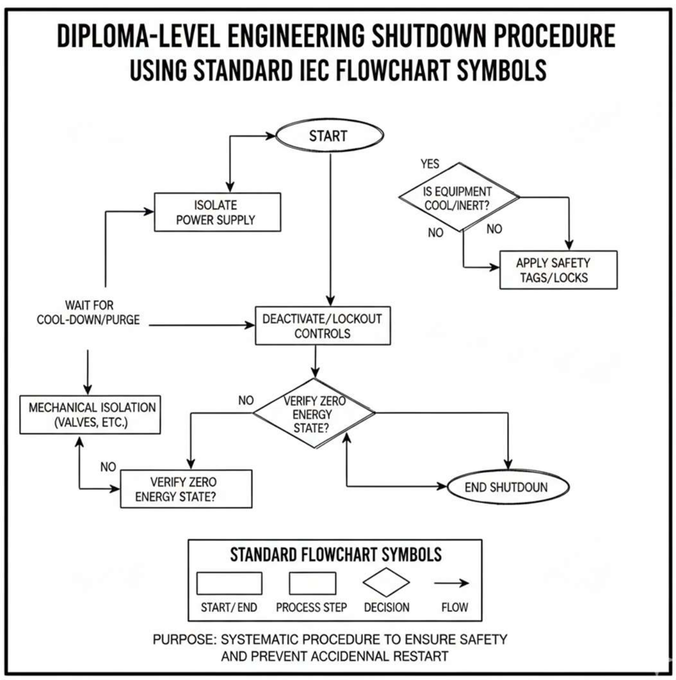
**Step-by-Step Shutdown Procedure:**

1. **Obtain Permission**
   - Written requisition for shutdown
2. **Switch OFF Supply**
   - Open circuit breakers and isolators
3. **Confirm Line is Dead**
   - Use voltage detector
4. **Apply Earthing**
   - Temporary earthing on lines and equipment
5. **Issue Permit to Work**

- Work allowed only after permit

6. **Display Safety Boards**
    - “MEN AT WORK” notice
7. **After Work Completion**
    - Remove tools and earthing
    - Inform control room
    - Restore supply

**Visual to draw:**
Flowchart of shutdown procedure steps.

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## 3️⃣ Real-World / Industry Applications (≈ 10 Minutes)

In substations:

- Shutdown procedures are legally mandatory
- Records maintained for every shutdown

In industries:

- Lock-out/tag-out systems used
- No work allowed without permit

In overhead line maintenance:

- Temporary earthing prevents induced voltage shocks

**Fun Fact:**
Many utilities follow the rule:
👉 *"No permit, no work."*

---

### 4️⃣ Summary & Q&A (≈ 5 Minutes)

✅ **Key Takeaways:**

- Earthing procedures vary with installation type
- Substations and generating stations require special earthing
- Shutdown procedures prevent fatal accidents
- Earthing + shutdown = **maximum safety**

🤔 **Common Student Doubt:**

**"Why do we earth lines after switching OFF supply?"**
👉 Because induced voltage or back-feed can still make lines dangerous.

---

### 🎓 Mentorship Note (Career Guidance)

*Industry values engineers who follow procedures, not shortcuts.*

Mastering earthing and shutdown procedures:

- Makes you **field-ready**
- Builds confidence during **site work and maintenance**
- Improves performance in **interviews, viva, and safety audits**

🔑 **Remember:**
*A good engineer knows how systems work.*
*A great engineer knows how to work safely.*

---

## 📘 Unit–5: Electrical Accidents and Safety

**Topic 5.8: Certificates & Fire Extinguishers**

*(Requisition for Shutdown, Permit to Work, Line Clear Certificate, Fixed & Portable Fire Extinguishers)*

---

### 1️⃣ Hook / Introduction (≈ 5 Minutes)

*"Before touching any electrical equipment, what protects you more—your tools or a piece of paper?"*

The correct answer is **the procedure written on that paper**. Many fatal electrical accidents happen **not due to technical failure**, but because **safety certificates are ignored**.

In today's lecture, we will learn:

- **Why safety certificates are compulsory**, and
- **How fire extinguishers protect life and property during electrical fires**

This topic combines **discipline, responsibility, and emergency response**—three qualities of a professional engineer.

---

### 2️⃣ Core Concepts (≈ 40 Minutes)

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#### 🔷 Part A: Safety Certificates in Electrical Work

Safety certificates are **formal written permissions** that ensure work is carried out safely on electrical systems.

---

#### 🔶 1. Requisition for Shutdown

**Meaning:**
A formal written request made to the control authority to **switch OFF electrical supply** for maintenance work.

**Purpose:**

- Prevents accidental energizing of equipment
- Ensures coordination between operating and maintenance staff

**Contents:**

- Location of work
- Date and time
- Reason for shutdown

**Exam Tip:**
Always mention that it is issued **before work begins**.

---

### 🔸 2. Permit to Work (PTW)

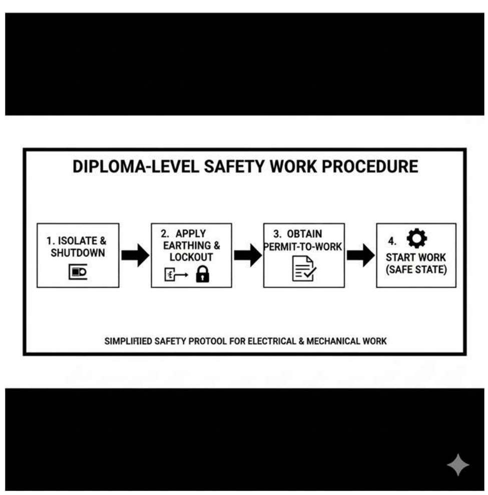
**Meaning:**
A legal document that **authorizes a person to start work** on electrical equipment after shutdown and earthing.

**Issued by:**
Authorized electrical officer

**Importance:**

- Confirms equipment is isolated and earthed
- Prevents unauthorized work

**Visual to draw:**
Flow diagram: Shutdown → Earthing → Permit to Work → Start Work



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◆ **3. Line Clear Certificate (LCC)**

**Meaning:**
A certificate issued **after completion of work**, confirming:

- All tools and personnel are removed
- System is safe to re-energize

**Purpose:**

- Prevents accidental energizing while someone is still working

**Fun Fact:**
In power utilities, **supply cannot be restored without LCC**.

---

◆ **Part B: Fire Extinguishers – Fixed Installations & Portable Devices**

Electrical faults can cause **fire due to short circuits or overheating**. Fire extinguishers are used to **control fires at early stages**.

---

◆ **Types of Fire Extinguishers (Electrical Focus)**

1. **Carbon Dioxide ($CO_2$) Extinguisher**
   - Suitable for electrical fires
   - Does not damage equipment
2. **Dry Powder Extinguisher**
   - Used for electrical and flammable fires
   - Smothers the fire

⚠ **Never use water on electrical fires.**

---

◆ **Fixed Fire Extinguishing Installations**

- Installed permanently in substations and control rooms
- Automatically detect and suppress fire

- Used in high-risk areas

---

◆ **Portable Fire Extinguishers**

- Hand-operated devices
- Easy to use and quick response
- Installed near panels and machines

**Visual to draw:**
$CO_2$ extinguisher with horn and pressure cylinder.


---

### 3 Real-World / Industry Applications (≈ 10 Minutes)

In substations:

- Work begins only after PTW
- Fixed fire protection systems are mandatory

In industries:

- Safety certificates are audited
- Fire drills conducted regularly

In commercial buildings:

- Portable extinguishers installed near electrical rooms

---

## 🔟 Summary & Q&A (≈ 5 Minutes)

### ✅ Key Takeaways:

- Safety certificates ensure:
    - Authorized work
    - Zero accidental energization
- Sequence is important:
    - Requisition → Permit → Work → Line Clear
- Electrical fires require:
    - $CO_2$ or dry powder extinguishers

### 🤔 Common Student Doubt:

**"Why is written permission needed when verbal approval is given?"**
👉 Because written records **prevent confusion, errors, and accidents**.

---

## 🎓 Mentorship Note (Career Guidance)

*In industry, safety certificates are treated as seriously as technical drawings.*

Mastering safety documentation and fire protection:

- Makes you **industry-ready**
- Builds trust as a **responsible professional**
- Prepares you for roles in **power utilities, industries, and safety audits**

🔑 **Remember:**
*Electricity respects discipline, not confidence.*

---

🎓 **Student AI Toolkit**

**Unit–5: Electrical Accidents and Safety**

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🟢 **A. Low-Level Prompts (Remember & Understand)**

*(10 Prompts – for basics, definitions, and clarity)*

1. **"Explain the meaning of electrical accident in simple terms with two examples."**
2. **"List the major causes of electrical accidents and explain each in one or two lines."**
3. **"Define electrical shock and explain why it is dangerous to the human body."**
4. **"Explain the importance of safety rules while working with electrical equipment."**
5. **"What is earthing? Explain its purpose in simple language."**
6. **"List different types of earthing methods and write one key feature of each."**
7. **"Explain what is meant by earth resistance and why it should be low."**
8. **"Define permit to work and explain why it is required before electrical maintenance."**
9. **"What is a line clear certificate? Explain its role in safety."**
10. **"Explain the types of fire extinguishers used for electrical fires in simple terms."**

---

🟡 **B. Moderate-Level Prompts (Apply & Analyze)**

*(10 Prompts – for understanding, comparison, and application)*

11. **"Compare causes of electrical accidents at domestic level and industrial level."**
12. **"Explain how severity of electrical shock changes with current, time, and body condition."**
13. **"Why is earthing more critical in substations than in domestic installations? Explain logically."**
14. **"Analyze a situation where earthing is absent. What possible accidents can occur?"**

15. **“Explain step-by-step procedure for shutting down an electrical system before maintenance.”**

16. **“Differentiate between permit to work and line clear certificate with purpose and timing.”**

17. **“Explain how proper earthing reduces the risk of fire and electric shock.”**

18. **“Given a maintenance task, explain which safety certificates are required and why.”**

19. **“Explain why water-based fire extinguishers should not be used for electrical fires.”**

20. **“Analyze the role of safety procedures in reducing electrical accidents in real workplaces.”**

---

### 🔴 C. High-Level Prompts (Design & Create)

*(5 Prompts – for exam distinction & advanced thinking)*

21. **“Design a safe workflow for electrical maintenance work, including shutdown, earthing, and certification steps.”**

22. **“Create a flowchart showing the complete safety procedure from requisition for shutdown to restoration of supply.”**

23. **“Develop a checklist for preventing electrical accidents at an industrial site.”**

24. **“Design a simple safety plan combining earthing, safety certificates, and fire protection measures.”**

25. **“Create an exam-ready answer explaining how electrical safety procedures protect both humans and equipment.”**

---

### 🌟 Mentor’s Advice

*Students who practice explaining concepts clearly using AI develop stronger understanding, confidence in exams, and better communication skills for industry.*

### ✅ Mastery Check

**Unit–5: Electrical Accidents and Safety**

## 1 Key Definitions / Glossary

*(Top 15 Important Terms – Diploma Level)*

1. **Electrical Accident** – An unexpected incident caused by electricity resulting in injury, damage, or death.
2. **Electric Shock** – Passage of electric current through the human body causing harm.
3. **Severity of Shock** – The extent of injury caused by electric shock depending on current, time, and body condition.
4. **Short Circuit** – A fault where current flows through an unintended low-resistance path.
5. **Earthing** – Connection of electrical equipment to the earth to safely discharge fault current.
6. **Earth Resistance** – Resistance offered by earth to the flow of fault current.
7. **Earth Electrode** – A conductor buried in the ground to provide an earth connection.
8. **Step Voltage** – Voltage difference between two points on the ground a step apart.
9. **Touch Voltage** – Voltage between an energized object and the ground touched by a person.
10. **Requisition for Shutdown** – A formal request to switch off electrical supply for maintenance work.
11. **Permit to Work** – Written authorization allowing safe execution of electrical work.
12. **Line Clear Certificate (LCC)** – Certificate issued after completion of work indicating the system is safe to energize.
13. **Fire Extinguisher** – A device used to control or extinguish fire.
14. **$CO_2$ Fire Extinguisher** – Fire extinguisher suitable for electrical fires without damaging equipment.
15. **Safety Procedure** – A set of rules followed to prevent electrical accidents.

## 2 FAQ & Assessment Section

**A. Multiple Choice Questions (MCQs)**

*(20 Questions – Conceptual & Application Based)*

1. Electrical accidents mainly occur due to:
   A) High voltage only
   B) Carelessness and unsafe practices
   C) New equipment
   D) Weather conditions

2. Severity of electric shock depends on:
   A) Voltage only
   B) Body weight
   C) Current magnitude and duration
   D) Wire length

3. Which factor increases severity of electric shock?
   A) Dry skin
   B) Low voltage
   C) Long contact time
   D) Rubber shoes

4. The main purpose of earthing is to:
   A) Improve efficiency
   B) Reduce power loss
   C) Protect human life
   D) Increase voltage

5. Which earthing method is commonly used in domestic installations?
   A) Plate earthing
   B) Pipe earthing
   C) Coil earthing
   D) Strip earthing

6. Low earth resistance is required to:
   A) Reduce voltage
   B) Increase current flow
   C) Safely discharge fault current
   D) Improve insulation

7. Substation earthing mainly controls:
   A) Power factor
   B) Step and touch voltages
   C) Load current
   D) Voltage regulation

8. Requisition for shutdown is issued:
   A) After completion of work
   B) During work
   C) Before starting work
   D) After fault occurrence

9. Permit to work ensures that:
   A) Equipment is energized
   B) Work is unauthorized
   C) Safety conditions are satisfied
   D) Load is increased

10. Line clear certificate is issued:
   A) Before shutdown
   B) Before earthing
   C) After work completion
   D) During maintenance

11. Which fire extinguisher is safest for electrical fires?
   A) Water type
   B) Foam type
   C) $CO_2$ type
   D) Sand

12. Water should not be used on electrical fires because it:
   A) Evaporates
   B) Conducts electricity
   C) Is expensive
   D) Is slow

13. Earth electrode is placed in:
   A) Air
   B) Concrete
   C) Ground
   D) Water tank

14. Touch voltage occurs when:
   A) Two lines touch
   B) Person touches energized equipment
   C) Earth resistance increases
   D) Current reduces

15. Step voltage exists between:
   A) Hand and foot
   B) Two points on ground

C) Two conductors
D) Phase and neutral

16. Industrial earthing generally requires:
A) Single earth pit
B) No earthing
C) Multiple earthing points
D) Temporary earthing

17. Shutdown procedures are necessary to:
A) Increase speed of work
B) Save time
C) Prevent electrical accidents
D) Improve power quality

18. Portable fire extinguishers are:
A) Fixed permanently
B) Used only outdoors
C) Easily movable
D) Automatic systems

19. Electrical fires are commonly caused by:
A) Water leakage
B) Overheating and short circuits
C) Wind
D) Dust only

20. Safety certificates are important because they:
A) Increase paperwork
B) Delay work
C) Ensure safe working conditions
D) Reduce manpower

---

**B. Short Answer / Viva Questions**

*(10 Questions – Exam & Viva Focused)*

1. Define electrical accident and state two causes.
2. List any four factors affecting severity of electrical shock.
3. Explain the necessity of earthing.
4. Why should earth resistance be kept low?

5. What is step voltage and why is it dangerous?
6. Explain the purpose of requisition for shutdown.
7. Differentiate between permit to work and line clear certificate.
8. Why is $CO_2$ extinguisher preferred for electrical fires?
9. State two advantages of proper earthing in substations.
10. Explain why safety procedures are essential in electrical work.

**Unit 5: Electrical Accidents and Safety**

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◆ **Section 1 — AI Tools & Digital Learning Tools**

| **Tool Name** | **Purpose / Use-Case** | **How it helps in learning this unit** |
|---|---|---|
| **PhET Interactive Simulations (Electricity & Circuits)** | Visualize current, voltage, resistance, and circuit faults | Students can simulate **short circuits, overloads, earthing conditions** and observe current flow, reinforcing accident-causing situations |
| **EveryCircuit / DCACLab (Virtual Circuit Simulator)** | Build and simulate electrical circuits | Helps students test **what happens when insulation fails, wrong connections, or excessive load occurs**, supporting safety awareness |
| **Google AI / ChatGPT** | Generate explanations, summaries, viva questions, check understanding | Students can ask: *"Explain electric shock," "How ELCB works?" "Safety precautions in substation"* and get step-wise learning support |
| **Electrical Symbols & Safety VR/AR Mobile Apps** | Visual and immersive learning | Visualizes **PPE, safety signs, lock-out tag-out, fire safety**, improving hazard recognition |
| **Ohm's Law & Electrical Safety Calculators** | Practice numerical problems on current, resistance, shock levels | Supports understanding of **shock severity vs current**, fuse rating selection, safe limits of touch voltage |

All tools above support **self-learning, visualization, simulation, revision, and NEP-2020 competency-based learning**.

- **Section 2 — Video Learning Repository**

| **Topic Name** | **Recommended Channel / Course / Lecturer Name** | **Search Keywords** |
|---|---|---|
| Fundamentals of Electrical Accidents | NPTEL – Basics of Electrical Engineering | **NPTEL electrical accidents causes effects** |
| Electric Shock – Causes, Effects & First Aid | Learn Engineering / NPTEL | **Electric shock causes effects first aid Learn Engineering** |
| Earthing & Grounding – Need and Types | GATE Academy / NPTEL | **Earthing grounding types purpose NPTEL** |
| Fuse, MCB, ELCB & RCCB – Protection Devices | Electrical4U / KnS Engineering | **Fuse MCB ELCB RCCB working Electrical4U** |
| Safety Precautions in Electrical Workshop | Skill India / ITI Electrical Trade | **Electrical workshop safety precautions ITI Skill India** |
| Personal Protective Equipment (PPE) in Electrical Work | OSHA / Government Training Resources | **Electrical PPE safety helmet gloves OSHA training** |
| Lockout–Tagout (LOTO) Procedure | Safety Education Channel | **Lockout tagout LOTO electrical procedure explained** |
| Fire Safety in Electrical Installations | National Safety Council India / Fire Safety Training | **Electrical fire safety causes prevention extinguisher** |
| Safe Use of Domestic Electrical Appliances | NIOS / SWAYAM | **Domestic electrical safety precautions SWAYAM NIOS** |
| Safety Signs, Symbols & Color Codes | Engineering Safety / HSE Channel | **Electrical safety signs symbols color codes explained** |

**Unit–5: Electrical Accidents and Safety (Diploma – Electrical Engineering)**
designed to match **standard Diploma examination patterns** (3-, 4- and 7-mark styles).

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🧭 **Predicted Question Bank**

**Unit–5: Electrical Accidents and Safety**

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1️⃣ **Most Repeated / High-Probability Questions**

*(Short-answer + descriptive + diagram/concept focused)*

**A. Core Definitions & Basic Concepts**

1. Define **electrical accident** and **electrical safety**.
2. Define **earthing** and **grounding** – state the difference.
3. Define **touch potential** and **step potential**.
4. Define **shock hazard**, **arc flash hazard**, and **burn hazard**.
5. Define **permit-to-work system** and state its importance.

**B. Causes & Effects**

6. List and explain **causes of electrical accidents**.
7. State **factors affecting earthing resistance**.
8. State the **effects of electric shock on the human body**.
9. Explain **external causes of fault in electrical equipment**.

**C. Safety Rules & Procedures**

10. Explain **safety rules to avoid electrical accidents** in workshops/substations.
11. Explain **procedure of shutdown for power lines/substations**.
12. Explain **permit-to-work** with steps and precautions.
13. Write **immediate actions when a person comes in contact with live part**.
14. Write **first-aid treatment for electric shock victim**.

**D. Earthing & Safety Systems (frequently asked)**

15. Explain **types of earth electrodes** with sketch.
16. List **methods of earthing** and explain any one.
17. List **methods for calculation/measurement of earthing resistance**; explain any one.
18. Explain **equipment earthing vs. system grounding** – similarities and differences.
19. Explain the **need of earthing in electrical installations**.
20. Explain **causes of increase in earthing resistance**.

**E. Protective Devices & Standards**

21. Explain working of **MCB, RCCB/ELCB** related to shock protection.
22. Explain **importance of insulation and IP rating** in accident prevention.
23. Explain **personal protective equipment (PPE)** used in electrical safety.
24. Explain **safety color codes and symbols** used in electrical installations.

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## 2️⃣ Application & Logical-Thinking Questions (5 Questions)

These test **concept application, reasoning, and real-life interpretation**—typically asked as 4–7 mark questions.

1. **A person receives an electric shock in a workshop.**
   Describe the **step-by-step immediate actions**, precautions, and first-aid procedure you will follow before medical help arrives.
2. A residential building frequently experiences **electric shocks from metal body appliances**.
   Identify **probable causes** and explain **how proper earthing and protective devices** can solve the problem.
3. A substation requires shutdown for maintenance.
   Prepare a **permit-to-work procedure**, including **isolation, tagging, earthing, and restoration** sequence.
4. In a rainy season, the **earthing resistance of an installation changes significantly**.
   Explain **why this happens**, influencing factors, and **how to improve earthing effectiveness**.

5. An operator enters a live switchyard without PPE and receives flash burns. Analyze **what safety rules were violated**, which **protective equipment** should have been used, and **preventive measures** for future.

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**Diploma – Electrical Engineering**
Subject: **Electrical Installation, Commissioning and Maintenance**

🌐 **External Exposure Module**

**Electrical Installation, Commissioning and Maintenance**

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## 1️⃣ Beyond the Syllabus – Emerging Technologies

### 🔹 1. Smart Grid & Digital Substations

**What it is:**

Modern power systems use **sensors, automation, SCADA, and IoT** to monitor and control substations in real time.

**Connection with the subject:**

- builds on concepts of **installation of switchgear, earthing, protection, commissioning tests, maintenance**
- extends them using **digital relays, remote monitoring, predictive maintenance**

**Why students should know it:**

- huge demand for **smart grid technicians & maintenance engineers**
- used in utilities, metro rail, renewable plants, and large industries
- foundation for future learning in **power automation, IIoT, AI in maintenance**

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### 🔹 2. Condition Monitoring & Predictive Maintenance

**What it is:**

Instead of repairing after failure, industries now use **thermal imaging, vibration analysis, oil testing, partial discharge monitoring, data analytics** to **predict faults in advance**.

**Connection with the subject:**

- related to your course topics:
  - **breakdown vs preventive maintenance**
  - **commissioning tests**
  - **insulating oil testing, earthing resistance, troubleshooting**

**Why students should know it:**

- improves **safety, reliability, and cost-saving**
- widely used in **solar plants, wind farms, transformers, motors, data centers**
- boosts employability in **maintenance, quality, reliability engineering**

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### 2 MOOC & Online Course Recommendations

| Course Title / Theme | Platform | How it supports this subject |
|---|---|---|
| **Electrical Installation & Safety Practices** | SWAYAM / NPTEL | Strengthens basics of **earthing, protection, wiring, safety rules, workshop practices** |
| **Power System Protection and Switchgear (Introductory level options available)** | NPTEL | Deepens understanding of **circuit breakers, relays, faults, commissioning & maintenance relevance** |
| **Electrical Preventive Maintenance – Basics of Reliability** | Coursera (audit mode available) | Connects classroom maintenance topics to **industry preventive & predictive practices** |
| **Renewable Energy Systems – Solar Plant Installation Basics** | SWAYAM / NPTEL | Links commissioning & maintenance to **modern solar installations and safety** |

Students may **audit for free**, build **certificates for CVs**, and support **lifelong learning habits**.

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### 3 Industrial Exposure / Field Visit Suggestions (Regional Focus)

Choose any **nearby** options in your state or region — industrial clusters and utility facilities are usually accessible through academic visits.

### 🏭 1. Electrical Substation (66 kV / 132 kV / 220 kV)

- **Type of work:** power transmission & distribution operation
- **Students can observe:**
  - switchgear, busbars, transformers
  - earthing systems
  - shutdown & permit-to-work procedures
  - real commissioning and maintenance practices

### 🌞 2. Solar Power Plant / Rooftop Solar Park

- **Type of work:** renewable energy generation and maintenance
- **Students can observe:**
  - inverter rooms, SCADA monitoring
  - installation practices and safety rules
  - fault diagnosis, cleaning & preventive maintenance
  - earthing & lightning protection at solar yards

### 🏭 3. Electrical Equipment Service Workshop

(Motor rewinding shops, panel manufacturing units, contractor workshops, MSME repair centers)

- **Type of work:** installation, testing, repairing, commissioning
- **Students can observe:**
  - winding drying, insulation testing
  - troubleshooting of motors and appliances
  - practical maintenance scheduling and documentation

These visits build **employability skills**—teamwork, communication, documentation, and safety culture.

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## 4️⃣ Conferences, Seminars & Technical Events

| **Event / Organization** | **Theme / Area** | **Why it is useful for students** |
|---|---|---|
| **IEEE PES (Power & Energy Society) Conferences / Webinars** | smart grid, protection, power systems, maintenance | exposure to **latest industry trends, expert talks, networking** |
| **IEI (Institution of Engineers India) State/Local Seminars** | electrical safety, installation practices, industry standards | improves **professionalism, ethics, and real-world awareness** |
| **National Safety Council Events** | electrical safety & occupational safety | builds strong **safety awareness** essential for site jobs |
| **Renewable Energy Expo / Solar Tech Conferences** | solar installation, commissioning, O&M | connects skills to **green jobs & future careers** |