

AI CONTENT FOR

Commissioning & Maintenance of Electrical Equipments

Diploma Engineering - Electrical
Subject Code: DI04009031
Semester: 4



Directorate of Technical Education
Gujarat

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UNIT-1 STUDY PLAN

Electrical Safety and Insulating Material

Total Teaching Hours: 7 Hours

Theory Weightage: 14%

Mapped Course Outcome: CO-1

Bloom's Level Focus: Remember (R), Understand (U), Apply (A)

Logical Pedagogical Flow

Why this sequence?

Students first learn “why safety matters”, then “how insulation protects systems”, and finally “how to test and maintain insulation in real practice.”

Concept Progression:

1. Safety awareness →
2. Workplace safety practices →
3. Insulation fundamentals →
4. Testing techniques →
5. Maintenance & real-life degradation →
6. Application with insulating oil

Topic-wise Detailed Study Plan (Tabular Format)

Sr. No.	Syllabus Topic (As per GTU)	Nature of Topic	Key Learning Focus (Diploma Level)	Suggested Teaching Hours	Exam Importance	Practical / Industry Relevance
1.1	Do's and Don'ts Regarding Safety in Substation / Power Station Operators	Core	Electrical hazards, human errors, safe working habits, PPE, signage, LOTO concept	1.0 hr	★★★★☆	★★★★★ (Direct field relevance)
1.2	Electrical Safety in Industry / Power Stations / Substations during Operation, Control & Maintenance	Core + Application	Live-line dangers, isolation procedures, earthing, permit-to-work, maintenance safety	1.0 hr	★★★★☆	★★★★★
1.3	Factors Affecting Life of Insulating Materials & Classification as per Indian Standards	Core Theory	Thermal, electrical, mechanical & environmental stresses; IS classification (Class A, B, F, H)	1.0 hr	★★★★☆	★★★★☆
1.4	Measuring Insulation Resistance by	Core + Application	Concept, test procedure,	1.5 hr	★★★★★	★★★★★

Sr. No.	Syllabus Topic (As per GTU)	Nature of Topic	Key Learning Focus (Diploma Level)	Suggested Teaching Hours	Exam Importance	Practical / Industry Relevance
	Methods: (i) Polarization Index (ii) Dielectric Absorption (iii) Megger		interpretation of readings, safety during testing			
1.5	Reconditioning of Insulation – Drying Out Procedures	Supporting + Application	Moisture removal, heating methods, transformer & motor insulation drying	1.0 hr	★★★★☆	★★★★☆
1.6	Insulating Oil – Properties & Causes of Deterioration	Core + Application	Dielectric strength, viscosity, flash point, moisture & oxidation effects	1.5 hr	★★★★★	★★★★★

Total = 7 Hours

Topic Classification Summary

● Core Topics (Must-Master)

- 1.1 Safety Do's & Don'ts
- 1.2 Electrical Safety Practices
- 1.3 Insulating Material Classification
- 1.4 Insulation Resistance Measurement
- 1.6 Insulating Oil Properties

→ High exam weight + essential for field engineers

● Supporting Topics (Concept Reinforcement)

- 1.5 Reconditioning & Drying of Insulation

→ Strengthens understanding of insulation life-cycle

● Application-Oriented Topics (Skill Development)

- 1.2 Workplace safety during operation & maintenance
- 1.4 IR, PI, DAR testing
- 1.6 Insulating oil deterioration & testing awareness

→ Directly linked with laboratory experiments and industrial practice

OBE Alignment (Outcome Mapping)

Course Outcome	Unit-1 Contribution
CO-1: Follow safety procedures with respect to earthing and insulating material	Strongly addressed through Topics 1.1–1.6

Course Outcome	Unit-1 Contribution
Employability Skills	Safety compliance, testing skills, preventive mindset
NEP-2020 Focus	Experiential learning, safety culture, industry readiness

Exam Preparation Guidance for Students

- Draw neat safety posters for Do's & Don'ts
 - Practice numerical-free explanation answers (testing procedures)
 - Remember: Safety + Insulation = Repeated exam questions
-

Mentor's Guidance (Career Angle)

Good engineers know machines. Great engineers protect lives first.

Mastering Unit-1 makes you industry-ready from Day-1, especially for roles in:

- Substations & power plants
- Maintenance departments
- Testing & commissioning teams
- Safety-compliance environments

This unit is not just for exams—it defines your professional attitude.

Topic-1.1: Do's and Don'ts Regarding Safety in Substation / Power Station Operators

Introduction (5 minutes)

Let start with a simple but serious question:

👉 *Is electricity dangerous—or is unsafe handling dangerous?*

Electricity itself follows rules. Accidents happen when humans break safety rules. Most electrical accidents in substations and power stations are not due to equipment failure, but due to ignoring basic Do's and Don'ts.

As future Diploma Engineers, many of you will work near live panels, transformers, circuit breakers, and busbars. This lecture is not just for exams—it is about coming back home safely every day.

Core Concepts (≈ 40 minutes)

Why Safety Rules Are Critical

- Do's and Don'ts Regarding Safety in Substation/ Power Station Operators.
Electricity itself follows rules. Accidents happen when humans break safety rules.

Most electrical accidents in substations and power stations are not due to equipment failure, but due to ignoring basic Do's and Don'ts.

- Substations and power stations handle high voltage, high current, and stored energy.

A small mistake can lead to:

- Electric shock
- Arc flash
- Fire or explosion
- Damage to costly equipment

- **Do's for Substation / Power Station Operators:**

1. Do wear proper PPE (Personal Protective Equipment)
 - Helmet, insulated gloves, safety shoes, goggles, and arc-flash suit where required.
2. Do ensure proper earthing before starting work
 - Always discharge and earth equipment before touching.
3. Do follow Lockout–Tagout (LOTO) procedures
 - Isolate supply, lock the switch, and place warning tags.
4. Do use insulated tools and tested instruments
 - Never use damaged cables, test leads, or tools.
5. Do maintain safe distance from live parts
 - Follow minimum approach distances as per voltage level.
6. Do display safety signboards and danger notices
 - “Men at Work”, “Danger – High Voltage” boards save lives.
7. Do work with proper authorization and permit
 - Never work on equipment without clearance.

- **Don'ts for Substation / Power Station Operators:**

1. **Don't touch live equipment without isolation**
 - Even low voltage can be fatal under certain conditions.
2. **Don't work alone in high-risk areas**
 - Always ensure supervision or standby support.
3. **Don't bypass interlocks or protection systems**
 - Interlocks are safety guards, not obstacles.
4. **Don't use wet hands or stand on wet surfaces**
 - Moisture reduces body resistance and increases shock risk.
5. **Don't wear loose clothes, metal chains, or rings**
 - They can cause short circuits or arc faults.

6. Don't ignore abnormal sounds, smell, or heating

– These are early warning signs of faults.

- **Simple Analogy**
- Think of a substation like a **wild animal enclosure**.
- If rules are followed → safe observation.
- If rules are ignored → serious injury.

Real-World / Industry Applications (≈ 10 minutes)

- In 132 kV / 220 kV substations, operators strictly follow LOTO before maintenance.
- During breaker maintenance, earthing rods are applied on both sides.
- Safety audits in industries often fail due to missing PPE or poor tagging.
- Accident investigation reports show that 90% accidents are preventable by following basic Do's and Don'ts.

Many companies today reject candidates who lack safety awareness—even if their technical knowledge is good.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Safety rules protect life, equipment, and career
- Follow Do's before starting work
- Avoid Don'ts at all costs
- Never compromise safety for speed

Common Student Doubts

- *Is PPE compulsory for small jobs?* → Yes
- *Can interlocks be bypassed temporarily?* → Never
- *Is safety asked in exams?* → Frequently

Mentorship Note

A skilled engineer may get a job, but a safe engineer keeps the job.

If you master electrical safety early:

- You gain industry trust
- You reduce accident risk
- You become eligible for site, maintenance, and commissioning roles

Remember:

⚡ *Electricity can be controlled only by those who respect it.*

Topic-1.2: Electrical Safety in Industry / Power Stations / Substations at the Time of Operation, Control & Maintenance

Introduction (≈ 5 minutes)

Let start with a simple but serious question:

“Why do most electrical accidents happen to trained staff and not beginners?”

The answer is overconfidence and casual approach during operation or maintenance.

Electrical systems in industries, power stations, and substations operate at high voltage, high current, and high fault levels. Even a small mistake—like operating a breaker without checking interlocks—can lead to fatal accidents or major equipment damage.

As future Diploma Engineers, many of you will operate panels, control equipment, and perform maintenance activities. Therefore, understanding electrical safety during operation, control, and maintenance is not optional—it is professional survival skill.

Core Concepts (≈ 40 minutes)

A. Electrical Safety During Operation

Operation means normal running of equipment such as switching ON/OFF, load control, and monitoring parameters.

Key safety practices:

- Always follow operating procedures and SOPs
- Verify correct sequence of switching
- Never operate equipment with wet hands or wet floor
- Maintain safe distance from live parts
- Monitor abnormal sound, smell, temperature, or vibration

Analogy:

Operating electrical equipment is like driving a vehicle—rules and discipline prevent accidents.

B. Electrical Safety During Control Activities

Control involves relay panels, SCADA, control switches, and indication lamps.

Safety rules:

- Confirm correct control voltage
- Avoid loose control wiring
- Never bypass protective relays
- Check status indications before operation
- Ensure control circuits are properly earthed

Fun Fact:

Most large blackouts occur due to control circuit errors, not power equipment failure.

C. Electrical Safety During Maintenance

Maintenance is the most dangerous phase because equipment may appear dead but still be live.

Mandatory safety steps:

1. Isolation – Disconnect supply from all sources
2. Lockout & Tagout (LOTO) – Prevent accidental re-energization
3. Earthing & Discharging – Remove stored charge
4. Testing for Dead – Use tester before touching
5. Use PPE – Gloves, helmet, shoes, arc-flash suit

Never assume equipment is safe until personally verified.

D. Common Unsafe Practices to Avoid

- Working without shutdown permission
- Ignoring earthing
- Using damaged tools
- Wearing metal accessories
- Rushing maintenance work

E. Visuals to Draw / Show in Class

Students should draw or search:

- Flowchart of **Safe Maintenance Procedure**
- Diagram of **Lockout–Tagout system**
- PPE kit layout for substation staff
- Control panel with safety labeling

Real-World / Industry Applications (≈ 10 minutes)

- In power stations, turbine and generator maintenance strictly follows isolation and earthing procedures
- In substations, breaker operation is permitted only after relay confirmation
- In industries, electrical maintenance permits are issued before work
- Safety audits ensure compliance with IS standards and safety codes

Many industries reject fresh engineers not because of lack of knowledge, but due to unsafe working attitude.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Electrical safety is critical during operation, control, and maintenance
- ✓ Isolation, earthing, and PPE are non-negotiable
- ✓ Most accidents are due to human error
- ✓ Safety procedures protect life, equipment, and career

Typical Student Doubts

Q: Is PPE necessary for low-voltage work?

A: Yes. Even LT systems can cause serious injury.

Q: Why test equipment after shutdown?

A: To ensure there is no back-feed or stored charge.

Mentorship Note (Career-Oriented)

Students who practice safety discipline are preferred in:

- Power utilities
- Industrial maintenance
- Electrical contracting
- Government and PSU jobs

A skilled engineer repairs machines.

A safe engineer protects lives.

Mastering electrical safety early will make you trusted, employable, and respected in your engineering career.

Topic-1.3: Factors Affecting Life of Insulating Materials & Classification of Insulating Materials as per Indian Standards

Introduction (≈ 5 minutes)

Let me begin with a practical question:

Why does a transformer or motor fail even when copper windings are still intact?

In most cases, the answer is insulation failure, not conductor failure.

Insulating material is like the skin of electrical equipment—once it weakens, the equipment becomes unsafe and unreliable.

As Diploma engineers, understanding what reduces insulation life and how insulation is classified as per Indian Standards is essential for safe operation, maintenance, and exam success.

Core Concepts (≈ 40 minutes)

A. Importance of Insulating Materials

Insulating materials:

- Prevent current leakage
- Withstand voltage stress
- Provide mechanical support
- Ensure safety of human life and equipment

Examples: paper, enamel, varnish, rubber, mica, oil, epoxy.

B. Factors Affecting Life of Insulating Materials

1. Thermal Stress (Temperature)

- High temperature is the biggest enemy of insulation
- Every 10°C rise roughly halves insulation life
- Caused by overloading, poor cooling

2. Electrical Stress

- Over-voltage, switching surges, partial discharge
- Leads to cracking and breakdown of insulation

3. Mechanical Stress

- Vibration, shock, bending
- Common in rotating machines and cables

4. Moisture and Humidity

- Moisture reduces insulation resistance
- Causes tracking and corrosion

5. Chemical Effects

- Oil oxidation, acids, fumes, pollution
- Deteriorates insulation gradually

6. Aging

- Natural degradation over time
- Accelerated by heat and moisture

Simple analogy:

Insulation is like rubber on a tyre—heat, load, water, and age decide its life.

C. Classification of Insulating Materials as per Indian Standards (IS)

As per IS 1271, insulating materials are classified based on maximum permissible temperature.

Class	Max Temperature (°C)	Typical Materials
Class Y	90°C	Cotton, silk, paper
Class A	105°C	Paper, cotton with impregnation
Class E	120°C	Synthetic enamel
Class B	130°C	Mica, glass fiber
Class F	155°C	Epoxy resins
Class H	180°C	Silicone, mica
Class C	>180°C	Ceramic, glass, quartz

Higher class → Higher cost but longer life and better safety.

D. Why Classification is Important

- Helps in selecting correct insulation
- Prevents overheating and premature failure
- Mandatory for design, installation, and maintenance
- Frequently asked in GTU exams

E. Visuals to Draw / Show

Students should draw or search:

- Graph showing temperature vs insulation life
- Table of insulation classes
- Cross-section of motor winding showing insulation layers

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

- Motors in industries use Class F or H insulation for higher reliability
- Transformers use oil + paper insulation carefully matched to temperature class
- Cables in humid areas require moisture-resistant insulation
- Maintenance engineers monitor temperature rise to protect insulation life

Wrong insulation selection can cause early failure, fire, and financial loss.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Insulation life decides equipment life
- ✓ Heat is the most dangerous factor
- ✓ IS classification helps safe design and operation
- ✓ Higher insulation class = better performance

Common Student Questions

Q: Which factor affects insulation most?

👉 Temperature

Q: Which insulation class is most commonly used today?

👉 Class F and Class H

📌 Mentorship Note (Career-Oriented)

Good engineers fix faults.

Smart engineers prevent insulation failure.

Understanding insulation behavior helps you:

- Diagnose faults faster
- Improve equipment reliability
- Become valuable in maintenance, testing, and commissioning jobs

Topic 1.4: Measuring Insulation Resistance by Different Methods (Polarization Method, Dielectric Absorption Method, Megger Method)

1. Hook / Introduction (≈ 5 minutes)

Imagine you have purchased a brand-new electric motor for an industry. It looks perfect from outside, windings are shiny, terminals are tight, and nameplate ratings match the supply. You switch it ON—and suddenly the fuse blows ⚡.

What went wrong?

In most such cases, the problem is hidden insulation failure—something we cannot see with naked eyes. Electrical insulation may look fine, but internally it could be moist, aged, cracked, or contaminated.

☞ This is why measuring insulation resistance (IR) is one of the most important safety tests in electrical engineering.

Before commissioning transformers, motors, cables, panels, or even domestic wiring, engineers always test insulation resistance.

Today's lecture will help you understand:

- What insulation resistance really means
- Why it changes with time
- How different methods like Polarization, Dielectric Absorption, and Megger testing are used in practice

Think of insulation like the skin of a wire—if it weakens, current leaks, causing shock, fire, or equipment damage.

2. Core Concepts (≈ 40 minutes)

2.1 What is Insulation Resistance?

Insulation Resistance (IR) is the resistance offered by insulating material against the flow of leakage current from conductor to earth or between conductors.

- Unit: Mega Ohms (MΩ)
- Higher IR value = better insulation
- Lower IR value = poor insulation

Why insulation resistance reduces?

- Moisture absorption
- Aging of insulation
- Dust, oil, chemicals
- Mechanical damage
- Overheating

2.2 Leakage Current in Insulation – Important Concept

When DC voltage is applied across insulation, three currents flow:

1. Capacitive Current – flows initially, reduces quickly
2. Absorption Current – decreases slowly with time
3. Leakage Current – remains constant

Good insulation shows decreasing current with time, while poor insulation shows nearly constant current.

This time-dependent behavior forms the basis of Polarization and Dielectric Absorption methods.

I) Polarization Method (Polarization Index – PI Method)

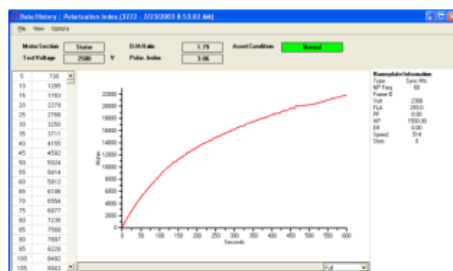


Figure 1. IRP of a Healthy Insulation System

Concept

The Polarization Index (PI) method evaluates insulation quality by observing how insulation resistance changes with time after applying DC voltage.

Definition

$$\text{Polarization Index (PI)} = \frac{\text{IR at 10 minutes}}{\text{IR at 1 minute}}$$

Procedure

1. Disconnect equipment from supply
2. Apply DC voltage using a Megger
3. Note insulation resistance at:
 - o 1 minute
 - o 10 minutes
4. Calculate PI ratio

Interpretation

PI Value Insulation Condition

- < 1 Dangerous
- 1 – 2 Poor
- 2 – 4 Good
- > 4 Excellent

Explanation in Simple Words

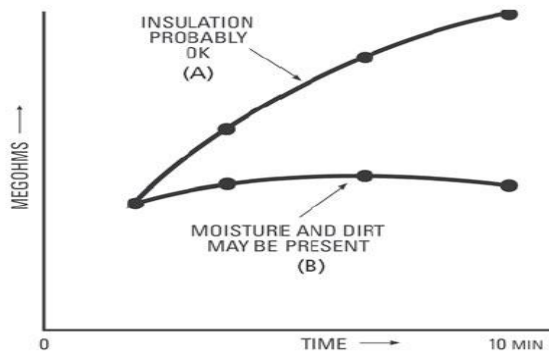
Good insulation “polarizes slowly”—molecules align gradually, causing IR to increase with time.

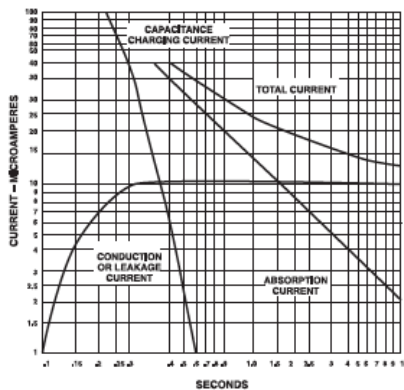
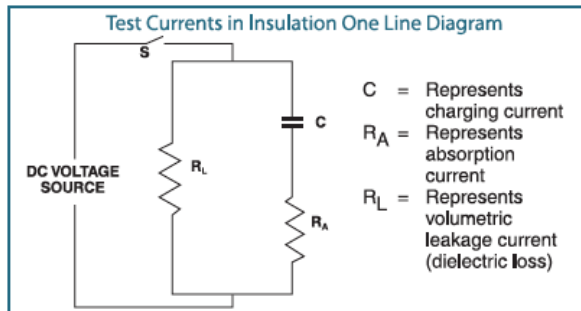
Bad insulation absorbs moisture, so IR does not increase much.

Diagram to Draw

- X-axis: Time (minutes)
- Y-axis: Insulation Resistance (MΩ)
- Curve rising steeply for good insulation

II) Dielectric Absorption Method (DAR Method)





Concept

Dielectric Absorption Ratio (DAR) measures insulation condition by comparing IR values at short time intervals.

Definition

$$DAR = \frac{\{IR \text{ at } 60 \text{ seconds}\}}{\{IR \text{ at } 30 \text{ seconds}\}}$$

Why this method?

- Faster than PI method
- Useful for small motors and low-voltage equipment
- Suitable where long testing time is not possible

Interpretation

DAR Value Condition

- < 1.25 Poor
- 1.25 – 1.6 Acceptable
- > 1.6 Good

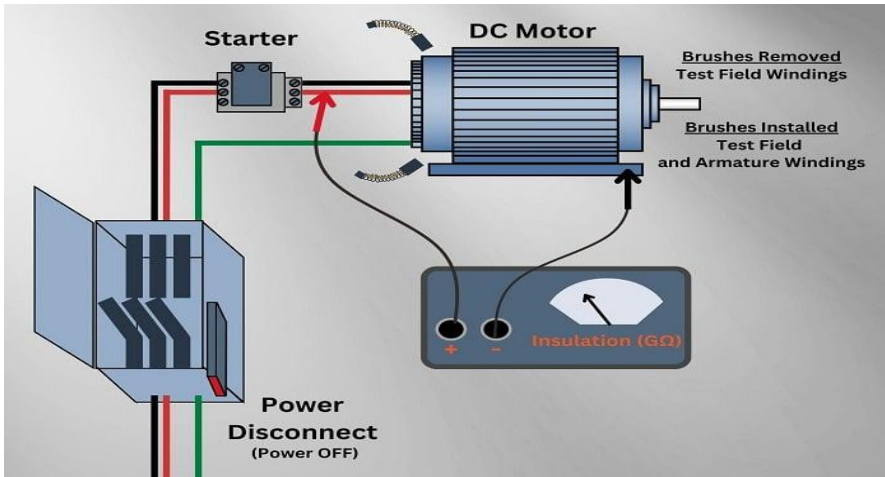
Key Difference from PI

Parameter	PI Method	DAR Method
Time	Long (10 min)	Short (1 min)
Accuracy	Higher	Moderate
Application	Large machines	Small machines

Visual Representation

- Graph of IR vs time
- Slowly rising curve indicates good insulation

III) Megger Method (Direct Insulation Resistance Test)



What is a Megger?
 A Megger is a portable instrument used to measure high resistance values (in mega ohms).
 It consists of:

- DC voltage generator
- Measuring coil
- Deflecting pointer (analog) or digital display

Types of Megger

- Hand-driven Megger
- Electronic / Digital Megger

Test Voltage Levels

Equipment	Test Voltage
Domestic wiring	500 V
Motors & LT panels	1000 V
HV equipment	2500 – 5000 V

Procedure

1. Isolate equipment from supply
2. Discharge capacitors
3. Connect:
 - Line terminal → Conductor
 - Earth terminal → Body / Ground
4. Apply voltage
5. Read insulation resistance

Acceptance Rule (General Rule)

$$[\text{IR} \geq (1 \text{ M}\Omega \text{ per kV}) + 1 \text{ M}\Omega]$$

Advantages

- Simple and fast
- Portable
- Widely used in field

Limitation

- Gives only instant IR value, not aging trend

3. Real-World / Industry Applications (\approx 10 minutes)

1. Power Plants

- PI test on generators before synchronization
- Prevents catastrophic insulation failure

2. Electrical Maintenance

- Megger testing during preventive maintenance
- Detects moisture ingress in motors

3. Cable Testing

- IR testing before cable laying and after jointing

4. Transformers

- Dielectric absorption test to assess oil-paper insulation health

5. Safety Compliance

- Mandatory test before issuing Electrical Safety Certificate

💡 Fun Fact:

Many electrical fires are caused not by overload—but by slow insulation deterioration detected early by IR tests.

4. Summary & Q&A (\approx 5 minutes)

Key Takeaways

- Insulation resistance indicates health of insulation
- Polarization Index shows long-term insulation quality
- Dielectric Absorption Ratio offers quick assessment
- Megger is the most commonly used instrument
- Higher IR value always means safer equipment

Typical Student Doubts

Q1: Why DC voltage is used instead of AC?

DC gives steady readings and avoids capacitive reactance.

Q2: Can Megger damage insulation?

No, if correct voltage rating is used.

Q3: Why IR decreases in rainy season?

Moisture absorption reduces insulation resistance.

Mentorship Note – Career & Future Scope

Mastering insulation resistance testing gives you a strong foundation in electrical safety, which is critical for:

- Maintenance Engineer
- Testing & Commissioning Engineer
- Power Plant Operator
- Electrical Inspector roles

Remember:

A good engineer does not wait for failure—he predicts and prevents it. Insulation testing is one of the first tools that teaches you this mindset.

Topic 1.5: Reconditioning of Insulation – Drying Out Procedures

Hook / Introduction (≈ 5 minutes)

Imagine buying a brand-new mobile phone and accidentally dropping it in water.

Even if it looks fine outside, internal moisture can slowly damage it.

Electrical insulation behaves in a very similar way.

Moisture is one of the biggest enemies of electrical insulation. A transformer, motor, or cable that has absorbed moisture may fail suddenly—even if its insulation resistance appears normal at first glance.

So today's question is:

“Instead of replacing expensive insulation, can we restore it safely?”

The answer is YES, using reconditioning and drying-out procedures.

Core Concepts (≈ 40 minutes)

2.1 What is Reconditioning of Insulation?

Reconditioning means restoring the dielectric strength and insulation resistance of electrical insulation that has deteriorated due to:

- Moisture absorption
- Aging
- Long storage
- Environmental conditions (humidity, dust)

👉 Drying-out is the most common and economical reconditioning method.

2.2 Why Drying Out is Required

Moisture inside insulation causes:

- Low insulation resistance (IR)
- Leakage current increase
- Partial discharge
- Heating and eventual breakdown

Important fact:

Even a small amount of moisture drastically reduces insulation life.

2.3 Indications That Drying Out is Needed

Drying out is required when:

- Insulation resistance is below standard limits
 - Polarization Index (PI) is less than 1
 - Equipment stored unused for long duration
 - After flooding or damp conditions
 - Before commissioning old or repaired equipment
-

2.4 Common Drying Out Methods

1 Hot Air Drying Method

- Heated air is circulated around windings
- Moisture evaporates gradually

Used for: Small motors, panels

Advantage: Simple and safe

Limitation: Slow process

2 Short Circuit (Current Heating) Method

- Low voltage is applied to circulate current
- Windings heat up internally

Used for: Transformers

Advantage: Uniform heating

Precaution: Strict temperature monitoring required

3 Infrared Lamp Drying

- Infrared lamps focus heat on insulation surfaces

Used for: Motors and coils

Advantage: Portable and controlled

Limitation: Surface heating mainly

4 Vacuum Drying Method

- Moisture removed under vacuum condition

- Often combined with heating

Used for: Power transformers

Advantage: Most effective

Limitation: Costly equipment

2.5 Drying Procedure (Step-by-Step)

1. Disconnect equipment completely
 2. Measure initial insulation resistance
 3. Apply selected drying method gradually
 4. Monitor:
 - Temperature
 - IR value
 - Leakage current
 5. Stop drying when:
 - IR stabilizes
 - PI improves
 6. Allow equipment to cool naturally
 7. Final IR test before energization
-

2.6 Safety Precautions During Drying

- Avoid overheating insulation
 - Maintain uniform temperature rise
 - Ensure proper earthing
 - Never apply rated voltage during drying
 - Keep fire safety equipment ready
-

Real-World / Industry Applications (≈ 10 minutes)

In power stations and substations, drying-out is commonly used:

- Before commissioning transformers after long shutdown
- During annual maintenance of motors
- After oil filtration in transformers
- For generators exposed to humidity

Fun Industry Fact:

Drying-out can increase transformer life by 5–10 years if done correctly.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Moisture severely damages insulation
- Drying-out restores insulation strength

- Multiple drying methods exist for different equipment
- Proper monitoring is critical
- Drying-out is economical compared to replacement

Typical Student Doubts

- ? Can insulation be dried multiple times? → Yes, within limits
- ? Is drying mandatory before commissioning? → If IR is low, yes
- ? Which method is best? → Depends on equipment size and condition

Mentorship Note (Career Guidance)

Mastering insulation reconditioning and drying procedures makes you valuable in:

- Power plants
- Electrical maintenance teams
- Commissioning agencies
- Utility companies

💡 Diploma engineers who understand drying-out methods are trusted with high-value equipment. This knowledge directly improves job safety, responsibility, and promotion opportunities. Good engineers don't just repair faults — they prevent failures.

Topic 1.6: Insulating Oil – Properties of Insulating Oil & Causes of Deterioration of Oil

Hook / Introduction (≈ 5 minutes)

Why do large power transformers not use air like overhead lines, but instead use oil inside the tank?

The answer is insulating oil—one of the most critical yet often underestimated materials in electrical engineering. A transformer may have the best design and strongest windings, but if its oil fails, the entire transformer is at risk. In fact, many catastrophic transformer failures are traced back not to copper or iron, but to poor oil condition.

Think of insulating oil as the blood of a transformer. Just like human blood carries oxygen and controls body temperature, insulating oil provides electrical insulation, cooling, and protection.

Today's lecture will help you understand:

- What insulating oil is,
- What properties make it suitable for electrical equipment, and
- Why and how insulating oil deteriorates with time.

2. Core Concepts (≈ 40 minutes)

2.1 What is Insulating Oil?

Insulating oil is a refined mineral oil specially processed for use in electrical equipment such as:

- Power and distribution transformers
- Oil circuit breakers
- Bushings and tap changers
- High-voltage switchgear

Main functions of insulating oil:

1. Electrical insulation between live parts and earth
2. Heat dissipation from windings and core
3. Protection against oxidation and moisture
4. Extinguishing electric arcs (in oil circuit breakers)

2.2 Why Oil is Preferred Over Air or Solid Insulation

Medium	Limitation
Air	Low dielectric strength, moisture sensitive
Solid insulation	Poor cooling, difficult to replace
Oil	High dielectric strength + excellent cooling

👉 *Fun Fact:* Transformer oil has dielectric strength nearly 8–10 times higher than air.

2.3 Properties of Insulating Oil

For oil to perform reliably, it must satisfy several electrical, physical, chemical, and thermal properties.

A. Electrical Properties of Insulating Oil

1) Dielectric Strength (Breakdown Voltage – BDV)

Definition:

The maximum voltage that oil can withstand without electrical breakdown.

Importance:

- Indicates oil's ability to act as an insulator
- Low BDV means presence of moisture, dirt, or gas bubbles

Typical value:

- New oil: ≥ 60 kV (2.5 mm gap)

Diagram to draw:

BDV test set with electrodes immersed in oil.

2) Insulation Resistance

Good oil offers high resistance to leakage current.

- Low resistance \rightarrow contaminated oil

B. Physical Properties of Insulating Oil

1) Viscosity

Definition:

Resistance offered by oil to flow.

Importance:

- Low viscosity \rightarrow better cooling
- High viscosity \rightarrow poor heat transfer

👉 Oil must flow freely through transformer ducts.

2) Flash Point & Fire Point

- Flash point: Lowest temperature at which oil vapours ignite momentarily
- Fire point: Temperature at which oil continues to burn

Importance:

- Indicates fire safety
- Higher values = safer operation

Typical values:

- Flash point: $> 140^\circ\text{C}$
- Fire point: $> 160^\circ\text{C}$

3) Pour Point

Definition:

Lowest temperature at which oil can still flow.

Importance:

- Important for transformers installed in cold regions

C. Chemical Properties of Insulating Oil

1) Acidity (Neutralization Number)

Acidity indicates the amount of acid present in oil.

Effects of high acidity:

- Corrosion of metal parts
- Degradation of paper insulation
- Sludge formation

2) Oxidation Stability

Good oil should resist oxidation when exposed to:

- Oxygen
- Heat
- Metal catalysts (copper, iron)

Poor oxidation stability leads to sludge formation.

D. Thermal Properties

Insulating oil must:

- Withstand high operating temperatures
- Maintain stability over long duration
- Not form excessive gases under heat

2.4 Summary Table – Desired Properties of Insulating Oil

Property	Requirement
Dielectric strength	High
Moisture content	Very low
Viscosity	Low
Acidity	Minimal
Flash & fire point	High
Oxidation stability	Excellent

2.5 Causes of Deterioration of Insulating Oil

Despite good initial quality, insulating oil deteriorates with time due to various internal and external factors.

1) Moisture Contamination

Sources of moisture:

- Breathing of transformer
- Leaky gaskets
- Improper storage
- Wet insulation paper

Effects:

- Sharp reduction in BDV

- Increased dielectric loss
- Accelerated ageing

Even 0.01% moisture can reduce dielectric strength drastically.

2) Oxidation

Process:

Oil reacts with oxygen in presence of heat and metal catalysts.

Results:

- Acid formation
- Sludge formation
- Darkening of oil

Diagram to draw:

Oxidation cycle showing oil → acid → sludge.

3) High Operating Temperature

Continuous overloading causes:

- Thermal breakdown of oil
 - Formation of combustible gases
 - Faster ageing of insulation
-

4) Solid Contaminants

Includes:

- Dust particles
- Fibres from insulation paper
- Metal particles

Effects:

- Reduced dielectric strength
 - Partial discharge initiation
-

5) Electrical Stress & Arcing

Arcing causes:

- Carbon particles in oil
- Gas formation
- Localized overheating

This is common in:

- Tap changers
 - Oil circuit breakers
-

6) Sludge Formation

Sludge is a sticky by-product formed due to oxidation.

Problems caused by sludge:

- Blocks cooling ducts
 - Reduces heat dissipation
 - Increases winding temperature
-

2.6 Effects of Deteriorated Oil on Equipment

Poor oil condition results in:

- Transformer overheating
- Reduced insulation life
- Frequent tripping
- Risk of explosion and fire

- Costly breakdowns

Most transformer failures are progressive, not sudden.

2.7 Preventive Measures to Reduce Oil Deterioration

- Regular oil testing (BDV, acidity, moisture)
- Use of silica gel breathers
- Oil filtration and dehydration
- Avoid overloading
- Periodic oil replacement or regeneration

3. Real-World / Industry Applications (\approx 10 minutes)

In Power Transformers

- Oil quality determines transformer life
- Online oil monitoring systems used in EHV transformers

In Substations

- Routine oil sampling is mandatory
- Oil condition decides maintenance schedule

In Industries

- Transformer oil testing prevents production loss
- Oil regeneration saves replacement cost

In Circuit Breakers

- Oil quality ensures effective arc quenching

In modern utilities, oil analysis is considered “preventive medicine” for transformers.

4. Summary & Q&A (\approx 5 minutes)

Key Takeaways

- ✓ Insulating oil acts as both insulator and coolant
- ✓ High dielectric strength and low moisture are critical
- ✓ Oil deteriorates mainly due to moisture, heat, and oxidation
- ✓ Regular testing and maintenance extend equipment life
- ✓ Oil condition directly affects system reliability

Typical Student Doubts

Q1. Can oil be reused after deterioration?

Yes, after filtration or regeneration.

Q2. Why is oil darker after long service?

Due to oxidation and sludge formation.

Q3. Is oil replacement always required?

No, condition-based maintenance is preferred.

Mentorship Note (Career-Oriented Tip)

A strong understanding of insulating oil is a core skill for maintenance, commissioning, and testing engineers. Knowledge of oil properties and deterioration helps you excel in:

- Transformer maintenance jobs
- Power utilities and substations
- Testing & commissioning companies
- Renewable energy plants
- Government and private utilities

Engineers who understand oil health understand transformer health.

Master this topic well—it directly connects theory, laboratory testing, and real-world engineering

decisions.

Student AI Toolkit – Unit 1: Electrical Safety and Insulating Material

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

(Use these to build strong fundamentals and revise before exams)

1. “Explain this topic in very simple language as if teaching a first-year diploma student. Use short points and examples.”
 2. “Give clear definitions of all key terms from this unit and explain why each term is important in practice.”
 3. “Summarize this topic in maximum 10 bullet points suitable for last-day exam revision.”
 4. “Explain the concept step-by-step and highlight common mistakes students make in exams.”
 5. “Create a simple table comparing related terms or ideas from this unit.”
 6. “Explain this topic using a real-life daily example so it becomes easy to remember.”
 7. “List all important keywords from this topic that are likely to appear in diploma examinations.”
 8. “Convert this topic into short question–answer format for quick oral revision.”
 9. “Explain this concept assuming I have weak basics and need clarity from zero level.”
 10. “Give a 5-minute reading note version of this topic for fast learning.”
-

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

(Use these to score well in descriptive and application-based questions)

11. “Explain how this concept is applied in real electrical systems with practical examples.”
 12. “Compare two related concepts from this unit using a table and practical viewpoint.”
 13. “Analyze what problems can occur if this concept is ignored during operation or maintenance.”
 14. “Give a typical exam-oriented answer (6–8 marks) for this topic with proper structure.”
 15. “Explain cause-and-effect relationships involved in this topic using a flowchart description.”
 16. “Create 5 application-based questions from this topic along with brief answers.”
 17. “Explain how this topic connects with safety, reliability, and maintenance of equipment.”
 18. “Describe a real-world failure scenario related to this topic and explain how it could be prevented.”
 19. “Differentiate theoretical knowledge vs practical field understanding of this topic.”
 20. “Explain how this topic is tested in laboratory experiments or practical exams.”
-

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

(Use these for distinction, interviews, and advanced understanding)

21. “Design a logical step-by-step procedure related to this topic suitable for a diploma engineer.”

22. "Create a decision-making checklist based on this topic for safe operation or maintenance."
23. "Develop a simple inspection or testing workflow using this concept and explain each step."
24. "Convert this topic into a neat flowchart or block diagram description for exam diagrams."
25. "Create a short case study from this topic and explain the problem, cause, and solution clearly."

✔ How Students Should Use This Toolkit

- Use A-level prompts for concept clarity & memory
- Use B-level prompts for exam answers & applications
- Use C-level prompts for top ranks, viva, and interviews

🌱 Assurance as a Learning Coach

If students master these prompts, they will not just *remember Unit-1* — they will understand, apply, and confidently explain it, exactly what GTU diploma exams and industry expect.

If you want, I can next:

- Convert these into a printable student handout
- Map prompts topic-wise (1.1 to 1.6)
- Create a Unit-1 AI study schedule for 7 days

Just tell me 🙌

Below is a complete, exam-ready "Mastery Check" section for Unit 1: Electrical Safety and Insulating Material, designed from the perspective of a Diploma examiner and

✔ **MASTERY CHECK – Unit 1: Electrical Safety and Insulating Material**

1. Key Definitions / Glossary (15 Important Terms)

(Frequently used in exams, viva, and practical sessions)

1. Electrical Safety – Practices followed to prevent injury, fire, and equipment damage due to electricity.
2. Insulating Material – Material that resists the flow of electric current.
3. Dielectric Strength – Maximum voltage an insulating material can withstand without breakdown.
4. Insulation Resistance (IR) – Resistance offered by insulation against leakage current.
5. Megger – Instrument used to measure insulation resistance of electrical equipment.
6. Polarization Index (PI) – Ratio of insulation resistance at 10 minutes to that at 1 minute.
7. Dielectric Absorption – Ability of insulation to absorb and retain electric charge.
8. Earthing – Connecting exposed metal parts to earth to ensure safety.
9. Breakdown Voltage (BDV) – Voltage at which insulating oil fails electrically.

10. Insulating Oil – Liquid insulation used for electrical insulation and cooling.
11. Moisture Content – Presence of water in insulation which reduces its effectiveness.
12. Oxidation – Chemical reaction of insulating oil with oxygen causing aging.
13. Sludge – Thick deposits formed in oil due to oxidation.
14. Drying Out – Process of removing moisture from insulation.
15. Preventive Maintenance – Planned maintenance to avoid failure and extend equipment life.

2. FAQ & Assessment Section

A. Multiple Choice Questions (MCQs)

(20 Questions – Conceptual + Application based)

1. The main purpose of electrical insulation is to:
 - A) Increase current
 - B) Reduce voltage
 - C) Prevent leakage current
 - D) Improve power factor
2. Which factor most severely reduces insulation resistance?
 - A) Temperature
 - B) Moisture
 - C) Pressure
 - D) Altitude
3. A Megger is used to measure:
 - A) Voltage
 - B) Current
 - C) Insulation resistance
 - D) Earth resistance
4. Polarization Index is mainly used to assess:
 - A) Conductor quality
 - B) Insulation condition
 - C) Earthing system
 - D) Load current
5. Dielectric strength is expressed in:
 - A) Ohms
 - B) Amperes
 - C) Volts per unit thickness
 - D) Watts

6. Which is a liquid insulating material?
 - A) Mica
 - B) Rubber
 - C) Transformer oil
 - D) PVC
7. Moisture in insulating oil causes:
 - A) Increase in BDV
 - B) Reduction in BDV
 - C) No effect
 - D) Cooling improvement
8. Oxidation of oil mainly results in formation of:
 - A) Gas
 - B) Sludge
 - C) Water
 - D) Carbon
9. Earthing mainly protects against:
 - A) Overloading
 - B) Electric shock
 - C) Voltage drop
 - D) Heating
10. Which test indicates long-term insulation health?
 - A) Megger test
 - B) PI test
 - C) Continuity test
 - D) Load test
11. Insulating materials are classified based on:
 - A) Color
 - B) Cost
 - C) Temperature withstand
 - D) Shape
12. High temperature in insulation causes:
 - A) Improved life
 - B) Reduced aging

- C) Faster deterioration
 - D) No effect
13. Dielectric absorption is related to:
- A) Magnetic field
 - B) Charge storage
 - C) Heat loss
 - D) Mechanical strength
14. Drying out of insulation is required mainly to remove:
- A) Dust
 - B) Oil
 - C) Moisture
 - D) Gas
15. Which property is most important for insulating oil?
- A) Color
 - B) Smell
 - C) Dielectric strength
 - D) Density
16. Sludge in oil mainly affects:
- A) Insulation only
 - B) Cooling only
 - C) Both insulation and cooling
 - D) Appearance
17. Electrical safety rules are mainly intended to protect:
- A) Only equipment
 - B) Only operators
 - C) Both personnel and equipment
 - D) Only system voltage
18. Insulation resistance value should be:
- A) Zero
 - B) Very low
 - C) Very high
 - D) Negative
19. Which condition accelerates oil deterioration?
- A) Low temperature

- B) Dry air
- C) Electrical stress
- D) Clean oil

20. Preventive maintenance helps to:

- A) Increase faults
- B) Reduce equipment life
- C) Avoid sudden failures
- D) Increase losses

Answer Key (MCQs)

1-C, 2-B, 3-C, 4-B, 5-C,
6-C, 7-B, 8-B, 9-B, 10-B,
11-C, 12-C, 13-B, 14-C, 15-C,
16-C, 17-C, 18-C, 19-C, 20-C

B. Short Answer / Viva Questions (10)

(Commonly asked in viva and theory exams)

1. Why is insulation resistance measured before energizing equipment?
2. Explain the importance of dielectric strength in insulating materials.
3. Why is moisture harmful to insulation?
4. What is the purpose of earthing in electrical installations?
5. Why is Polarization Index preferred over single IR reading?
6. List any four causes of deterioration of insulating oil.
7. What happens if insulating oil forms sludge?
8. Explain why drying out of insulation is necessary.
9. How does temperature affect insulation life?
10. Why is preventive maintenance important for safety?

 **Digital Resource Library – Unit 1: Electrical Safety and Insulating Material**

1. AI Tools & Digital Learning Tools

1. AI Conversational Assistants (Chat-based Learning)

Purpose / Use-case:

- Concept clarification, summaries, exam-oriented explanations, viva practice

How it helps in Unit 1:

- Explains electrical safety rules, insulation concepts, IR tests, oil deterioration in simple language
- Can generate definitions, MCQs, short answers, and revision notes

- Very useful for last-day revision and doubt clearing

2. Virtual Electrical Lab Platforms

Purpose / Use-case:

- Simulated experiments and demonstrations

How it helps in Unit 1:

- Visualizes Megger test, insulation resistance measurement, BDV test of oil
- Helps students understand practical procedures even without physical lab access
- Builds confidence before actual laboratory sessions

3. Electrical Concept Visualization Tools

Purpose / Use-case:

- Animated explanations and diagrams

How it helps in Unit 1:

- Helps visualize electric shock paths, earthing systems, insulation breakdown
- Makes abstract concepts like dielectric strength and leakage current easier to understand
- Ideal for students who struggle with textbook-only learning

4. Digital Safety Training Simulators

Purpose / Use-case:

- Safety awareness and hazard identification

How it helps in Unit 1:

- Demonstrates Do's and Don'ts in substations and industrial environments
- Reinforces safe operation and maintenance practices
- Supports OBE outcomes related to electrical safety and compliance

5. Online Quiz & Self-Assessment Platforms

Purpose / Use-case:

- Practice MCQs, quizzes, and concept checks

How it helps in Unit 1:

- Helps students test understanding of definitions, causes, effects, and applications
- Immediate feedback improves retention
- Useful for internal assessment and exam readiness

2. Video Learning Repository

Note: Students should use the *Search Keywords* exactly as given to find the correct, reliable video.

Topic Name	Recommended Channel / Course / Lecturer Name	Search Keywords
Electrical Safety Basics	NPTEL / SWAYAM	“Electrical safety basics NPTEL”

Topic Name	Recommended Channel / Course / Lecturer Name	Search Keywords
Do's and Don'ts in Substations	Power Engineering Lectures	"Substation safety do's and don'ts diploma"
Insulating Materials Overview	NPTEL Electrical Engineering	"Insulating materials electrical NPTEL"
Classification of Insulating Materials	SWAYAM	"Classification of insulating materials IS standard"
Insulation Resistance Measurement	Electrical Practical Channels	"Megger test insulation resistance diploma"
Polarization Index & DAR Test	NPTEL High Voltage Engineering	"Polarization index dielectric absorption test"
Earthing and Safety	Government Skill Channels	"Earthing system electrical safety explanation"
Insulating Oil Properties	NPTEL / GATE Academy	"Transformer insulating oil properties"
Causes of Deterioration of Insulating Oil	Electrical Engineering Portal Videos	"Insulating oil deterioration causes"
BDV Test of Insulating Oil	Diploma Practical Videos	"BDV test of transformer oil procedure"

How Students Should Use This Library

- Before class: Watch 1 short video for concept familiarity
- After class: Use AI tools for explanation + summary
- Before lab: Use virtual labs and visualizers
- Before exam: Attempt quizzes + ask AI for revision notes

Predicted Question Bank – Unit 1: Electrical Safety and Insulating Material

1. Most Repeated / High-Probability Questions

(Frequently asked as 2-mark, 3-mark, 4-mark, or 6–8 mark questions in Diploma exams)

A. Core Definitions (Very High Probability)

1. Define electrical safety.
2. Define insulating material.
3. Define dielectric strength of an insulating material.
4. Define insulation resistance (IR).
5. What is a Megger? State its purpose.
6. Define earthing and state its objective.
7. What is insulating oil? Mention its main functions.
8. Define Polarization Index (PI).

9. What is meant by dielectric absorption?
10. Define breakdown voltage (BDV) of insulating oil.

B. Explanatory / Descriptive Questions (High Probability)

11. Explain Do's and Don'ts regarding safety for substation or power-station operators.
12. Explain electrical safety practices to be followed during operation and maintenance.
13. List and explain factors affecting the life of insulating materials.
14. Explain the classification of insulating materials as per Indian Standards.
15. Explain the measurement of insulation resistance using a Megger.
16. Explain the Polarization Index method for insulation testing.
17. Explain the Dielectric Absorption test and its significance.
18. Describe the drying-out (reconditioning) of insulation and its necessity.
19. State and explain the properties of good insulating oil.
20. Explain the causes of deterioration of insulating oil.

C. Diagram- / Concept-Focused Questions (Moderate to High Probability)

21. With a neat sketch, explain the Megger connection for insulation resistance measurement.
22. Draw and explain a basic earthing arrangement used for electrical safety.
23. Explain the effect of moisture on insulation with suitable explanation.
24. Explain how temperature affects the life of insulation.
25. Explain the formation of sludge in insulating oil and its effects.

2. Application & Logical Thinking Questions (5 Questions)

(These distinguish average answers from high-scoring answers)

1. A machine shows low insulation resistance during testing.
What could be the possible causes and what corrective actions should be taken?
2. Insulating oil in a transformer shows reduced BDV value.
Explain the likely reasons and suitable maintenance actions.
3. Why is Polarization Index considered more reliable than a single insulation resistance reading?
Justify your answer logically.
4. During maintenance, an operator ignores earthing practices.
Explain the possible hazards and consequences from a safety point of view.
5. A transformer operates continuously at high temperature.
Explain how this affects insulating materials and oil in the long run.

Detailed Study Plan Unit 2: Installation and Maintenance of Electrical Equipment

(Diploma Engineering – Electrical | Semester 4)

Unit Weightage: 27%

Total Lecture Hours: 12

Nature of Unit: Skill-oriented + Procedure-based + IS Standards aligned

OBE Focus: Installation competency, maintenance planning, safety compliance

1. Unit Overview & Learning Philosophy (For Students)

“A machine does not fail suddenly — it fails because of improper installation or poor maintenance.”

In this unit, you will learn **how equipment is installed correctly, why alignment and foundation matter**, and **how planned maintenance prevents costly breakdowns**. These are **core job-site skills** expected from a Diploma Engineer.

2. Topic-wise Structured Study Plan (As Per Syllabus)

Legend

- C – Core Topic
- S – Supporting Topic
- A – Application-Oriented Topic

Table: Detailed Study Plan for Unit–2

Sr. No.	Syllabus Topic (Strictly As Per GTU)	Topic Nature	Key Learning Focus	Suggested Lecture Hours	Exam Importance	Practical / Industry Relevance
2.1	Requirements of Foundation for Static and Rotating Electrical Machinery	C	Load distribution, vibration control, foundation types, importance of grouting	1.0	Medium	Very High (site installation)
2.2	Concept of Levelling and Aligning	C	Purpose of levelling, alignment methods, tolerances, real-life consequences	1.0	High	Very High
2.2.1	Procedure for Levelling and Aligning	A	Step-by-step field procedure, use of spirit level, dial gauge	—	—	—
2.2.2	Alignment of Direct Coupled Drive	A	Motor–pump / motor–generator alignment	—	—	—
2.2.3	Effects of Misalignment	A	Bearing failure, vibration, noise, power loss	—	—	—

Sr. No.	Syllabus Topic (Strictly As Per GTU)	Topic Nature	Key Learning Focus	Suggested Lecture Hours	Exam Importance	Practical / Industry Relevance
2.3	Installation Procedure of Power Transformer as per IS	C	Handling, placement, oil filling, earthing, safety clearances	2.0	Very High	Extremely High
2.4	Installation Procedure of Rotating Electrical Machines (IM & Alternator) as per IS	C	Mounting, coupling, ventilation, pre-start checks	2.0	Very High	Extremely High
2.5	Installation Procedure of Switchgear (CB, Isolator, Control Panel) as per IS	C	Panel erection, interlocks, earthing, clearances	2.0	High	Very High
2.6	Devices and Tools Required for Installation of Electrical Equipment	S	Tools list, measuring instruments, lifting tools, safety tools	0.5	Low–Medium	High
2.7	Factors Affecting Preventive Maintenance Schedules	S	Load, environment, duty cycle, manufacturer guidelines	0.5	Low–Medium	Medium
2.8	Concept of Maintenance and Types of Maintenance	C	Routine, preventive, breakdown maintenance philosophy	1.0	Medium	Very High
2.9	Preventive Maintenance – Procedure for Developing Maintenance Schedules	A	Maintenance planning, checklists, periodicity	1.0	High	Extremely High
2.10	Maintenance Schedules as per IS (Transformer, IM, Alternator, CB, Batteries, Solar & Wind	A	Standard maintenance charts, inspection frequency	1.0	Very High	Extremely High

Sr. No.	Syllabus Topic (Strictly As Per GTU)	Topic Nature	Key Learning Focus	Suggested Lecture Hours	Exam Importance	Practical / Industry Relevance
	Plants)					

Total = 12 Lecture Hours

3. Logical Sequencing Rationale (Faculty Guidance)

Phase 1 – Installation Fundamentals

- Foundation → levelling → alignment
 ☞ *Build mechanical correctness before electrical energization*

Phase 2 – Equipment-wise Installation

- Transformer → rotating machines → switchgear
 ☞ *From static to dynamic systems*

Phase 3 – Maintenance Philosophy

- Maintenance concepts → preventive schedules → IS-based charts
 ☞ *Shift student mindset from “repair” to “prevent”*

4. Core, Supporting & Application Mapping (OBE Alignment)

Core Topics (Must Master)

- Foundation requirements
- Levelling & alignment
- Installation of transformer, machines, switchgear
- Maintenance concepts

Supporting Topics (Conceptual Strength)

- Tools & devices
- Factors affecting maintenance schedules

Application-Oriented Topics (Skill Development)

- Preventive maintenance scheduling
- IS-based maintenance charts
- Misalignment effects & troubleshooting logic

5. Exam Orientation (GTU Pattern Insight)

Area	Likely Question Type
Installation procedures	Long descriptive (5–7 marks)
Alignment & foundation	Short notes / numerical logic
Maintenance schedules	Table-based / list-type questions
Preventive maintenance	Application-based questions

💡 *Students should practice writing answers in **step-by-step format**.*

6. Practical & Industry Relevance Snapshot

- **Directly supports lab experiments** (installation checks, alignment demos)
 - **Strong linkage with Unit–3, 4 & 5 commissioning**
 - **Highly valued by employers** (site engineer, maintenance supervisor roles)
 - Encourages **NEP-2020 skills, internships & project-based learning**
-

7. Mentor’s Closing Note to Students 🌱

If you install it right, you will never need to repair it frequently.

Master this unit not just for exams—but for **confidence on site, respect from technicians, and trust from your employer.**

If you want next:

- ✓ **Lecture-wise teaching plan**
- ✓ **PowerPoint outline**
- ✓ **Question bank mapped to COs**
- ✓ **AI-ready content prompts for each topic**

Lecture 1: 2.1 – Requirements of Foundation for Static and Rotating Electrical Machinery

1. Hook / Introduction (≈ 5 minutes)

👉 *Why do you think a heavy electrical machine like a transformer or motor is never placed directly on the floor?*

Many beginners think, “*Sir, machine electrical hai, foundation civil ka topic hai.*”

But in real industry, **most electrical machine failures start from a weak foundation**, not from windings.

Think of a ceiling fan fixed loosely — it vibrates, makes noise, and finally fails. Now imagine a **500 kVA transformer or a 50 HP motor** running on a poor foundation. Dangerous, right?

So today, we will understand **why proper foundation is the first step of correct installation.**

Content:

2. Core Concepts (≈ 40 minutes)

2.1.1 What is a Foundation?

A **foundation** is a **strong supporting base** provided below electrical machinery to:

- Support the **weight of the machine**
- Maintain **correct alignment**
- Absorb **vibrations**
- Ensure **safe and long operation**

👉 *Rule to remember:*

“No foundation → No stable operation.”

2.1.2 Need for Proper Foundation

A good foundation is required to:

1. Prevent vibration and noise
2. Avoid misalignment of shafts
3. Reduce mechanical stress on bearings
4. Increase machine life
5. Ensure safety of operators

Fun Fact:

Around **30–40% bearing failures** in motors are due to vibration caused by poor foundation.

2.1.3 Foundation Requirements for Static Machinery

Static machines like:

- Power transformers
- Reactors
- Control panels

Key requirements:

- Must withstand **dead weight**
- No moving parts → vibration is minimal
- Foundation should be **level and rigid**
- Provision for **earthing pits**
- Proper **oil drainage** (for transformers)



Fig.2.1.A.Side view showing **transformer mounted on concrete foundation with rollers, plinth, and oil drain channel**

2.1.4 Foundation Requirements for Rotating Machinery

Rotating machines like:

- Induction motors
- Alternators
- Generators

These create **dynamic forces** due to rotation.

Special requirements:

- Strong RCC foundation
- Heavier than static machine foundation
- Must absorb **dynamic load and vibration**
- Proper **grouting** after alignment
- Anchor bolts firmly fixed

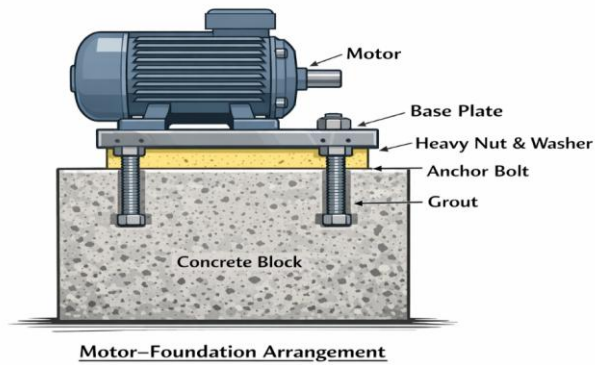


Fig.2.1.a. Motor–foundation arrangement showing **base plate, anchor bolts, grout, and concrete block**

2.1.5 Types of Foundations

1. Block Type Foundation

- Common for motors and generators
- Simple and economical

2. Raft Foundation

- Used where soil is weak

3. Pile Foundation

- Heavy machinery in poor soil conditions

2.1.6 General Foundation Design Guidelines

- Foundation weight = **2 to 3 times machine weight**
- Top surface must be **perfectly level**
- Foundation must be **isolated from nearby machines**
- No cracks or loose bolts allowed

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

In **substations**, transformers are installed on elevated RCC foundations to:

- Protect from flooding
- Allow oil collection during leakage
- Improve cooling

In **industries**, motors are frequently stopped due to:

- Loose foundation bolts

- Uneven foundation settlement

Industry Practice:

Before commissioning, engineers always check:

- Foundation strength
- Bolt tightness
- Level using spirit level



A Diploma engineer is often the **first person** to notice foundation problems during maintenance.

3. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Foundation is the base of safe installation
- ✓ Static machines need load-bearing foundations
- ✓ Rotating machines need vibration-absorbing foundations
- ✓ Poor foundation leads to vibration, noise, and failure

Common Student Doubts

- “*Sir, can alignment fix foundation problems?*”
 No. Alignment works only on a **good foundation**.
- “*Is foundation electrical or civil work?*”
 It is **both**, but responsibility lies with the electrical engineer.


Mentorship & Career Tip

Mastering foundation concepts helps you:

- Perform confidently during **site work**
- Answer **interview questions** related to installation
- Design better **maintenance schedules**
- Earn trust as a **practical engineer**, not just a theory student

Lecture 2: Topic 2.2: Concept of Levelling and Aligning of Electrical Machinery

1. Hook / Introduction (≈ 5 minutes)

 *If the wheels of a bicycle are not aligned, can you ride smoothly?*

You may pedal hard, but the ride will be shaky, noisy, and unsafe.

The same problem happens in electrical machines.

In industry, many motors fail not due to electrical faults, but due to poor levelling and misalignment. Bearings heat up, shafts bend, vibration increases—and finally the machine stops.

Today’s topic explains how correct levelling and alignment save machines, money, and manpower.

2. Core Concepts (≈ 40 minutes)

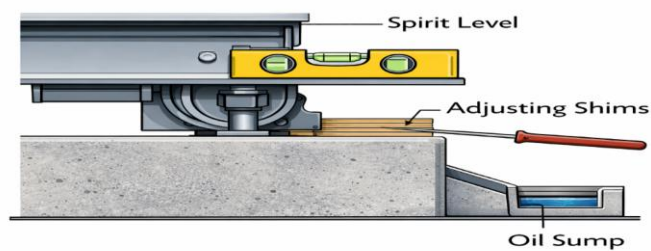
2.2.1 Concept of Levelling

Levelling means placing the electrical machine perfectly horizontal on its foundation so that:

- Load is evenly distributed
- No tilting or twisting occurs
- Shaft remains straight

Levelling is done using:

- Spirit level / precision level
- Shims (thin metal sheets placed under machine feet)



Levelling of Electrical Machine

Fig.2.2.a. Levelling of Electrical Machine

Description:

- Concrete foundation at bottom
- Machine base plate resting on foundation
- Shims placed under machine feet
- Spirit level placed on top of machine

👉 Exam Point:

Alignment is impossible without proper levelling.

2.2.2 Concept of Alignment

Alignment is the process of positioning two rotating shafts so that:

- Their centre lines lie on the same straight line
- Power transmission is smooth
- Mechanical stress is minimized

Alignment is required in:

- Motor–pump sets
- Motor–compressor systems
- Motor–generator sets

Description:

- Two shafts connected by coupling
- One figure showing perfect alignment

- Another figure showing misalignment

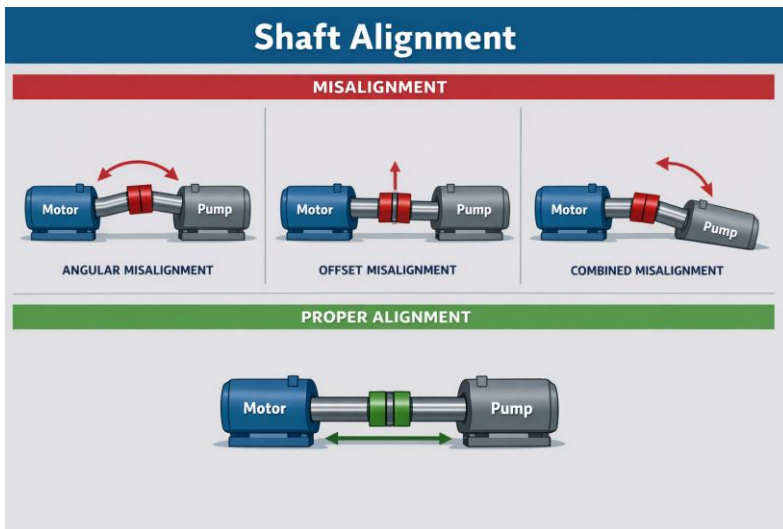


Fig. 2.2.b: Shaft Alignment Diagram

2.2.3 Types of Misalignment

1. **Parallel (Offset) Misalignment**
Shafts are parallel but displaced sideways
2. **Angular Misalignment**
Shafts meet at an angle
3. **Combined Misalignment**
Combination of both (most common)

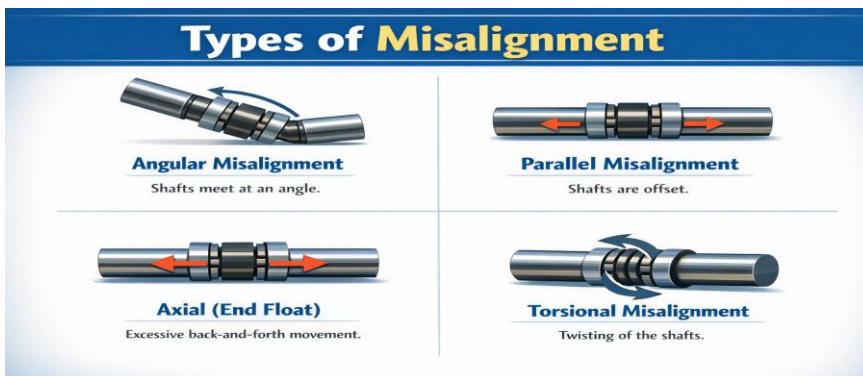


Fig.2.2.c: Types of Misalignments

Description:

- Three small sketches labelled:
Parallel, Angular, Combined

Exam Tip:

“Explain types of misalignments with neat sketches” is a frequently asked question.

2.2.4 Procedure for Levelling and Aligning

Step-by-step procedure:

1. Clean foundation and base plate
2. Place machine on foundation
3. Insert shims under feet
4. Check levelling in longitudinal & transverse directions
5. Tighten foundation bolts lightly
6. Perform alignment using:
 - Straight edge
 - Feeler gauge
 - Dial gauge (industrial practice)
7. Adjust shims to correct alignment
8. Final tightening of bolts
9. Grouting after confirmation

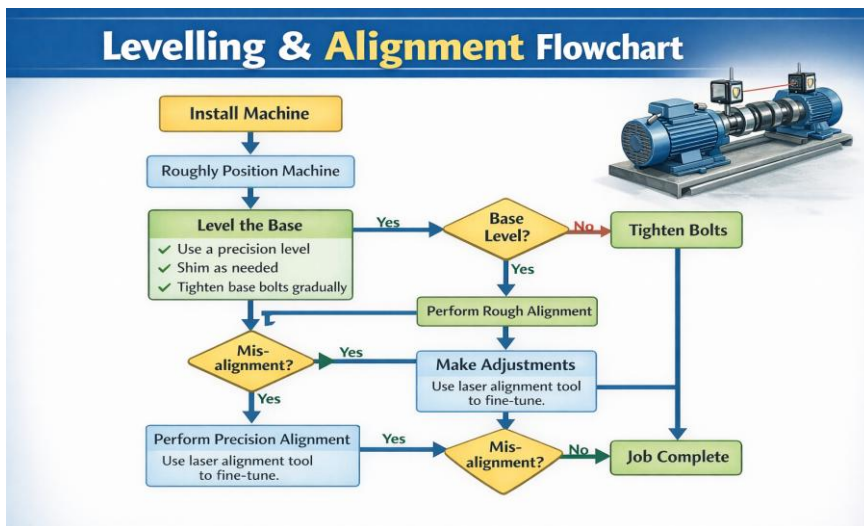


Fig.2.2.d: Levelling & Alignment Flowchart

2.2.5 Alignment of Direct Coupled Drive

In direct coupled drive, motor shaft is directly connected to load shaft using a coupling.

Key points:

- Shafts must rotate smoothly
- Coupling gap should be uniform
- Alignment must be rechecked after tightening

Examples:

- Motor-pump
- Motor-blower

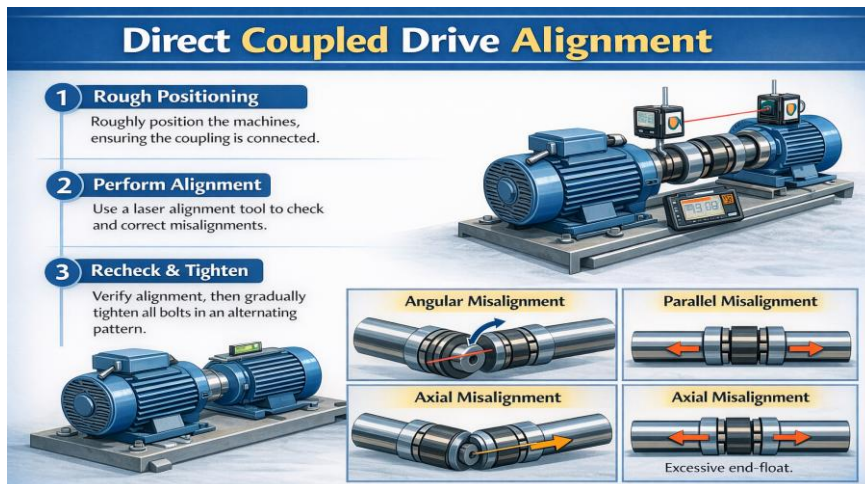


Fig.2.2.e: Direct Coupled Drive Alignment

Description:

- Motor on left, pump on right
- Flexible coupling in between
- Dial gauge touching coupling surface

2.2.6 Effects of Misalignment

Misalignment causes:

- Excessive vibration
- Bearing overheating
- Shaft bending
- Noise

- Reduced efficiency
- Frequent breakdowns

⚠ Fun Fact:

A misalignment of 0.1 mm can reduce bearing life by 50%.

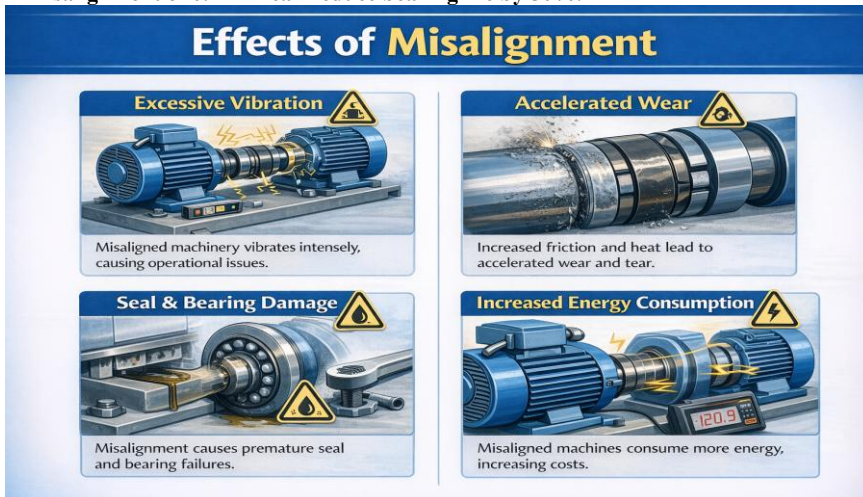


Fig.2.2.f.: Effects of Misalignment

Description:

- Vibrating motor
- Overheated bearing
- Bent shaft illustration

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

In industries:

- Alignment is checked after installation and maintenance
- Dial gauges and laser alignment tools are used
- Readings are recorded in maintenance logbooks

In power plants, alternator alignment is a critical supervised activity.

Diploma engineers usually perform:

- Initial levelling
- Routine alignment checks
- Vibration reporting

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Levelling ensures stability

- ✓ Alignment ensures smooth power transmission
- ✓ Levelling comes before alignment
- ✓ Misalignment causes mechanical failures

Common Student Doubts

- Can flexible coupling absorb misalignment?
 - ☞ Only small misalignment
- Is alignment a one-time process?

Lecture 3: Unit 2.3: Installation Procedure of Power Transformer (As per Indian Standards)

1. Hook / Introduction (≈ 5 minutes)

Good morning students 🙌

Let me begin with a serious question:

☞ Can a brand-new transformer fail on the very first day?

Many of you may think, “No sir, new equipment means safe operation.”

But in real life, **most early transformer failures happen due to improper installation**, not due to manufacturing defects.

A transformer is like a **human heart of the power system**. Even a small mistake during installation—like poor earthing or moisture entry—can reduce its life drastically. Today’s lecture will help you understand **how transformers are installed step-by-step as per Indian Standards (IS)** to ensure safety and long service life.

SESSION-1 (60 Minutes)

Introduction to Power Transformer & Applicable Indian Standards

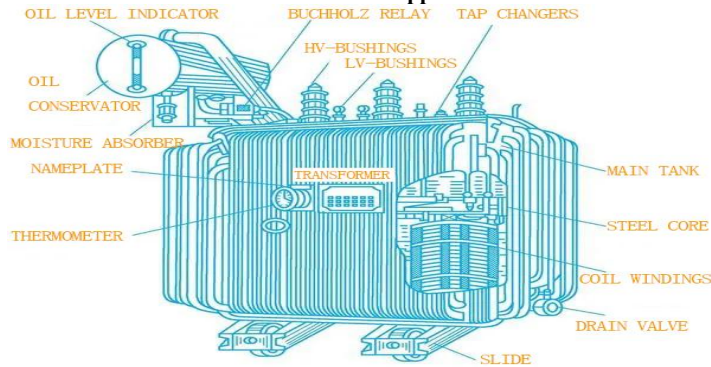


Fig.2.3.a. Schematic Diagram of 3 phase Transformer



Fig.2.3.b Onsite Power Transformer with colling arrangement

1. Introduction to Power Transformer (15 min)

A power transformer is a static electrical device used to transfer electrical energy from one circuit to another at the same frequency but usually at different voltage levels. It works on the principle of mutual induction and is mainly used in generation, transmission, and distribution systems to step up or step-down voltage.

Power transformers are designed for high efficiency at full load and operate continuously. They play a critical role in reducing transmission losses and ensuring safe voltage levels for consumers.

2. Need for Standards in Power Transformers (10 min)

To ensure safety, reliability, interchangeability, and quality, power transformers must be designed, manufactured, tested, and installed according to Indian Standards (IS).

Indian Standards ensure:

- Uniform design practices
- Safe operation and protection
- Compatibility with Indian power system conditions
- Compliance with utilities and inspection agencies

The main Indian Standard governing power transformers is IS 2026, which is harmonized with IEC standards.

3. Overview of IS 2026 – Power Transformers (15 min)

IS 2026 is divided into multiple parts covering design, temperature rise, insulation, testing, and loading.

Key aspects covered:

- Rated voltage and frequency
- Temperature rise limits
- Insulation levels
- Losses and efficiency

- Testing procedures
- Cooling methods

Standard frequency: 50 Hz

Permissible temperature rise:

- Oil: ~50°C (depending on class)
- Winding: ~55–60°C

4. Basic Construction as per IS (20 min)

Main parts of a power transformer:

- Magnetic core: CRGO steel laminations to reduce losses
- Primary & secondary windings: Copper or aluminum
- Insulation system: Paper, pressboard, oil
- Transformer oil: Acts as coolant and insulator
- Tank & conservator: For oil expansion
- Bushings: Safe external connections
- Cooling system: ONAN, ONAF, OFAF

Construction must ensure:

- Mechanical strength during short-circuits
- Adequate insulation clearance
- Proper cooling arrangement

Lecture 4: SESSION–2 (60 Minutes)

Unit 2.3: Installation Procedure of Power Transformer (As per Indian Standards)

Procedure, Ratings, Losses & Testing of Power Transformer as per IS

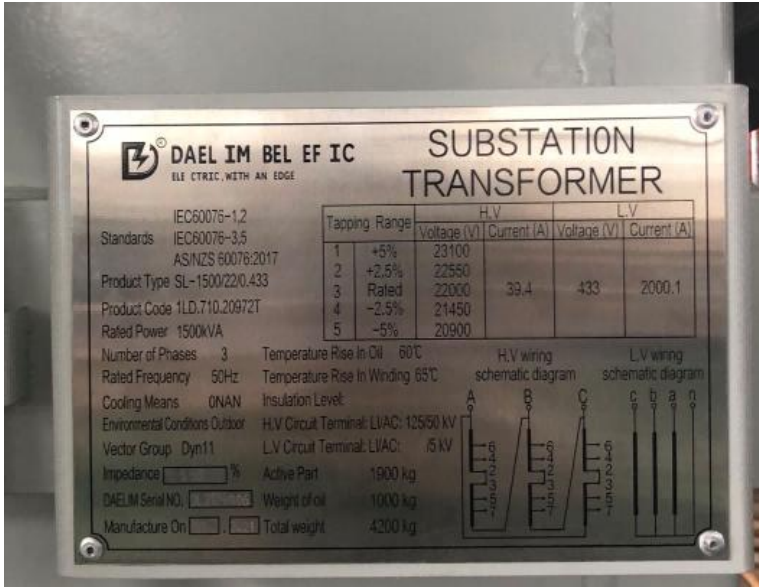


Fig.2.3.c.Specification of Substation Transformer



Fig.2.3.d. Power Transformer

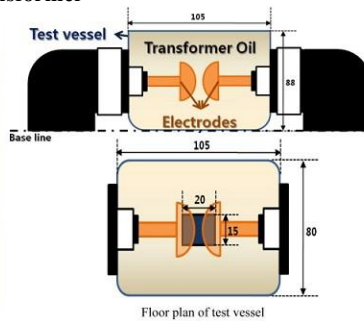


Fig.2.3.e. Power Transformer Oil Testing

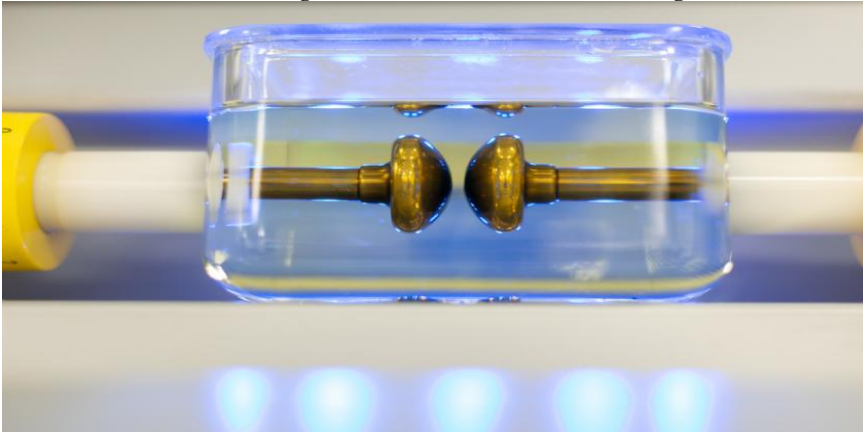


Fig.2.3.f. Power Transformer oil testing with sphere gap

1. Nameplate Details as per IS (10 min)

Each power transformer must have a nameplate showing:

- Rated power (kVA/MVA)
- Primary & secondary voltage
- Rated current
- Frequency (50 Hz)
- Vector group
- Cooling type
- Percentage impedance
- Oil quantity

This information helps in proper selection, installation, and maintenance.

2. Transformer Ratings & Vector Groups (15 min)

Ratings include:

- Power rating (kVA/MVA)
- Voltage rating
- Current rating
- Insulation level

Vector group indicates winding connection and phase displacement

Examples:

- Dyn11 (commonly used in distribution)
- YNd1 (used in power systems)

Correct vector group selection avoids circulating currents and phase issues.

3. Losses in Power Transformer (10 min)

As per IS, transformer losses are categorized as:

- Core (iron) losses: Constant, occur due to hysteresis & eddy currents
- Copper losses: Variable, depend on load current

IS standards specify maximum permissible losses to ensure high efficiency?

4. Testing of Power Transformers as per IS (20 min)

IS 2026 specifies three categories of tests:

a) Routine Tests

- Winding resistance test
- Turns ratio test
- Insulation resistance test
- No-load and short-circuit test

b) Type Tests

- Temperature rise test
- Impulse voltage test

c) Special Tests

- Zero-sequence impedance
- Noise level measurement

Testing ensures the transformer meets performance and safety requirements before commissioning.

5. Importance of IS-Compliant Procedures (5 min)

Following IS procedures ensures:

- Long service life
 - Safe operation
 - Reduced failures
 - Easy acceptance by utilities
-

Conclusion

Power transformers are vital components of the electrical power system. Understanding their introduction, construction, ratings, losses, and testing as per Indian Standards is essential for diploma engineers. Proper adherence to IS procedures ensures reliability, efficiency, and safety in power system operation.

Lecture 5: Unit 2.4 Installation Procedure of Rotating Electrical Machine (Induction Motor and Alternators) as Per I.S.

1. Hook / Introduction (5 minutes)

Imagine a giant 250 kW induction motor running in a steel plant. If its foundation is weak, the floor starts vibrating, bolts loosen, and the motor misaligns — eventually leading to bearing failure.

👉 *Question to students:* “What carries the load of an electrical machine when it starts or stops?”

This topic focuses on how the foundation ensures stability, alignment, and safety for electrical machines. Foundations are the “legs” on which machines stand.

2.4.1 Core Concepts (40 minutes)

2.4.1 What is a Foundation?

A *foundation* is the rigid, strong base on which a machine is installed.

Functions:

- Support total static and dynamic loads.
 - Maintain correct alignment between coupled machines.
 - Dampen vibrations and noise.
 - Distribute load uniformly to the ground.
-

2.4.2 Classification of Machines

- **Static Machines:** Do not move. Examples – Transformers, reactors, switchgear panels.
 - **Rotating Machines:** Have moving parts. Examples – Motors, generators, alternators.
-

2.4.3 Types of Foundations

1. **Masonry / Brick Foundation** – used for small static equipment like distribution transformers.
 2. **Reinforced Cement Concrete (RCC) Foundation** – used for heavy rotating machines; ensures rigidity and vibration control.
 3. **Grouted Baseplate Foundation** – base frame is anchored using foundation bolts and grouted with non-shrink cement to fill voids.
-

2.4.4 Foundation Requirements (as per I.S. standards)

- **IS 2974 (Part I–V):** Covers design of foundations for machines.
- **Foundation should:**
 - Withstand *static loads* (machine weight) and *dynamic loads* (vibration, torque).
 - Have sufficient mass (3–5 times machine mass for rotating types).
 - Be rigid and vibration-free.
 - Maintain level surface and proper alignment of shaft centre lines.
 - Include foundation bolts with sleeves for adjustments.
 - Provide drainage and earthing provisions.

2.4.5 Foundation for Static Machines

Example: Power Transformer

- Must rest on a level RCC pad with oil containment pit.
- Anchor bolts are embedded before casting.
- Vibration and noise are negligible, so dynamic analysis not critical.
- Adequate space for cable entry and maintenance access.

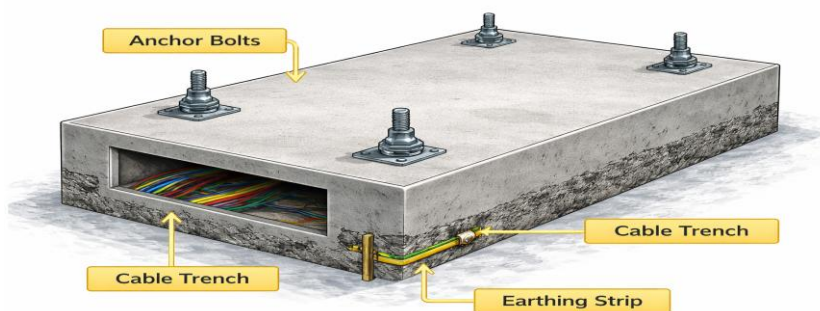


Fig. 2.4.a. Draw a rectangular RCC foundation with anchor bolts, cable trench, and earthing strip indicated.

2.4.6. Real-World / Industry Applications (10 minutes)

- In thermal power stations, alternators rest on vibration-isolated RCC blocks.
- Industrial motors above 50 HP always use grouted foundations to prevent misalignment.
- Transformers in substations use oil soak pits and plinths designed per IS 1180.

Fun Fact 💡 : The vibration of a 500 kW motor can reach 2000 N—equal to the weight of a small car if the foundation isn't properly designed!

2.4.7. Summary & Q&A (5 minutes)

Key Points:

- Foundation = Stability + Alignment + Safety
- Follow IS 2974 standards.
- Static vs. Rotating foundations differ in design and load considerations.

Typical Student Doubts:

- “Why should foundation mass be 3 times machine mass?”
→ To absorb dynamic energy and avoid resonance.
- “Can we install a motor directly on a steel frame?”
→ Only for small fractional HP motors.

Mentorship Note:

Understanding foundations helps future engineers design reliable installations and avoid costly vibration problems in industries. A good foundation is the first step toward machine reliability.

Lecture 6 Unit 2.4 Installation Procedure of Rotating Electrical Machine (Induction Motor and Alternators) as Per I.S. (60 minutes)

2.4.2.1. Hook / Introduction (5 minutes)

Think of a washing machine spinning off balance — it “walks” across the floor!

Now imagine a 3 MW alternator doing the same. The foundation design becomes crucial for safety, precision, and longevity.

2. 4.2.2 Core Concepts (40 minutes)

2.1 Foundation for Rotating Machines

Rotating machines generate vibratory forces due to imbalance, torque, and cyclic load changes.

Key Requirements:

- **Heavy and rigid base:** To prevent excessive vibration.
- **Proper damping:** Avoids resonance.
- **Accurate alignment:** Coupled machines must remain co-axial.
- **Provision for grouting and leveling:** Non-shrink grout fills the gap between baseplate and foundation.
- **Anchor bolts with sleeves:** Allow adjustment before final tightening.

2.2 Foundation Design Parameters

- **Mass Ratio:** 3–5 times machine mass.
- **Natural Frequency:** Should not coincide with operating speed (avoid resonance).
- **Bolt Projection:** 20–30 mm above nut for adjustment.
- **Depth:** At least 1–1.5 times machine width.
- **Material:** RCC with M20 or higher concrete grade.

Visual Aid Description: Sketch of an induction motor on RCC foundation block showing:

1. Base plate
2. Grout layer
3. Anchor bolts with nuts
4. Earth connection point
5. Coupled driven equipment

2.4.2.3 Foundation Bolts and Grouting

- Bolts set using *templates* before pouring concrete.
- After installation, space between base and foundation is filled with epoxy or cement grout.

- Grouting ensures full contact and eliminates vibration gaps.
- Allow 48–72 hours curing before tightening bolts.

2.4.2.4 Alignment and Levelling

- Check level using spirit level or laser level.
- Correct unevenness with steel shims or grout.
- For coupled machines, alignment of shafts checked with dial gauge.

2.4.2.5 Earthing and Cable Entry

- Foundation should include earthing pits and cable ducts before casting.
- Maintain safe distances from nearby structures to avoid magnetic coupling.

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

- **Hydroelectric plants:** Turbine alternators require massive RCC foundations built on rock.
- **Petrochemical plants:** Vibrations from compressors are minimized through isolation pads.
- **Metro traction substations:** Induction motors for pumps and fans are grouted on antivibration pads.

Example: In the NTPC power station, the alternator foundation weighs over 100 tons, carefully isolated from turbine foundations to prevent mechanical coupling.

2.4.3.6 Summary & Q&A (5 minutes)

Key Points:

- Foundation must be vibration-free, level, and aligned.
- Follow IS 2974 and IS 10028 guidelines.
- Dynamic analysis ensures machine life and safety.

Typical Doubts:

- “Why avoid resonance frequency match?” → To prevent amplified vibrations and mechanical damage.
- “What is grouting?” → A cement or epoxy mix used to fill the gap between base and foundation for rigidity.

Mentorship Note:

Mastering foundation concepts prepares you for installation, site supervision, and vibration analysis roles in industries like NTPC, GSECL, and ABB. It also builds core knowledge for future subjects like “Vibration Analysis” and “Plant Maintenance.”

◆ Lecture 7 (60 Minutes)

Topic 2.5: Installation Procedure of Switchgear – Circuit Breakers and Isolators (as per I.S.)

2.5.1. Hook / Introduction (≈ 5 minutes)

“What happens if a circuit breaker trips and fails to reclose in a substation supplying an entire city block?”

The answer — blackout, equipment damage, and financial losses.

Every switchgear, whether in a **power station, industrial plant, or commercial complex**, must be **installed precisely as per Indian Standards (IS)** to ensure safe and uninterrupted power supply.

Think of switchgear as the **“nervous system” of an electrical network** — if one nerve is wrongly connected, the entire body reacts!

2.5.2. Core Concepts (≈ 40 minutes)

2.5.2.1 Definition and Purpose

Switchgear includes all the switching and protective devices controlling, isolating, or protecting electrical circuits —

like **Circuit Breakers (CBs), Isolators, Relays, Fuses, and Control Panels**.

It ensures:

- Safety of personnel and equipment
 - Quick isolation during faults
 - Reliable system operation
-

2.5.2.2 Pre-Installation Activities

Before physical installation:

1. **Site Inspection:** Verify room layout, cable trench, earthing, and lighting as per design drawing.
 2. **Equipment Verification:** Cross-check nameplate details — voltage, current rating, short-circuit capacity.
 3. **Tools and PPE:** Ensure availability of torque wrenches, meggers, spirit level, gloves, and insulated tools.
 4. **Foundation Preparation:** Floor must be **flat, level, and vibration-free** for panel alignment.
-

2.5.3 Installation Procedure for Circuit Breakers (as per IS 10118 & IS/IEC 62271)

1. Positioning:

- Place circuit breaker panels on the prepared plinth using lifting tackles or trolleys.
- Maintain inter-panel clearances as per layout drawing.

2. Leveling and Fixing:

- Align using a spirit level; fix with anchor bolts.
- Adjust gaps using steel shims before tightening.

3. Busbar and Cable Connections:

- Connect copper/aluminium busbars with correct torque and apply petroleum jelly.

- Terminate incoming/outgoing cables using crimped lugs.

4. Control Wiring:

- Wire auxiliary contacts, tripping and closing coils as per schematic diagram.

5. Earthing:

- Provide two separate earth connections: one for body, one for control circuit.

6. Testing Before Energization:

- IR test ($\geq 1 \text{ M}\Omega$ with 1000 V megger)
- Functional test of trip and close mechanisms
- Check interlocks and mimic diagram indications.

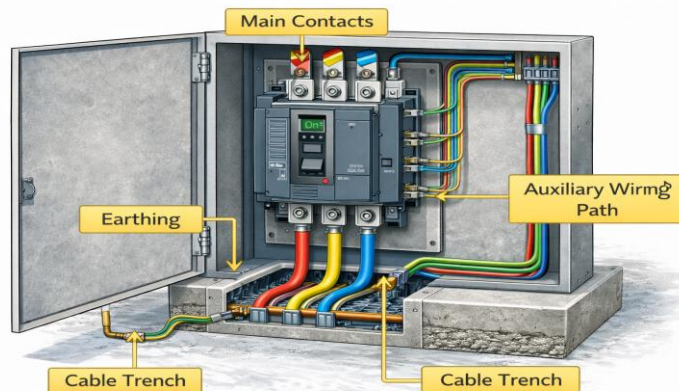


Fig.2.5.a. Draw a **layout of a circuit breaker panel**, showing main contacts, earthing, cable trench, and auxiliary wiring path.

2.5.4 Installation of Isolators

1. Fix isolator base frame on foundation bolts.
2. Align moving and fixed contacts accurately.
3. Connect interlocking linkages to operating handle.
4. Check free mechanical movement 10–15 times.
5. Verify that the **OFF position** provides a visible isolation gap.
6. Connect earthing blades (if provided).

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

- In **GETCO** or **PGCIL** substations, isolators are installed on 33 kV or 132 kV lines to ensure visible disconnection before maintenance.

- **Vacuum and SF₆ circuit breakers** are now replacing oil types for improved safety and compactness.
- In **industrial panels**, circuit breakers coordinate with relays for motor and feeder protection.

Fun Fact 💡 :

The world's largest circuit breakers can interrupt currents exceeding **80 kA** within **milliseconds** — faster than the blink of an eye!

2.5.6. Summary & Q&A (≈ 5 minutes)

Key Points:

- Switchgear protects and isolates electrical circuits.
- Always follow IS 10118 and IS/IEC 62271 for installation.
- Key steps: Positioning, leveling, wiring, earthing, testing.
- Proper alignment and grounding ensure long-term reliability.

Common Doubts:

- *Why double earthing?* → For redundancy and safety compliance.
- *Can a breaker operate without interlock?* → No, it's unsafe and violates IS code.

Mentorship Note:

Mastering switchgear installation prepares you for roles in **substation commissioning, panel design, and protection engineering** — key areas in utilities and manufacturing industries.

◆ **Lecture 8 (60 Minutes)**

Topic 2.5: Installation Procedure of Switchgear – Control Panels and Testing (as per I.S.)

2.5.2.1. Hook / Introduction (≈ 5 minutes)

Imagine standing in front of a control panel filled with hundreds of meters, relays, and switches. Each wire and connection must be perfect — because **one wrong link could trip an entire feeder**. Let's explore how **control panels** are installed, interconnected, and tested as per Indian Standards to make electrical systems "intelligent and safe."

2.5.2.2. Core Concepts (≈ 40 minutes)

2.1 Control Panel Overview

A **control panel** is an assembly of switchgear, protection, and metering components mounted on a metal enclosure.

Functions:

- Monitor and control circuits
- Protect against overload and faults
- Indicate operational status through meters and lamps

2.2 Pre-Installation Activities

- Verify panel layout, cable trenches, and gland plates.
- Check all compartments and components for physical damage.

- Confirm inter-panel busbars and earth links are ready.
- Ensure availability of as-built **control wiring diagrams** and terminal schedules.

2.5.2.3 Installation Procedure (as per IS 8623 & IS 10118)

1. Positioning and Alignment:

- Place panels on foundation plinth using rollers or cranes.
- Align with a straight line using a chalk line and spirit level.

2. Inter-Panel Connections:

- Connect busbars with bolts and spring washers; apply contact grease.
- Tighten to specified torque using calibrated tools.

3. Cable Termination:

- Terminate control and power cables through glands; use ferrules for identification.
- Follow color code: Red–Yellow–Blue (phases), Black (neutral), Green (earth).

4. Earthing:

- Connect the panel earth bar to the main earth grid using two separate conductors.

5. Functional Testing:

- Check continuity and insulation resistance of all circuits.
- Test relay operations, alarms, and indication lamps.
- Perform interlock checks between panels.

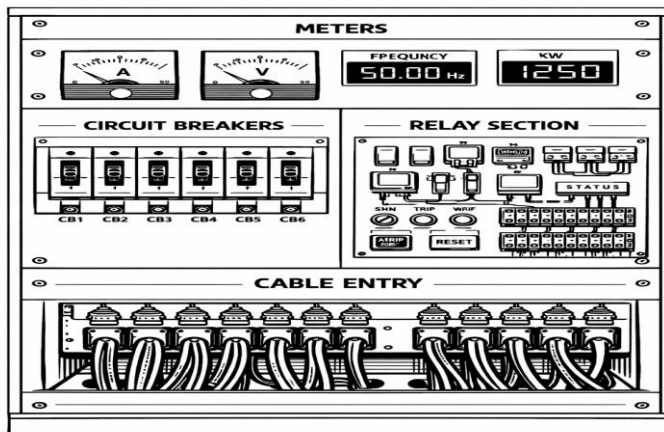


Fig.2.5.b Sketch a front view of control panel, showing meters, breakers, relay section, and cable entry at bottom.

Commented [A1]:

2.5.2.4 Safety and Quality Compliance

- Ensure all joints are tight and corrosion-protected.
- Maintain clear labeling on all switches and relays.
- Verify control logic through “dry run” (no-load) testing.
- Record insulation and functional test results for documentation.

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

- **Industrial control rooms** use modular panels for process automation (motors, pumps, conveyors).
- **Power utilities** use relay panels for 11 kV and 33 kV protection.
- **Renewable energy plants** integrate switchgear with SCADA for remote operation.

Example:

In a **solar plant**, control panels monitor inverter output, grid voltage, and relay trips — all controlled via communication panels.

Fun Fact 💡 :

A modern GIS (Gas-Insulated Switchgear) can pack the same functionality of 10 old air-insulated panels in just one compact enclosure!

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways:

- Control panels are central to monitoring and protection.
- Installation steps: Position → Wiring → Earthing → Testing → Documentation.
- Compliance with IS 8623 and IS 10118 ensures safety and reliability.
- Final testing before energization prevents costly breakdowns.

Typical Student Questions:

- *Why are two earthing points necessary?* → Ensures fail-safe grounding.
- *What is interlock testing?* → Verifies that incorrect switching sequences are mechanically/electrically blocked.

Lecture : 9: Topic–2.6: Devices and Tools Required for Installation of Electrical Equipment
Topic–2.7: Factors Affecting Preventive Maintenance Schedules

1. Hook / Introduction (≈ 5 minutes)

Let us begin with a simple question:

Can a skilled electrician install a transformer safely without proper tools and testing devices?

The answer is **no**. Even the best technical knowledge fails without the right tools and maintenance

planning. In industry, **70–80% of electrical failures are due to improper installation or poor maintenance practices**. Today's lecture will help you understand **what tools are essential for installation** and **why preventive maintenance schedules differ from one system to another**.

2. Core Concepts (\approx 40 minutes)

Topic–2.6 Devices and Tools Required for Installation of Electrical Equipment

Electrical installation involves **mechanical accuracy, electrical safety, and testing reliability**. Tools are broadly classified as follows:

(a) Mechanical Tools

Used for mounting, alignment, and fixing of equipment.

- Spanners (open, ring, torque wrench)
- Screwdrivers (flat and Phillips)
- Hammer, chisel, pliers
- Spirit level and dial gauge (for levelling and alignment)
- Bearing puller and chain pulley block

Analogy: Just as a doctor needs surgical instruments, an electrical engineer needs mechanical tools to “prepare the body” of the machine.

(b) Electrical Installation Tools

Used for wiring and connections.

- Cable cutters and cable stripping tools
- Crimping tools for lugs
- Soldering iron and solder wire
- Insulation tapes and heat-shrink sleeves

(c) Measuring and Testing Instruments

Essential for safety and commissioning.

- Digital Multimeter (voltage, current, resistance)
- Insulation Resistance Tester (Megger)
- Earth resistance tester
- Clamp meter
- Phase sequence indicator



Fig.2.6.a.Block diagram showing **equipment** → **testing instruments** → **safety confirmation** → **energization**.

(d) Safety Tools and PPE

- Insulated gloves and shoes
- Safety helmet, goggles
- Earthing rods
- Danger boards and barricading tape

Fun Fact: Most utilities mandate **Class-0 insulated gloves (up to 1 kV)** for LT installation work.

Topic–2.7 Factors Affecting Preventive Maintenance Schedules

Preventive maintenance means **maintaining equipment before failure occurs**. However, maintenance frequency is not the same for all equipment.

Key factors affecting maintenance schedules:

1. **Type of Equipment**
Transformers need oil testing; motors require bearing and vibration checks.
2. **Operating Conditions**
 - Dusty areas → frequent cleaning
 - Humid environments → insulation checks more often
3. **Load Conditions**
Overloaded machines age faster, requiring shorter maintenance intervals.
4. **Environmental Conditions**
High temperature accelerates insulation deterioration.
5. **Age of Equipment**
Older machines require more frequent inspections.
6. **Criticality of Equipment**
Equipment feeding hospitals or substations gets **strict maintenance schedules**.

7. Manufacturer's Recommendations & IS Standards

Maintenance intervals are often specified in manuals and IS/IEC standards.

Operating Conditions	Risk Level	Maintenance Frequency	Inspection Checklist
Normal Environment	Low	Every 6 Months	<ul style="list-style-type: none"> ✓ Visual Inspection ✓ Check Lubrication ✓ Inspect Belts & Hoses ✓ Test Safety Devices
Harsh Environment (Dust, Moisture, Chemicals)	Medium	Every 3 Months	<ul style="list-style-type: none"> ✓ Clean & Remove Debris ✓ Check Seals & Gaskets ✓ Inspect Electrical Components ✓ Check for Corrosion
Heavy Usage / High Load	High	Monthly	<ul style="list-style-type: none"> ✓ Check for Wear & Fatigue ✓ Test Alignment ✓ Inspect Bearings & Gears ✓ Monitor Temperature
Critical Systems / Safety Equipment	Very High	Weekly	<ul style="list-style-type: none"> ✓ Test Emergency Stops ✓ Verify Alarm Systems ✓ Check Backup Power ✓ Test Sensors & Controls

Fig.2.7.a. Operating conditions → Risk level → Maintenance frequency → Inspection checklist

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

- In **power substations**, torque wrenches ensure correct tightening of busbars.
- Industries maintain **tool inventory registers** and **maintenance logbooks**.
- Preventive maintenance reduces **unexpected shutdowns**, saving lakhs of rupees.
- Predictive tools like **thermal scanners and vibration analyzers** are now used in modern plants.

Industry practice: Maintenance schedules are often integrated into **Computerized Maintenance Management Systems (CMMS)**.

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Proper tools ensure **safe, accurate, and standard installation**.
- Testing instruments are mandatory before energization.
- Preventive maintenance depends on **equipment type, environment, load, and age**.
- Maintenance is **planned reliability**, not just repair work.

Typical Student Doubts

- *Is Megger testing done before or after installation?* → **Both**
- *Why older machines fail faster?* → **Insulation aging and wear**

Mentorship Note (Career-Oriented Tip)

Mastering **tools, testing devices, and maintenance planning** directly prepares you for roles such as **Maintenance Engineer, Substation Technician, Field Service Engineer, and Commissioning Supervisor**. These topics are **frequently asked in interviews, practical exams, and site jobs**. Students who understand preventive maintenance often grow faster into **shift in-charge and reliability engineer roles**.

Remember: Good engineers fix faults; **great engineers prevent them**.

Lecture:10

Unit 2.8. Concept of Maintenance and Types of Maintenance

1. Hook / Introduction (≈ 5 minutes)

👉 *Do you wait for your mobile phone to completely stop working before servicing it?*

Today's lecture will help you understand:

- What maintenance really means
- Why different types of maintenance are required
- How industries decide *when* and *how* to maintain equipment

2. Core Concepts (≈ 40 minutes)

2.8.1 What is Maintenance?

Maintenance is defined as:

"All activities carried out to keep electrical equipment in good working condition or to restore it to working condition."

Maintenance ensures:

- Reliability
- Safety
- Efficiency
- Longer equipment life

🔴 **Simple analogy:**

Maintenance is like **regular health check-ups for machines**.

2.8.2 Need for Maintenance of Electrical Equipment

Maintenance is required to:

- Avoid sudden failures
- Reduce downtime
- Ensure safety of personnel
- Maintain performance and efficiency
- Reduce repair cost

Fun Fact:

Studies show that **preventive maintenance can reduce breakdowns by 60–70%**.

2.8.3 Classification of Maintenance

As per syllabus and industry practice, maintenance is broadly classified into:

1. **Routine Maintenance**
2. **Preventive Maintenance**
3. **Breakdown Maintenance**

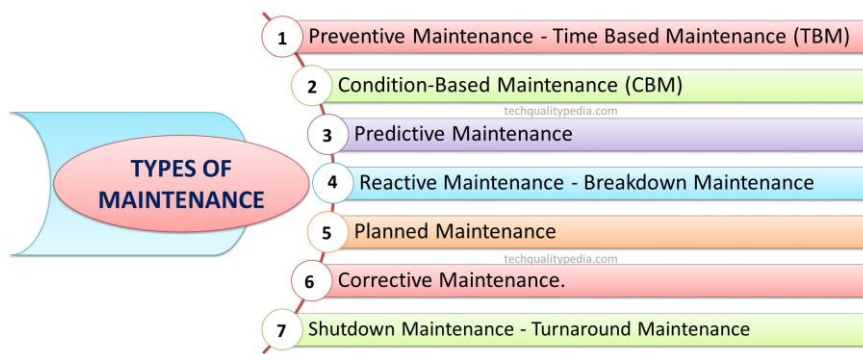


Fig.2.8.a.Flowchart showing *Maintenance* → *Routine / Preventive / Breakdown*

2.8.4 Routine Maintenance

Routine maintenance consists of **regular, simple activities** carried out during normal operation.

Examples:

- Cleaning of machines
- Checking oil level
- Tightening loose connections
- Observing noise, vibration, temperature

Characteristics:

- Simple and repetitive
- Does not require shutdown
- Performed by operators or technicians

Exam Tip:

Routine maintenance is often asked as a **short-note question**.

2.8.5 Preventive Maintenance

Preventive maintenance is **planned maintenance**, carried out at predetermined intervals to prevent failure.


Examples:

- Insulation resistance testing

- Bearing lubrication
- Checking earthing resistance
- Calibration of protection devices

Advantages:

- Reduces unexpected failures
- Improves reliability
- Saves repair cost
- Extends equipment life

MAINTENANCE SCHEDULE 		
WEEKLY	MONTHLY	YEARLY
✓ Inspect Equipment	✓ Check Fluid Levels	✓ Perform Full Inspection
✓ Lubricate Moving Parts	✓ Inspect Belts & Hoses	✓ Service HVAC System
✓ Check for Leaks	✓ Test Electrical Systems	✓ Calibrate Equipment
✓ Test Safety Devices	✓ Examine Filters	✓ Check Fire Extinguishers
✓ Clean Work Area	✓ Check for Wear & Tear	✓ Review Safety Protocols

■ WEEKLY TASKS
 ■ MONTHLY TASKS
 ■ YEARLY TASKS

Fig.2.8.b.Maintenance schedule chart showing weekly, monthly, yearly tasks.

👉 *Golden statement:*

“Prevention is better than breakdown.”

2.8.6 Breakdown Maintenance

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

Examples:

- Motor rewinding after burn-out
- Replacement of damaged breaker
- Repair after cable fault

Disadvantages:

- Sudden stoppage
- High repair cost
- Production loss

- Safety risk

⚠ Important:

Industries prefer breakdown maintenance **only when preventive maintenance is not possible.**

2.8.7 Comparison of Maintenance Types

Aspect	Routine	Preventive	Breakdown
Planning	No	Yes	No
Cost	Low	Medium	High
Safety	Good	Very High	Risky
Reliability	Medium	High	Poor

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

In power plants and industries:

- Maintenance schedules are mandatory
- Logbooks are maintained
- Shutdown maintenance is planned yearly

A Diploma engineer often:

- Performs routine inspections
- Assists preventive maintenance teams
- Records maintenance data
- Identifies early signs of failure

🏭 Industry reality:

Companies with good maintenance culture have **higher productivity and fewer accidents.**

2.8.9. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Maintenance keeps equipment reliable and safe
- ✓ Routine maintenance is simple but essential
- ✓ Preventive maintenance avoids costly failures
- ✓ Breakdown maintenance should be minimized

Common Student Doubts

- “*Sir, is preventive maintenance costly?*”
 👉 Initially yes, but cheaper than breakdowns.
- “*Can breakdown maintenance be avoided fully?*”
 ❌ No, but it can be greatly reduced.

Mentorship & Career Tip 🌱

Understanding maintenance makes you:

- Valuable in **industry and utilities**

- Better prepared for **site jobs**
- Strong in **interviews and promotions**

👉 Remember:

Good engineers don't wait for failures — they prevent them.

Lecture :11

Unit 2.9: Preventive Maintenance – Procedure for Developing Maintenance Schedules for Electrical Machines

1. Hook / Introduction (≈ 5 minutes)

Electrical machines like motors, alternators, and transformers behave the same way. They rarely fail suddenly. If we plan and follow **preventive maintenance schedules**, we can detect problems early and avoid costly breakdowns.

Today, you will learn **how preventive maintenance schedules are developed**, not just what preventive maintenance is.

2. Core Concepts (≈ 40 minutes)

2.9.1 What is Preventive Maintenance Scheduling?

A **preventive maintenance schedule** is a **planned timetable** that specifies:

- What maintenance activity is to be done
- When it should be done
- How frequently it should be done
- Who is responsible for it

📌 Simple definition:

Preventive maintenance scheduling means **maintaining machines before they fail**.

2.9.2 Objectives of Preventive Maintenance Schedules

The main objectives are:

- To minimize breakdowns
- To increase equipment life
- To ensure safety of operators
- To maintain efficiency and reliability
- To reduce maintenance cost

🧠 Fun Fact:

Industries with proper maintenance schedules save up to **30% operational cost**.

2.9.3 Factors Considered While Developing Maintenance Schedules

Before preparing a schedule, the following factors are studied:

1. **Type of Electrical Machine**
(Motor, alternator, transformer)

2. Operating Conditions

- Load variation
- Ambient temperature
- Dust, moisture, chemicals

3. Duty Cycle

- Continuous
- Intermittent

4. Manufacturer's Recommendations

5. Past Maintenance Records

2.9.4 Procedure for Developing Preventive Maintenance Schedule

Step-by-step procedure:

Step 1: Identify Equipment

- List all electrical machines
- Note ratings and location

Step 2: Decide Maintenance Activities

- Cleaning
- Inspection
- Lubrication
- Electrical testing (IR, vibration)

Step 3: Decide Maintenance Frequency

- Daily
- Weekly
- Monthly
- Quarterly
- Yearly

Step 4: Prepare Maintenance Schedule Chart

- Tabular format showing activity vs time

Step 5: Assign Responsibility

- Operator
- Technician
- Engineer

Step 6: Maintain Records

- Logbooks
- Checklists
- Test reports

Activity	Frequency	Responsible Person
Visual inspection of equipment	Daily / Weekly	Operator / Shift Technician
Cleaning of panels and equipment	Weekly	Maintenance Technician
Checking tightness of terminals	Monthly	Electrical Supervisor
Insulation resistance testing	Quarterly	Electrical Engineer
Lubrication of moving parts	Monthly	Maintenance Technician
Functional testing of protective devices	Quarterly	Electrical Engineer
Earth resistance measurement	Half-yearly	Electrical Engineer
Thermographic inspection (if applicable)	Half-yearly	Maintenance Engineer
Calibration of meters and relays	Yearly	Authorized Service Engineer
Overhaul and detailed inspection	Yearly	Maintenance Manager
Record updating and documentation review	Continuous / Monthly	Maintenance Supervisor

Fig :2.9.a. Maintenance schedule table with columns: *Activity – Frequency – Responsible Person*

2.9.5 Example: Preventive Maintenance Schedule of Induction Motor

- **Daily:**
Check noise, vibration, temperature
- **Monthly:**
Clean motor body, check terminals
- **Quarterly:**
Measure insulation resistance
- **Yearly:**
Bearing inspection and lubrication

✦ **Exam Tip:**

GTU often asks “Prepare preventive maintenance schedule of induction motor.”

2.9.6 Advantages of Proper Maintenance Scheduling

- Fewer emergency shutdowns
- Better planning of manpower
- Availability of spare parts
- Improved safety culture
- Predictable machine performance

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

In industries and power plants:

- Preventive maintenance schedules are **mandatory**
- Maintenance software or logbooks are used
- Shutdowns are planned annually

A Diploma engineer often:

- Follows prepared schedules
- Performs scheduled inspections
- Records test results
- Reports abnormal conditions

Industry Practice:

Machines without maintenance records are considered **unsafe for operation**.

2.9.8. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Preventive maintenance is planned and systematic
- ✓ Schedules are based on machine type and usage
- ✓ Records are as important as maintenance work
- ✓ Good scheduling prevents breakdowns

Common Student Doubts

- “*Sir, who prepares maintenance schedules?*”
 - 👉 Engineers, based on IS and manufacturer guidelines.
- “*Can one schedule fit all machines?*”
 - ✗ No, each machine needs a customized schedule.

Mentorship & Career Tip

Mastering preventive maintenance scheduling helps you:

- Think like a **maintenance engineer**
- Handle responsibilities confidently
- Excel in **industry, utilities, and power plants**

👉 Remember:

Engineers who plan maintenance control machines—others only react to failures

Lecture 12

Unit 2.10: Maintenance Schedules of Electrical Equipment as per IS

1. Hook / Introduction (≈ 5 minutes)

Good morning students 🙌

Let me ask you a powerful question:

👉 *Why do large power plants run continuously for years without major failure?*

The answer is **not luck**, and not expensive equipment alone.

The real secret is **disciplined maintenance schedules followed as per Indian Standards (IS)**.

In this lecture, we will not just talk about “maintenance”, but **what to maintain, when to maintain, and how often**, for the most important electrical equipment you will face in industry.

2. Core Concepts (≈ 40 minutes)

2.10.1 What Are IS-Based Maintenance Schedules?

Maintenance schedules as per IS are **standardized guidelines** that specify:

- Inspection activities
- Test intervals
- Cleaning and servicing frequency

🔑 **Key idea:**

IS standards ensure **uniform safety, reliability, and performance** across industries.

2.10.2 Maintenance Schedule of Power Transformer

Daily / Weekly

- Check oil level in conservator
- Observe breather silica gel colour
- Check for oil leakage and abnormal noise

Monthly

- Clean bushings
- Check earthing connections

Yearly

- Insulation resistance (IR) test
 - Oil BDV test
 - Buchholz relay inspection
-

2.10.3 Maintenance Schedule of Three-Phase Induction Motor

Daily

- Check temperature, vibration, noise

Monthly

- Clean cooling fan and air passages
- Tighten terminals

Quarterly

- Measure insulation resistance
- Check alignment and foundation bolts

Yearly

- Bearing inspection and lubrication

✦ **Exam Tip:**

This is one of the **most frequently asked schedules** in GTU exams.

2.10.4 Maintenance Schedule of Alternator

Routine

- Observe vibration and sound
- Check cooling system

Monthly

- Clean rotor and stator ventilation paths
- Check excitation system

Yearly

- IR test of windings
- Bearing inspection
- Alignment verification with prime mover

✦ **Important:**

Alternators demand **higher precision** than motors.

2.10.5 Maintenance Schedule of Circuit Breaker

Weekly

- Visual inspection
- Check mechanical operation

Monthly

- Clean contacts and insulating parts
- Check interlocks

Yearly

- Contact resistance measurement
 - Insulation resistance test
 - Timing test (for large breakers)
-

2.10.6 Maintenance Schedule of Batteries

Daily

- Check electrolyte level
- Check terminal cleanliness

Monthly

- Measure specific gravity
- Check charging voltage

Yearly

- Capacity test
- Replacement of weak cells

Fun Fact:

Battery failure is a major cause of **control and protection system failure**.

2.10.7 Maintenance Schedule of Solar & Wind Power Plants

Solar Plant

- Clean panels weekly
- Check inverter connections monthly
- Earthing and insulation check yearly

Wind Plant

- Blade inspection
- Gearbox oil check
- Generator and brake system inspection

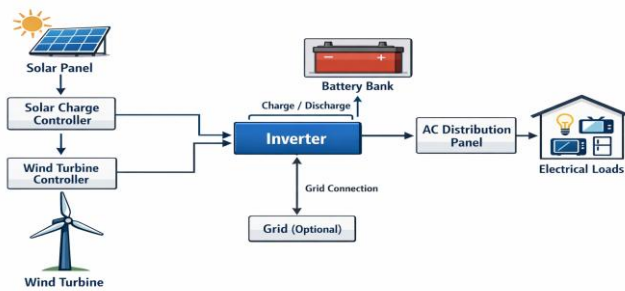


Fig.2.10.a.Block diagram of solar PV system and wind turbine.

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

In real industries:

- Maintenance schedules are displayed on panels
- Logbooks are mandatory
- IS-based schedules help during **audits and inspections**

A Diploma engineer:

- Follows schedules
- Records observations
- Assists in testing
- Learns equipment behaviour over time

Industry Reality:

Machines without maintenance records are treated as **unsafe assets**.

2.10.9. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ IS standards guide maintenance frequency
- ✓ Each equipment has a unique schedule
- ✓ Records are as important as maintenance work
- ✓ Renewable energy systems also need disciplined maintenance

Common Student Doubts

- “Sir, are IS numbers required in exams?”
 - 👉 Not mandatory—focus on **procedure and frequency**.
 - “Can schedules be modified?”
 - ✅ Yes, based on site conditions.
-

Mentorship & Career Tip

If you master IS-based maintenance schedules:

- You gain confidence in **power plants, substations, and industries**
- You perform better in **interviews and site work**
- You develop a **system-oriented engineering mindset**

👉 Remember:

Engineers who maintain systems well keep the nation powered.

STUDENT AI TOOLKIT – UNIT 2

Installation and Maintenance of Electrical Equipment

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

(Definitions, basics, simple explanations – Diploma friendly)

1. “**Explain the topic of installation and maintenance of electrical equipment in simple language suitable for diploma students.**”
2. “**Define maintenance of electrical equipment and explain its importance with two simple examples.**”
3. “**List and explain different types of maintenance used in electrical engineering.**”
4. “**Explain preventive maintenance in simple words and why it is preferred over breakdown maintenance.**”
5. “**What are the basic requirements of foundation for static and rotating electrical machines? Explain briefly.**”
6. “**Explain the concept of levelling and alignment of machines with neat explanation.**”

7. “Describe the installation procedure of a power transformer step by step in simple terms.”
8. “What is a maintenance schedule? Explain its purpose in electrical installations.”
9. “List the factors affecting preventive maintenance schedules and explain each briefly.”
10. “Prepare short notes on IS-based maintenance schedules of electrical equipment.”

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

(Application, comparison, examples, exam-oriented thinking)

11. “Compare routine maintenance, preventive maintenance, and breakdown maintenance with advantages and disadvantages.”
12. “Explain how environmental conditions affect the maintenance schedule of electrical machines.”
13. “Prepare a simple preventive maintenance schedule for a three-phase induction motor used in an industrial environment.”
14. “Analyze the effects of poor alignment in rotating electrical machines.”
15. “Explain how load conditions influence the maintenance frequency of electrical equipment.”
16. “Give a real-life industrial example where preventive maintenance helped avoid a major electrical failure.”
17. “Differentiate between maintenance requirements of static equipment and rotating equipment.”
18. “Explain the role of maintenance records and logbooks in improving system reliability.”
19. “Why are IS standards important while installing and maintaining electrical equipment? Explain with reasons.”
20. “Solve this situation: A motor frequently overheats. Analyze possible maintenance-related causes and solutions.”


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


(Design thinking, planning, distinction-level preparation)


21. “Design a complete preventive maintenance schedule for an electrical substation considering safety, reliability, and cost.”
22. “Create a flowchart showing the decision-making process for selecting the type of maintenance for electrical equipment.”
23. “Prepare a comparative maintenance plan for conventional power equipment and renewable energy systems.”


24. “Develop a checklist for installation and maintenance of electrical equipment that follows standard engineering practices.”

25. “Act as a maintenance engineer and create a one-year maintenance strategy for multiple electrical machines operating under different conditions.”

 **Learning Coach Tip for Students**

 Use **Low-Level prompts** before exams for quick revision

 Use **Moderate-Level prompts** for writing strong theory answers

 Use **High-Level prompts** for projects, interviews, and distinction-level preparation

If you can explain a topic to AI clearly, you truly understand it.

 **MASTERY CHECK – UNIT 2**

Installation and Maintenance of Electrical Equipment

1. Key Definitions / Glossary (15 Important Terms)

(Frequently used in exams, viva, labs, and site work)

1. **Installation** – The process of placing, assembling, and connecting electrical equipment for safe operation.
2. **Foundation** – A rigid base provided to support electrical machines and absorb vibration.
3. **Levelling** – The process of making equipment perfectly horizontal on its foundation.
4. **Alignment** – Correct positioning of machine shafts so they lie on the same axis.
5. **Misalignment** – Incorrect shaft positioning causing vibration, noise, and wear.
6. **Switchgear** – Devices used for controlling, protecting, and isolating electrical circuits.
7. **Circuit Breaker** – A protective device that interrupts current during fault conditions.
8. **Isolator** – A mechanical switch used to disconnect equipment from supply under no-load condition.
9. **Control Panel** – An enclosure containing instruments, switches, and protection devices.
10. **Maintenance** – Activities carried out to keep equipment in good working condition.
11. **Routine Maintenance** – Regular simple maintenance performed during normal operation.
12. **Preventive Maintenance** – Planned maintenance done at fixed intervals to prevent failures.
13. **Breakdown Maintenance** – Maintenance carried out after equipment fails.
14. **Maintenance Schedule** – A planned timetable of maintenance activities.
15. **Earthing** – Connecting equipment body to ground to ensure safety.

2. FAQ & Assessment Section

A. Multiple Choice Questions (20 MCQs)

1. The main purpose of foundation for rotating machines is to:

- A. Improve efficiency
- B. Reduce current
- C. Absorb vibration
- D. Increase speed

2. Levelling of machines is checked using:

- A. Vernier caliper
- B. Spirit level
- C. Megger
- D. Clamp meter

3. Alignment is most critical in:

- A. Static equipment
- B. Lighting circuits
- C. Direct-coupled drives
- D. Control panels

4. Misalignment mainly results in:

- A. Low voltage
- B. High vibration
- C. Reduced insulation
- D. Poor earthing

5. Which device provides visible isolation?

- A. Circuit breaker
- B. Fuse
- C. Isolator
- D. Relay

6. Circuit breaker is designed to operate under:

- A. No-load condition only
- B. Normal condition only
- C. Fault condition
- D. Mechanical fault only

7. Control panels mainly house:

- A. Cables only
- B. Mechanical tools
- C. Control and protection devices
- D. Batteries only

8. Preventive maintenance is carried out:

- A. After failure
- B. Before failure
- C. During breakdown
- D. Accidentally

9. Which maintenance type is unplanned?

- A. Routine
- B. Preventive
- C. Predictive
- D. Breakdown

10. The main disadvantage of breakdown maintenance is:

- A. High reliability
- B. Low cost
- C. Sudden downtime
- D. Easy planning

11. Maintenance schedules help in:

- A. Increasing voltage
- B. Reducing manpower
- C. Avoiding failures
- D. Increasing losses

12. Which factor affects preventive maintenance schedule most?

- A. Paint colour
- B. Operating conditions
- C. Machine weight
- D. Room size

13. Dusty environment requires:

- A. Less maintenance
- B. No maintenance
- C. Frequent cleaning
- D. Higher voltage

14. Insulation resistance is measured using:

- A. Ammeter
- B. Voltmeter
- C. Megger
- D. Wattmeter

15. Overloading mainly affects:

- A. Shaft length
- B. Temperature
- C. Colour
- D. Shape

16. Earthing is provided mainly for:

- A. Appearance
- B. Cooling
- C. Safety
- D. Speed control

17. Which maintenance has lowest cost initially?

- A. Preventive
- B. Routine
- C. Breakdown
- D. Predictive

18. Manufacturer recommendations are used for:

- A. Design only
- B. Installation only
- C. Maintenance planning
- D. Cost calculation

19. Solar power plant maintenance mainly includes:

- A. Fuel checking
- B. Panel cleaning
- C. Oil testing
- D. Rewinding

20. Maintenance records are useful for:

- A. Decoration
- B. Audits and planning
- C. Voltage control
- D. Wiring design

Answer Key (MCQs)


1-C, 2-B, 3-C, 4-B, 5-C, 6-C, 7-C, 8-B, 9-D, 10-C, 11-C, 12-B, 13-C, 14-C, 15-B, 16-C, 17-C, 18-C, 19-B, 20-B

B. Short Answer / Viva Questions (10)

1. Why is proper foundation necessary for rotating electrical machines?
 2. Explain levelling and alignment with respect to machine installation.
 3. State any four effects of misalignment.
 4. Differentiate between circuit breaker and isolator.
 5. Define preventive maintenance and state its advantages.
 6. Why is breakdown maintenance not preferred in industries?
 7. List any four factors affecting preventive maintenance schedules.
 8. What is the importance of maintenance records?
 9. Explain why earthing is essential for electrical equipment.
 10. Write short note on maintenance schedule of induction motor.
-

 **Examiner's Tip for Students**

- **Glossary** → 2-mark & viva answers
- **MCQs** → Competitive exams & internal tests
- **Short answers** → 5-mark theory questions

 If you can **explain these answers confidently**, you are **exam-ready for Unit-2**.

Unit 3: Commissioning of Transformer

Subject: Commissioning & Maintenance of Electrical Equipment's

Programme: Diploma Electrical Engineering (GTU – w.e.f. 2025–26)

Total Duration: 10 Lectures (10 Hours)

Unit Weightage: 23% (High Exam Weightage)

Prepared in the role of an **expert lecturer & mentor**, aligned with **OBE** and **NEP-2020**, and fully based on the **uploaded GTU syllabus**

UNIT AIM (OBE-ALIGNED)

After completing **Unit-3**, students will be able to:

- Explain the importance and need of transformer commissioning
- Differentiate type, routine, and special tests
- Perform and interpret pre-commissioning tests safely
- Describe energization procedure and final checks
- Identify faults and troubleshoot transformer & auxiliaries

UNIT-3: DETAILED STUDY PLAN (10 LECTURE MODEL)

Topic-wise Breakdown, Sequencing & Time Allocation

Lecture No.	Syllabus Topic (Strictly as per GTU)	Topic Category	Hours	Exam Importance	Practical / Industry Relevance
L1	3.1 Importance of Commissioning of Transformer	Core	1	Medium	High
L2	3.2 Difference Between Type Test, Routine Test & Special Test	Core	1	High	Medium
L3	3.3 Pre-Commissioning Checks – Significance & Overview	Core	1	High	Very High
L4	3.3.1 Insulation Resistance Measurement (All Circuits & PI)	Core	1	Very High	Very High
L5	3.3.2 Transformer Oil BDV Test & Oil Filtering	Core	1	Very High	Very High
L6	3.3.3 Polarity & Vector Group Test + 3.3.4 Ratio Test (All Taps)	Core	1	Very High	Very High
L7	3.3.5 to 3.3.10 Magnetizing Current, Magnetic Balance, Tan δ , SC Impedance, Contact & Winding Resistance Tests	Core	2	Very High	Very High
L8	3.4 Final Commissioning Checks	Supporting	1	Medium	High
L9	3.5 Procedure – Energization of Transformer	Application	1	High	Very High
L10	3.6 Faults & Troubleshooting of Transformer and Auxiliary Equipment	Application	1	High	High

Total = 10 Lectures

LOGICAL PEDAGOGICAL SEQUENCING

- 1 Why commissioning is necessary
- 2 What tests exist and why they differ
- 3 How readiness is verified before charging
- 4 Electrical & oil health verification
- 5 Verification of polarity, ratio & magnetic behaviour
- 6 Final readiness and energization
- 7 Fault identification and troubleshooting

This sequence ensures: **Concept → Testing → Interpretation → Energization → Fault handling**

TOPIC CLASSIFICATION (For Teaching & Assessment Strategy)

- ◆ **CORE TOPICS (High Weightage + Must-Know)**
 - Importance of commissioning
 - Type, routine & special tests
 - All pre-commissioning tests (IR, BDV, ratio, polarity, vector group, etc.)
 - Energization procedure
 - ◆ **SUPPORTING TOPICS**
 - Significance of pre-commissioning checks
 - Final commissioning checks
 - ◆ **APPLICATION-ORIENTED TOPICS**
 - Energization procedure
 - Faults & troubleshooting of transformer and auxiliaries
-

EXAM ORIENTATION (Based on GTU Trends)

Very High Probability (4–7 Marks)

- Pre-commissioning tests of transformer
- IR test & polarization index
- Oil BDV test and significance
- Difference between type, routine & special tests
- Procedure for energization of transformer

Short Answer / Viva

- Define commissioning
 - Purpose of vector group test
 - Why $\tan \delta$ test is required
 - Importance of magnetizing current test
-

NEP-2020 & SKILL INTEGRATION

✓ Emphasis on **hands-on testing awareness**

- ✓ Strong safety and responsibility culture
- ✓ Exposure to real commissioning documentation
- ✓ Supports internship, apprenticeship & site readiness

Lecture 1: Topic 3.1: Importance of Commissioning of Transformer

(Designed for a 60-minute lecture, ~500 words, Diploma Electrical Engineering)

3.1.1 Hook / Introduction (≈ 5 minutes)

👉 Would you start a brand-new vehicle without checking brakes, engine oil, and fuel system?

Of course not. Even though the vehicle is new, **checking before use is essential.**

A transformer is similar—but far more expensive and critical. Once installed, if it fails, the loss is not just money, but **power supply, safety, and trust.**

This is where **commissioning** plays a vital role. Commissioning is the *final health check* of a transformer before it is energized and put into service. Today, we will understand **why commissioning of transformer is so important** and why industries never skip it.

3.1.2. Core Concepts (≈ 40 minutes)

3.1.1 What is Commissioning of Transformer?

Commissioning is the process of carrying out **systematic inspection, testing, and verification** of a transformer after installation and before energization to ensure that:

- It is safe to operate
- It meets design and IS standards
- It will perform reliably under load



Fig.3.1.a. Flow diagram: Installation → Testing → Inspection → Energization

3.1.2 Why Commissioning is Necessary

Even a new transformer may have:

- Hidden transport damage
- Moisture in insulation
- Loose connections
- Oil contamination

Commissioning helps to **detect and correct these issues before failure.**

🔴 **Analogy:**

Commissioning is like a *medical check-up before joining a physically demanding job.*

3.1.3 Importance of Transformer Commissioning

1. Ensures Electrical Safety

- Prevents insulation failure
- Reduces risk of short circuit and fire
- Protects operating personnel



Fig.3.1.b. Transformer with earthing and testing instruments shown.

2. Improves Reliability and Life of Transformer

- Detects weak insulation and winding problems
- Prevents early breakdown
- Ensures long service life

⚠ Fun Fact:

Many transformer failures occur within the **first few days of operation** due to poor commissioning.

3.1.4. Confirms Correct Installation

Commissioning verifies:

- Correct connections
- Proper earthing
- Correct tap settings
- Functional accessories.

3.1.5. Ensures Compliance with IS Standards

Indian Standards require:

- Mandatory pre-commissioning tests
- Safe energization procedures

Commissioning ensures the transformer meets **statutory and technical requirements**.

3.1.6. Reduces Costly Breakdowns

- Prevents damage to transformer and connected equipment
- Avoids power outages and penalties
- Saves repair and replacement cost

With Commissioning



Without Commissioning



Fig.3.1.c.Comparison sketch:With commissioning → Safe operation
Without commissioning → Failure & fire

3.1.6 Consequences of Skipping Commissioning

If commissioning is ignored:

- Transformer may fail at first energization
- Oil may break down
- Insulation may puncture
- Fire and explosion risks increase

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

In real industries and substations:

- No transformer is energized without commissioning report
- Tests are conducted in presence of utility engineers
- Commissioning records are kept for audits and insurance

3.1.3. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Commissioning ensures safety
- ✓ It confirms readiness before energization
- ✓ It improves reliability and service life
- ✓ It prevents early and costly failures

Common Student Doubts

Q: *Is commissioning required for new transformers also?*

👉 **Yes**, new transformers must be commissioned.

Q: *Can a transformer work without commissioning?*

👉 It may work temporarily, but risk of failure is very high.

Mentorship & Career Tip 🌱

If you understand the **importance of commissioning**:

- You develop a **safety-first engineering mindset**
- You gain confidence during substation and industrial work
- You become a **trusted engineer**, not just a technician

👉 *Good engineers never hurry to switch ON without checking.*

Lecture :2: Topic 3.2: Difference Between Type Test, Routine Test & Special Test (60-minute session | ~500 words | Diploma Electrical Engineering)

3.2.1. Hook / Introduction (≈ 5 minutes)

👉 When you buy a mobile phone, what do you expect from the company?

- It should be **designed properly**
- It should be **checked before delivery**
- It should work **reliably under special conditions**

A transformer is also checked in **three different ways**, but at **three different stages**.

These checks are called **Type Tests, Routine Tests, and Special Tests**.

Many students confuse these tests in exams—but today, we will clearly understand **why all three are required, how they differ, and where they are used**.

3.2.2. Core Concepts (≈ 40 minutes)

3.2.2.1 Why Testing of Transformer is Required

Testing ensures that:

- The transformer design is correct
- Manufacturing quality is maintained

- The transformer is safe and reliable before commissioning

3.2.2.2 Type Test

Definition

Type tests are performed on a **prototype or sample transformer** to check the **design and performance** as per IS standards.

Purpose

- To prove the design is correct
- To verify performance under rated conditions

Important Points

- Conducted **once** for a particular design
- Not repeated for every transformer
- Done at manufacturer's works

Examples of Type Tests

- Temperature rise test
- Impulse voltage test
- Short-circuit test



Fig.3.2.a. Factory testing setup with high-voltage impulse generator connected to transformer.

3.2.2.3 Routine Test

Definition

Routine tests are performed on **every transformer** manufactured to ensure it is free from manufacturing defects.

Purpose

- To check workmanship
- To ensure safe operation before dispatch

Important Points

- Conducted on **each unit**
- Mandatory before supply

- Simple and quick tests

Examples of Routine Tests

- Measurement of winding resistance
- Insulation resistance test
- Ratio test
- Polarity test



Fig.3.2.b. Technician measuring winding resistance using test instruments.

3.2.2.4 Special Test

Definition

Special tests are conducted **only when required** by customer or operating conditions.

Purpose

- To check special performance requirements
- To simulate actual operating conditions

Important Points

- Not compulsory
- Conducted on request
- Useful for critical applications

Examples of Special Tests

- Zero sequence impedance test
- Noise level test
- Vibration test

3.2.2.5 Comparison of Tests (Exam-Oriented)

🔴 **Visual Table to draw in exam:**

Parameter	Type Test	Routine Test	Special Test
Purpose	Design verification	Quality check	Special condition
Frequency	Once per design	Every unit	As required
Compulsory	Yes	Yes	No
Conducted at	Manufacturer	Manufacturer	Manufacturer / Site

⚠️ **Exam Tip:**

GTU frequently asks “Differentiate between Type, Routine & Special Tests” (4 or 7 marks).

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

In power utilities:

- Type tests are checked during **tender approval**
- Routine test certificates are verified before acceptance
- Special tests are required for:
 - Power transformers
 - Railway substations
 - Heavy industrial loads

A **Diploma Engineer** is expected to:

- Understand test certificates
- Identify which test is applicable
- Assist during commissioning verification

3.2.4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Type tests check **design**
- ✓ Routine tests check **manufacturing quality**
- ✓ Special tests check **special operating needs**
- ✓ All tests ensure transformer safety and reliability

Common Student Doubts

Q: Are type tests conducted on every transformer?

👉 No, only on a prototype.

Q: Are special tests compulsory?

👉 No, they are done only if required.

Mentorship & Career Tip 🌱

Understanding transformer tests:

- Makes you confident during **commissioning & inspection**
- Helps you read **test reports and tender documents**
- Prepares you for **utility, maintenance, and QA roles**

👉 Engineers who understand testing are trusted with responsibility.

Lecture:3:Topic 3.3: Pre-Commissioning Checks – Significance & Overview
(60-minute lecture | Diploma Electrical Engineering | ~500 words)

3.1. Hook / Introduction (≈ 5 minutes)

👉 Would you start a brand-new bike at full speed without checking fuel, oil, brakes, or tyres? Of course not. Even a small mistake can cause serious damage.

Similarly, **before energizing a transformer**, we must perform **pre-commissioning checks**. In real industries, many transformer failures occur **not due to design faults**, but due to **poor or skipped pre-commissioning checks**.

Today's topic is extremely important because **one wrong step before switching ON can damage equipment worth lakhs of rupees**.

3.2. Core Concepts (≈ 40 minutes)

3.2.1 What are Pre-Commissioning Checks?

Pre-commissioning checks are a series of inspections and tests carried out **after installation but before energizing the transformer**.

Purpose

- To ensure correct installation
- To verify safety and readiness for operation
- To prevent damage during first energization



Fig.3.2.a.Block diagram showing stages:
Installation → Pre-Commissioning Checks → Energization → Normal Operation

3.2.2 Significance of Pre-Commissioning Checks

Pre-commissioning checks help to:

- Detect installation errors
- Confirm electrical and mechanical safety
- Reduce chances of breakdown at initial start

⚠️ **Important Note:**

Once a transformer is energized, **rectifying faults becomes risky and expensive.**

◆ **Fun Fact:**

Over 60% of early transformer failures are due to poor commissioning practices.

3.2.3 Categories of Pre-Commissioning Checks

Pre-commissioning checks are broadly divided into **three categories:**

A. Visual & Mechanical Checks

These checks ensure physical correctness.

Examples:

- Tightness of all bolts and connections
- Condition of bushings (no cracks or damage)
- Proper earthing of transformer tank
- Oil leakage inspection

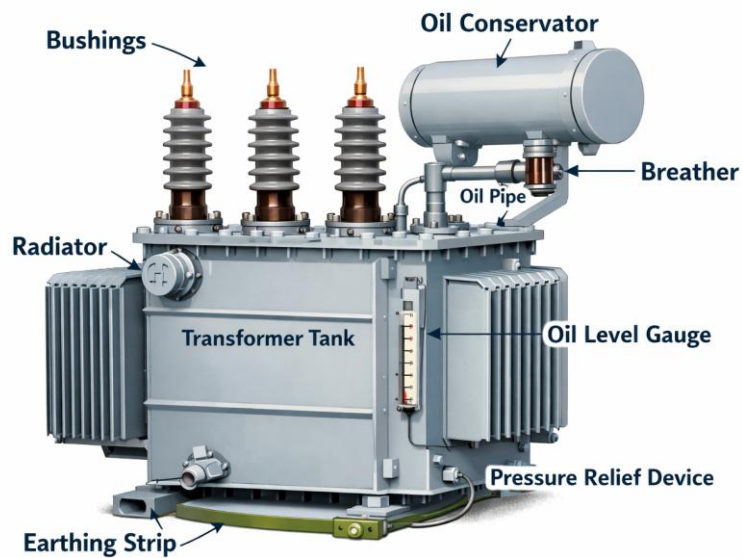


Fig.3.2.b. Transformer diagram showing bushings, earthing strip, oil conservator.

B. Electrical Checks

These checks ensure electrical safety.

Examples:

- Insulation resistance (IR) test
- Continuity of windings

- Polarity check
- Correct tap-changer position



Fig.3.2.c.Megger connected between winding and earth.

C. Oil & Accessory Checks

These checks ensure healthy insulation and cooling.

Examples:

- Oil level in conservator
- Oil dielectric strength (BDV)
- Breather condition (silica gel color)
- Operation of Buchholz relay (if provided)

3.2.4 Sequence of Pre-Commissioning Checks

Pre-commissioning must follow a **logical order**.

⚠ Exam Tip:

Questions like “*Explain the significance of pre-commissioning checks*” or “*List pre-commissioning checks of transformer*” are commonly asked.

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

In power utilities and industries:

- Pre-commissioning is mandatory before energization
- Engineers maintain **checklists and test records**
- Utilities do not allow energization without clearance

A **Diploma Engineer’s role** includes:

- Assisting in inspection
- Recording test values
- Reporting abnormal observations

In substations, **senior engineers verify pre-commissioning reports before issuing energization permission.**

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Pre-commissioning checks are done **before energization**
- ✓ They ensure safety, reliability, and long service life
- ✓ Checks include visual, mechanical, electrical, and oil tests
- ✓ Skipping checks can cause serious failures

Common Student Doubts

Q: *Are pre-commissioning checks compulsory?*

👉 Yes, especially for power transformers.

Q: *Can energization be done without these checks?*

👉 Never recommended—it is unsafe.

Mentorship & Career Tip 🌱

If you master pre-commissioning checks:

- You gain **confidence in substations and industries**
- You become valuable in **maintenance and commissioning teams**
- You develop a **safety-first engineering mindset**

👉 *Good engineers don't just switch ON machines—they prepare them correctly.*

Lecture :4:Topic 3.3.1: Insulation Resistance (IR) Measurement – All Circuits & Polarization Index (PI)(60-minute lecture | Diploma Electrical Engineering | ~500 words)

1. Hook / Introduction (≈ 5 minutes)

Good morning students 🌞

Before I start today's topic, think about this:

👉 Would you touch a live wire if its insulation is damaged?

Obviously not—because **insulation is life-saving**.

In a transformer, insulation separates:

- High voltage from low voltage
- Windings from earth
- Electrical safety from disaster

That is why **Insulation Resistance (IR) measurement** is the **most important pre-commissioning test**.

No matter how big or expensive the transformer is, **if insulation fails, the transformer fails**.

2. Core Concepts (≈ 40 minutes)

3.3.1.1 What is Insulation Resistance (IR)?

Insulation Resistance is the resistance offered by insulation material to the flow of leakage current.

🔴 **Simple meaning:**

Higher IR value = Better insulation = Safer transformer

IR is measured using a **Megger (Insulation Resistance Tester)**.

3.3.1.2 Purpose of IR Measurement

IR test is performed to:

- Check insulation condition before energization

- Detect moisture, dirt, or insulation damage
- Prevent internal faults

⚠ Important Rule: Transformer should **never be energized if IR value is low.**

3.3.1.3 IR Measurement for All Circuits

IR measurement is carried out between different transformer parts.

Common IR Tests

1. **HV to Earth**
2. **LV to Earth**
3. **HV to LV**

✦ Visual: Three separate diagrams showing:

- HV winding → Earth
- LV winding → Earth
- HV winding → LV winding

Each test ensures proper insulation separation.

3.3.1.4 Test Procedure (Basic Steps)

1. Isolate transformer completely
2. Discharge windings
3. Connect Megger leads properly
4. Apply test voltage
5. Record readings at 1 minute and 10 minutes

3.3.1.5 What is Polarization Index (PI)?

Polarization Index (PI) measures insulation quality in electrical equipment by comparing insulation resistance (IR) values over time.

Definition

PI is defined as the ratio of the IR value measured after 10 minutes to the IR value after 1 minute, confirming the formula $PI = \frac{IR \text{ at } 10 \text{ min}}{IR \text{ at } 1 \text{ min}}$. This diagnostic test applies DC voltage to windings in motors, generators, or transformers and tracks resistance changes. It isolates absorption current effects from leakage, revealing moisture or contamination.

Purpose

The test distinguishes capacitive, absorption, and leakage currents during insulation assessment. Healthy insulation shows PI above 2, as absorption current decays significantly by 10 minutes. Values below 1.5 signal deterioration needing maintenance.

✦ Meaning:

- PI indicates **dryness and health of insulation**
- High PI = Good insulation
- Low PI = Moisture or contamination present

3.3.1.6 Importance of PI Test

PI test helps to:

- Detect moisture in insulation
- Judge long-term insulation reliability
- Decide readiness for commissioning

⚠ **Exam Tip:** GTU often asks: “*Define Polarization Index and explain its significance.*”

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

In power utilities and industries:

- IR and PI tests are mandatory before commissioning
- Results are recorded in commissioning reports
- Transformers with low PI are **dried or oil filtered**

A Diploma Engineer’s responsibility:

- Perform IR test safely
- Record readings correctly
- Report abnormal values

In substations, **energization permission is denied if PI is unsatisfactory.**

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ IR measures insulation health
- ✓ Megger is used for IR testing
- ✓ IR is measured between HV, LV, and Earth
- ✓ PI indicates dryness of insulation
- ✓ Good insulation ensures safe commissioning

Common Student Doubts

Q: *Can we energize transformer with low IR?*

👉 No, it is dangerous.

Q: *Is PI test compulsory?*

👉 Yes, especially for large transformers.

Mentorship & Career Tip 🌱

Mastering IR and PI testing will:

- Make you confident during commissioning jobs
- Improve your practical and safety skills
- Prepare you for **substation, utility, and maintenance roles**

👉 *Good engineers test before they trust.*

Lecture:5:Topic 3.3.2: Transformer Oil BDV Test & Oil Filtering

(60-minute lecture | Diploma Electrical Engineering | ~500 words)

👉 Can a transformer survive without good insulation oil?

Transformer oil is not just a cooling medium—it is the **liquid insulation** that protects the transformer from electrical breakdown.

Many transformer failures occur **not because of winding faults**, but because **oil quality deteriorates** due to moisture, dust, and aging.

That is why **BDV (Breakdown Voltage) test of transformer oil** is a **critical pre-commissioning test**.

Today, we will understand **how oil strength is tested** and **how oil filtering restores its quality**.

2. Core Concepts (≈ 40 minutes)

3.3.2.1 Role of Transformer Oil

Transformer oil serves two main purposes:

- **Electrical insulation** between live parts
- **Cooling** by carrying heat away from windings

🔴 **Fun Fact:** Clean oil can withstand **very high voltage**, but even a **drop of moisture can reduce its strength drastically**.

3.3.2.2 What is BDV Test?

BDV (Breakdown Voltage) test measures the voltage at which transformer oil electrically breaks down.

🔴 **Simple meaning:**

Higher BDV value = Better oil quality

The test is carried out using a **BDV test set**.

3.3.2.3 Purpose of BDV Test

BDV test is performed to:

- Check insulation strength of oil
- Detect moisture, dust, and impurities
- Decide whether oil is fit for service

⚠️ **Exam Tip:** BDV test is always performed **before energizing the transformer**.

3.3.2.4 BDV Test Procedure (Overview)

1. Take oil sample from transformer
 2. Pour oil into test cup
 3. Maintain standard electrode gap
 4. Apply voltage gradually
 5. Note voltage at breakdown
 6. Repeat test and take average value
-

3.3.2.5 Causes of Low BDV Value

Low BDV may be due to:

- Moisture content
- Dust or sludge
- Aging of oil
- Improper storage

⚠ **Important Point:** Low BDV oil can cause **internal flashover**.

3.3.2.6 What is Oil Filtering?

Oil filtering is the process of removing:

- Moisture
- Solid impurities
- Dissolved gases

This improves:

- Insulation strength
 - Cooling performance
 - Transformer life
-

3.3.2.7 Oil Filtering Process (Basic Steps)

1. Oil is drained from transformer
2. Oil is heated to remove moisture
3. Oil passes through filters
4. Clean oil is re-filled into transformer

♦ **Key Idea:**

Oil filtering restores oil quality **without replacing oil**.

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

In substations and industries:

- BDV test is performed periodically
- Oil filtering plants are used on-site
- Records are maintained in maintenance logs

Diploma Engineers are often responsible for:

- Collecting oil samples
- Assisting in BDV testing
- Monitoring oil filtration process

⚡ In power utilities, transformers are **never energized if BDV value is below standard**.

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Transformer oil provides insulation and cooling
- ✓ BDV test checks oil insulation strength
- ✓ Low BDV indicates moisture or contamination
- ✓ Oil filtering improves oil quality
- ✓ Clean oil ensures safe commissioning

Common Student Doubts

Q: *Can oil be reused after filtering?*

👉 Yes, if BDV value becomes satisfactory.

Q: *Is BDV test compulsory?*

👉 Yes, it is a mandatory commissioning test.

Mentorship & Career Tip 🌱

Understanding BDV testing and oil filtering:

- Makes you job-ready for substations
- Improves safety awareness
- Helps in maintenance and commissioning roles

👉 *Good engineers don't guess oil quality—they test it.*

Lecture:6:Topic 3.3.3 Polarity & Vector Group Test and 3.3.4 Ratio Test (All Taps)(60-minute lecture | Diploma Electrical Engineering | ~500 words)

1. Hook / Introduction (≈ 5 minutes)

👉 If two transformers are connected in parallel with wrong polarity or wrong ratio, what will happen?

Instead of sharing load, they will **oppose each other**, causing **circulating current, overheating, and damage**.

That is why before commissioning a transformer, engineers must confirm:

- Correct **polarity**
- Correct **vector group**
- Correct **voltage ratio on all taps**

Today's topic ensures that the transformer is **electrically compatible** with the system before energization.

2. Core Concepts (≈ 40 minutes)

3.3.3 Polarity Test

What is Polarity?

Polarity indicates the **relative direction of induced voltages** in the primary and secondary windings of a transformer.

🔴 Simple meaning:

It tells us whether primary and secondary voltages **add or subtract**.

Purpose of Polarity Test

Polarity test is carried out to:

- Ensure correct terminal connections
- Avoid short circuits during parallel operation
- Confirm transformer suitability for system connection

✦ **Exam Tip:** Polarity test is compulsory for **single-phase transformers**.

Polarity Test Procedure (Basic)

1. Apply low AC voltage to primary
2. Measure voltages across selected terminals
3. Observe whether voltages add or subtract

✦ **Visual to draw:**

Single-phase transformer showing additive and subtractive polarity connections.

Vector Group Test

What is Vector Group?

Vector group represents:

- Phase difference between HV and LV voltages
- Type of winding connection (Star / Delta)

Example: **Dyn11**

✦ **Meaning of Dyn11:**

- D → Delta (HV)
 - y → Star (LV)
 - n → Neutral
 - 11 → 30° phase displacement
-

Importance of Vector Group Test

Vector group test ensures:

- Correct phase sequence
- Compatibility for parallel operation
- Safe system integration

⚠ Wrong vector group = transformer **cannot be paralleled**.

3.3.4 Ratio Test (All Taps)

What is Transformation Ratio?

The transformation ratio K equals $\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1}$, where V_1 and N_1 denote primary voltage and turns, while V_2 and N_2 denote secondary values. The provided formula

Primary Voltage:Secondary Voltage (or $V_1:V_2$) actually describes the turns ratio $a = \frac{N_1}{N_2}$, the

reciprocal of transformation ratio. This distinction matters for step-up ($K > 1$) versus step-down ($K < 1$) transformers.[\[bez\]](#)

Applications

Engineers use K to predict voltage changes and design power systems. For ideal transformers, it directly follows from Faraday's law, ensuring voltage scales with turns. Real-world testing verifies K to detect winding faults.[\[doubtnut\]](#)

✦ Example:

11 kV / 433 V transformer

Purpose of Ratio Test

Ratio test is performed to:

- Confirm correct turns ratio
- Check tap changer operation
- Detect shorted or open turns

Ratio Test on All Taps

Transformers are provided with **tap changers** to control voltage.

Ratio test must be done:

- At normal tap
- At each tap position

Ratio Test Procedure (Overview)

1. Apply known voltage to one winding
2. Measure induced voltage on other winding
3. Calculate ratio
4. Compare with nameplate value

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

In substations:

- Polarity and vector group tests are verified before parallel operation
- Ratio test ensures voltage accuracy on load

Diploma Engineers are involved in:

- Assisting testing engineers
- Recording readings
- Verifying nameplate data

⚡ **Most transformer failures during commissioning are due to connection mistakes, not manufacturing defects.**

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Polarity defines voltage direction
- ✓ Vector group defines phase displacement
- ✓ Correct vector group is essential for parallel operation
- ✓ Ratio test confirms voltage transformation
- ✓ All tap positions must be tested

Common Student Doubts

Q: *Is polarity test required for three-phase transformers?*

👉 Mostly for single-phase; three-phase focuses on vector group.

Q: *Why test all taps?*

👉 To ensure correct voltage control under different load conditions.

Mentorship & Career Tip 🌱

Understanding polarity, vector group, and ratio testing:

- Builds strong commissioning skills
- Prevents costly system failures
- Prepares you for **substation, utility, and EPC roles**

👉 *A smart engineer checks compatibility before connection.*

Lecture :7: Topics 3.3.5 Magnetizing Current Test, 3.3.6 Magnetic Balance Test, and 3.3.7 Capacitance & Tan Delta Measurement

(60-minute lecture | Diploma Electrical Engineering | ~500 words)

1. Hook / Introduction (≈ 5 minutes)

Good morning students 🌞

Let me ask you a question:

👉 If a transformer is energized with no load, why does it still draw current?

That small current is called **magnetizing current**, and it tells us a lot about the **health of the magnetic core**.

Similarly, even when insulation looks fine from outside, **hidden weaknesses** can exist inside windings and bushings.

To detect these invisible problems, engineers use **magnetizing current test, magnetic balance test, and Tan Delta test**.

These tests are like a **medical check-up for a transformer before it is put into service**.

2. Core Concepts (≈ 40 minutes)

3.3.5 Magnetizing Current Test

What is Magnetizing Current?

Magnetizing current is the current drawn by a transformer:

- When secondary is open
- To establish magnetic flux in the core

📌 **Simple meaning:** It is the current required to magnetize the transformer core.

Purpose of Magnetizing Current Test

This test is performed to:

- Detect core defects
- Identify shorted turns
- Check symmetry of windings

Interpretation

- Normal magnetizing current → Healthy core
- Abnormally high current → Core fault or winding issue

⚠ **Exam Tip:** Magnetizing current is **small compared to rated current**.

3.3.6 Magnetic Balance Test (Three-Phase Transformer)

What is Magnetic Balance Test?

Magnetic balance test checks:

- Uniformity of magnetic circuit
- Equality of induced voltages in phases

It is carried out on **three-phase transformers**.

Test Procedure (Overview)

1. Apply single-phase voltage to one phase
2. Measure voltages in other phases
3. Repeat for all phases



Fig.3.3.6.a.Three-phase transformer showing voltage measurements across different phases.

Importance

Magnetic balance test helps to:

- Detect shorted turns
- Detect core imbalance
- Ensure proper flux distribution

⚠ Large variation in readings indicates **internal faults**.

3.3.7 Capacitance & Tan Delta Measurement

What is Capacitance Measurement?

Transformer insulation behaves like a capacitor.

Capacitance measurement checks:

- Insulation condition
 - Physical changes in insulation
-

What is Tan Delta?

Tan Delta (Dissipation Factor) indicates:

- Dielectric losses in insulation

✦ **Simple meaning:** Lower Tan Delta = Better insulation quality

Purpose of Tan Delta Test

Tan Delta test is used to:

- Detect aging of insulation
 - Identify moisture content
 - Assess bushing condition
-

Where is Tan Delta Test Applied?

- Transformer windings
- HV and LV bushings

⚠ Tan Delta test is especially important for **high-voltage transformers**.

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

In power utilities and substations:

- Magnetizing current test is done during pre-commissioning
- Magnetic balance test confirms winding health
- Tan Delta test is performed during major maintenance

A Diploma Engineer may:

- Assist in test setup

- Record readings
- Compare results with standard limits

These tests help avoid **catastrophic transformer failures**.

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Magnetizing current indicates core health
- ✓ Magnetic balance test checks phase symmetry
- ✓ Capacitance measurement assesses insulation structure
- ✓ Tan Delta measures insulation losses
- ✓ These tests detect hidden internal defects

Common Student Doubts

Q: *Is magnetizing current same as no-load current?*

👉 Magnetizing current is the major part of no-load current.

Q: *Why Tan Delta is preferred over IR sometimes?*

👉 Tan Delta gives more accurate insulation condition.

Mentorship & Career Tip 🌱

Mastering these diagnostic tests:

- Builds advanced commissioning skills
- Makes you valuable in testing and maintenance teams
- Opens opportunities in **substations, utilities, and EPC companies**

👉 *Good engineers don't just energize—they verify.*

Lecture:7:Topics 3.3.8 Short Circuit Impedance Test, 3.3.9 Contact Resistance Measurement, and 3.3.10 Measurement of Winding Resistance for All Taps of OLTC

(60-minute lecture | Diploma Electrical Engineering | ~500 words)

1. Hook / Introduction (≈ 5 minutes)

Good morning students 🙌

Let me ask you a practical question:

👉 If a transformer faces a short circuit in the system, how do we ensure it will not get damaged?

Also, consider this:

👉 Even if windings are perfect, what happens if contacts inside the transformer are loose or resistive?

Many transformer failures occur **not due to insulation**, but due to **mechanical and resistive issues**.

That is why today's tests focus on:

- **Short-circuit behavior**
- **Quality of electrical contacts**
- **Uniformity of winding resistance across tap positions**

These tests ensure the transformer is **electrically strong, mechanically sound, and ready for service.**

2. Core Concepts (≈ 40 minutes)

3.3.8 Short Circuit Impedance Test

What is Short Circuit Impedance?

Short-circuit impedance is the impedance offered by the transformer when:

- Secondary is short-circuited
- Reduced voltage is applied to primary

✦ **Simple meaning:** It limits the short-circuit current during faults.

Purpose of Short Circuit Impedance Test

This test is carried out to:

- Verify impedance value as per nameplate
- Ensure transformer can withstand short-circuit forces
- Confirm parallel operation suitability



Fig.3.3.8.a.:Transformer with secondary shorted and voltmeter, ammeter on primary side.

Importance

- Correct impedance ensures **fault current limitation**
- Incorrect impedance may cause **overheating and damage**

⚠ **Exam Tip:**

Short-circuit impedance is expressed in **percentage (%)**.

3.3.9 Contact Resistance Measurement

What is Contact Resistance?

Contact resistance is the resistance offered at:

- Joints
- Bolted connections
- Tap changer contacts

✦ **Simple meaning:**

Poor contacts = higher resistance = heating.

Why Measure Contact Resistance?

This test helps to:

- Detect loose or oxidized contacts
- Prevent excessive temperature rise
- Ensure efficient current flow



Fig.3.3.9.a. Micro-ohmmeter connected across breaker or tap changer contacts.

Key Point

Even a **small resistance** at contacts can cause **huge power loss** at high current.

3.3.10 Measurement of Winding Resistance for All Taps of OLTC

What is Winding Resistance Test?

Winding resistance test measures:

- DC resistance of transformer windings
- Resistance at different tap positions of OLTC

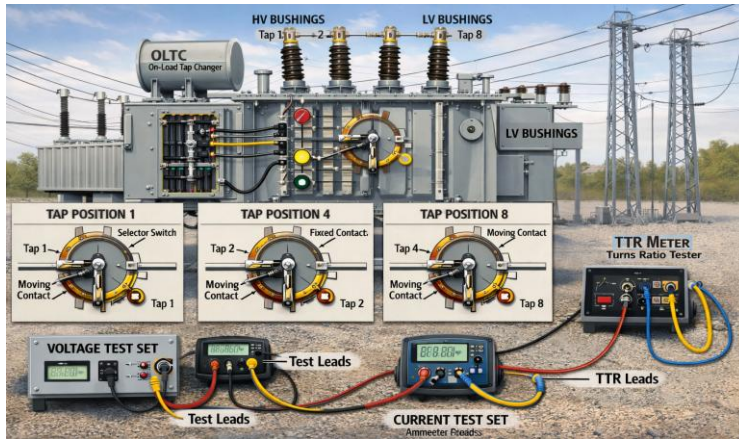


Fig3.3.10: a. Transformer with OLTC showing different tap positions and test connections.

Purpose of Winding Resistance Measurement

This test is done to:

- Detect shorted or open turns
- Check condition of tap changer contacts
- Compare resistance balance between phases

Why Test All Taps of OLTC?

Because:

- OLTC operates frequently
- Contact wear varies at different taps
- Uneven resistance causes voltage imbalance

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

In substations and power plants:

- Short-circuit impedance test ensures transformer survives faults
- Contact resistance measurement prevents overheating failures
- Winding resistance test helps detect OLTC problems early

A Diploma Engineer may be responsible for:

- Assisting in test setup
- Recording readings
- Comparing values with previous records

⚡ These tests play a major role in **preventive maintenance and commissioning approval.**

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- ✓ Short-circuit impedance limits fault current
- ✓ Contact resistance affects heating and efficiency
- ✓ Winding resistance test checks internal health
- ✓ OLTC taps must be tested individually
- ✓ These tests ensure safe and reliable operation

Common Student Doubts

Q: *Is short-circuit test done at full voltage?*

👉 No, only reduced voltage is applied.

Q: *Why is OLTC resistance measurement important?*

👉 OLTC contacts wear out faster than windings.

Mentorship & Career Tip 🌱

If you master these tests:

- You become confident in commissioning and testing jobs
- You can identify faults before failure
- You gain an edge in **substation, testing, and utility careers**

Lecture :8 Topic 3.4: Final Commissioning Checks

1. Hook / Introduction (≈ 5 minutes)

Instructor Script / Talking Points:

“Good morning, everyone! Imagine you’ve just installed a brand-new transformer in a substation. The connections are complete, the oil is filled, and it looks perfect. But how do we know it’s truly ready to supply power safely and reliably?”

This is where **final commissioning checks** come in. These are not just routine steps—they are critical to ensuring safety, performance, and longevity. A missed check could mean catastrophic failure, downtime, or even accidents.

Fun fact: Some transformer failures in history were traced back to skipped commissioning checks, costing utilities millions in repair and lost power supply! Today, we’ll learn exactly what engineers do to prevent this. Think of it as the ‘final inspection before the machine goes live.’”

2. Core Concepts (≈ 40 minutes)

2.1 Purpose of Final Commissioning Checks

- Ensure **mechanical, electrical, and safety integrity** before energization.
- Verify that all **connections, insulation, and protection systems** are correctly installed.
- Detect **potential faults** early to avoid costly failures.

Analogy: Final commissioning is like a pilot’s pre-flight checklist: engines may be fine individually, but the whole system must work safely together before takeoff.

2.2 Step-by-Step Checks

Visual Reference: Figure 1 – Flowchart of Final Commissioning Checks

- Flowchart shows steps:
 1. Mechanical Inspection
 2. Electrical Tests
 3. Protection System Check
 4. Cooling & Oil System Check
 5. Final Energization & Observation
- Students can follow this as a roadmap for the lecture.

2.2.1 Mechanical Inspection

Key Points:

- Check for proper alignment of bushings, tap changers, and core.
- Tightness of bolts, clamps, and external fittings.
- Condition of conservator, breather, and radiators.

Visual Reference: Figure 2 – Mechanical Inspection Diagram

- Side view of transformer labeled with: bushings, radiator fins, conservator tank, bolts/fittings.
- Arrows highlight areas to inspect physically.

Analogy: Think of checking a transformer's mechanical setup like inspecting a car engine—loose bolts or misalignment can lead to failure.

2.2.2 Electrical Tests

Key Points:

- **Insulation Resistance Test (Megger Test)** – check winding insulation health.
- **Turns Ratio Test** – verify voltage transformation ratio.
- **Polarity Test** – ensure primary and secondary windings are correctly connected.
- **Grounding Check** – proper earthing of transformer tank and neutral.

Visual Reference: Figure 3 – Electrical Test Setup Diagram

- Shows megger connected to primary and secondary windings, plus grounding.

2.2.3 Protection System Check

Key Points:

- Verify relays (overcurrent, differential) operate correctly.
- Check circuit breakers trip on simulated faults.

Visual Reference: Figure 4 – Protection Test Block Diagram

- Transformer → Relay → Circuit Breaker → Simulated fault arrow.

2.2.4 Cooling & Oil System Check

Key Points:

- Inspect oil level, temperature indicators, and pumps.
- Check for leaks, proper radiator operation, and Buchholz relay function.

Visual Reference: Figure 5 – Cooling & Oil System Diagram

- Shows transformer with radiator, oil pumps, oil level gauge, Buchholz relay.

2.2.5 Final Energization & Observation

- Energize transformer with no load initially.
- Observe unusual sounds, vibrations, temperature rise, or abnormal readings.
- Only after stable observation, connect to the grid.

3. Real-World / Industry Applications (≈ 10 minutes)**Instructor Talking Points:**

- In **substations**, final checks prevent transformer faults that could interrupt power to thousands of homes.
- In **industrial plants**, skipping these checks can halt production, damage equipment, and endanger personnel.
- **Fun Fact:** Large utility transformers often undergo commissioning checks for several days before energization to meet regulatory and safety standards.

Example Exercise: Ask students to identify all visual inspection points in a transformer photo and discuss what could happen if a fault is missed.

4. Summary & Q&A (≈ 5 minutes)**Key Takeaways:**

1. Final commissioning checks ensure safety, reliability, and longevity.
2. Steps include mechanical inspection, electrical tests, protection verification, cooling system check, and observation after energization.
3. Flowcharts and diagrams help systematically verify all aspects of the transformer.

Typical Student Doubts:

- “Can we skip some tests if the transformer is brand new?” → No; all steps are essential.
- “How long does final commissioning take?” → Depends on size; large power transformers may take 2–3 days.

Mentorship Note / Career Tip:

Mastering final commissioning is a **highly valued skill** in electrical engineering careers. It develops your attention to detail, problem-solving, and safety mindset. Whether you work in power utilities, industrial installations, or renewable energy, knowing how to verify machinery before energization will make you a reliable and competent engineer.

Lecture:9:Topic 3.5: Procedure – Energization of Transformer

1. Hook / Introduction (≈ 5 minutes)

Instructor Script / Talking Points:

“Good morning, everyone! Imagine you’ve spent days preparing and commissioning a new transformer. You’ve checked the mechanical setup, verified the windings, tested protection systems, and now comes the moment of truth: energization.

Have you ever thought about what could go wrong if a transformer is energized incorrectly? A sudden surge, wrong phase connection, or unbalanced supply can damage the transformer instantly. Energization is the most critical step in commissioning—it’s when all your checks are put to the test. Fun fact: In large power utilities, energization of a transformer is often treated like a major operation—sometimes requiring a team of engineers, pre-energization approval, and step-by-step documentation!”

2. Core Concepts (≈ 40 minutes)

2.1 Purpose of Energization

- To safely introduce the transformer into the power system.
- To confirm that the transformer is operating correctly under load and no abnormal conditions exist.
- To observe voltage, current, temperature, and other parameters before full commissioning.

Analogy: Energization is like starting a brand-new car for the first time—you check all systems under light conditions before taking it on a long drive.

2.2 Step-by-Step Procedure

Visual Reference Suggestion: Figure 1 – Transformer Energization Flowchart

- Flowchart steps:
 1. Pre-Energization Checks
 2. Connection to Supply
 3. No-Load Energization
 4. Observation & Measurements
 5. Gradual Load Application

Step 1: Pre-Energization Checks

- Verify all mechanical and electrical commissioning steps are complete.
- Check for proper grounding, tight connections, and no visible defects.
- Ensure switchgear, breakers, and relays are operational.

Visual Idea: Side-view diagram of transformer with labeled grounding, bushings, and breaker connection.

Step 2: Connection to Supply

- Connect the transformer to the low- and high-voltage sides carefully.
- Ensure correct **phase sequence and polarity** to avoid circulating currents or short circuits.

- Double-check control and protection circuits before energization.

Analogy: Think of connecting a transformer like plugging in a complex multi-device power strip—connect the right devices in the correct order to avoid short circuits.

Step 3: No-Load Energization

- Energize the transformer at **no load** first.
- Monitor **voltage, current, and oil temperature**.
- Observe for abnormal sounds, vibrations, or unusual heating.

Visual Idea: Simple diagram showing transformer connected to supply with no load; arrows indicating voltage and current flow.

Step 4: Observation & Measurements

- Take readings of:
 - Primary and secondary voltages
 - No-load current
 - Transformer temperature rise
- Compare measurements with manufacturer specifications.

Visual Idea: Table layout diagram for recording readings, including columns for voltage, current, and temperature.

Step 5: Gradual Load Application

- Connect transformer to load in stages.
- Monitor **voltage regulation, current balance, and temperature rise** continuously.
- Ensure protection devices operate correctly under real conditions.

Fun Fact: Large transformers in substations may be loaded gradually over several hours to prevent thermal stress.

2.3 Safety Precautions During Energization

- Keep personnel clear of energized equipment.
- Use protective gear and barriers.
- Have emergency disconnection ready in case of faults.

Visual Idea: Safety layout diagram showing transformer, safe distance for operators, and protective equipment.

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

Instructor Talking Points:

- **Substations:** Energization ensures the transformer integrates safely with the grid. Any error could trip the system or damage downstream equipment.

- **Industrial Plants:** Energization is done in stages to protect motors, generators, and process equipment from sudden voltage spikes.
- **Renewable Energy Systems:** Transformers connecting solar or wind plants to the grid require careful no-load checks due to variable supply conditions.

Example Exercise: Ask students: “If a transformer is energized with reversed polarity, what happens to the system and the transformer?” Discuss circulating currents and potential damage.

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways:

1. Energization is the final and critical step in transformer commissioning.
2. Steps include pre-energization checks, connection to supply, no-load energization, observation, and gradual loading.
3. Safety, monitoring, and stepwise procedures prevent damage and ensure reliability.

Typical Student Doubts:

- “Why start with no-load energization?” → To observe transformer behavior safely before full load.
- “What instruments are used during energization?” → Voltmeters, ammeters, temperature sensors, and protection relay indicators.

Mentorship Note / Career Tip:

Mastering transformer energization develops **practical operational skills**, critical for power plants, substations, and industrial electrical projects. Understanding this process makes you competent in **safe commissioning, troubleshooting, and system integration**, skills highly valued in electrical engineering careers.

Lecture 10: Topic 3.6: Faults & Troubleshooting of Transformer and Auxiliary Equipment

1. Hook / Introduction (≈ 5 minutes)

Good morning students!

Let me start with a question: **Why do you think a transformer, which has no moving parts, still fails?**

Many people assume transformers are “fit and forget” equipment. But in reality, a transformer is like the **heart of a power system**—quietly working day and night. A small fault inside it can cause **blackouts, fire hazards, or costly shutdowns**.

You already know about transformer construction, oil, windings, and tests. Today, we connect that knowledge to **real-life problem solving**—identifying faults and correcting them systematically. Remember, in industry, **an engineer is valued not for knowing formulas, but for restoring supply quickly and safely**.

2. Core Concepts (≈ 40 minutes)

2.1 Classification of Transformer Faults

Transformer faults can be broadly classified into:

1. **Electrical Faults**
2. **Mechanical Faults**
3. **Thermal Faults**

4. Auxiliary Equipment Faults

Think of this like a human body:

- Electrical faults = nervous system problems
- Mechanical faults = bone/joint issues
- Thermal faults = fever/overheating
- Auxiliary faults = support system failures

2.2 Common Electrical Faults & Troubleshooting

a) Winding Short Circuit (Inter-turn or Phase-to-Phase)

Symptoms: High current, tripping of protection relay, heating, burning smell

Causes: Insulation failure, aging, moisture, overloading

Troubleshooting:

- Measure insulation resistance (IR)
- Conduct winding resistance test
- If values are abnormal → transformer must be taken out of service

b) Earth Fault

Symptoms: Earth fault relay operation

Causes: Breakdown of insulation to core or tank

Action:

- Check earthing system
- Perform megger test

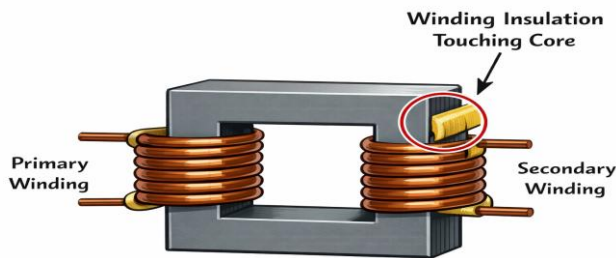


Fig.3.6.a: A simple transformer showing winding insulation touching the core.

2.3 Mechanical & Thermal Faults

a) Excessive Vibration or Noise

Causes: Loose core bolts, magnetostriction, over-fluxing

Solution:

- Tighten core clamping
- Check applied voltage and frequency

b) Overheating of Transformer

Symptoms: High oil temperature alarm, insulation deterioration

Causes: Overloading, cooling failure, high ambient temperature

Remedy:

- Reduce load
- Check cooling system (fans, pumps, radiators)

2.4 Faults in Auxiliary Equipment

Auxiliary equipment ensures **safe and continuous operation**.

a) Cooling System Faults (Fans / Oil Pumps)

Symptoms: Temperature rise despite normal load

Checks:

- Supply to motors
- Fan rotation
- Thermostat operation

b) Conservator & Breather Problems

Fault: Moisture entering transformer oil

Cause: Silica gel turns pink

Action: Replace or dry silica gel

c) Buchholz Relay Operation

Indicates: Internal fault (gas generation)

Action:

- Analyze gas
- If severe → shutdown transformer immediately

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

In substations and industries, engineers follow a **fault-finding flowchart**:

1. Observe alarm/trip
2. Identify fault type (electrical/mechanical/thermal)
3. Perform tests (IR, oil BDV, winding resistance)
4. Decide: repair, dry-out, or replace

For example, in a **33/11 kV substation**, a cooling fan failure during summer can cause oil temperature to rise rapidly. A diploma engineer's quick action—starting standby fans or reducing load—can prevent transformer failure worth **lakhs of rupees**.

Fun Fact: **Most transformer failures are not sudden—they give warning signs first!**

4. Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Transformer faults are electrical, mechanical, thermal, or auxiliary-related
- Early detection saves equipment and lives
- Auxiliary equipment is as important as the main transformer
- Troubleshooting follows a logical, step-by-step approach

Common Student Doubts

- *Can a transformer run with one cooling fan failed?* → Yes, but with reduced load
- *Is Buchholz relay provided for all transformers?* → Only oil-filled transformers with conservator

Mentorship Note (Career-Oriented Tip)

Mastering transformer fault analysis makes you **industry-ready**. Whether you work in **power utilities, industries, solar plants, or maintenance firms**, troubleshooting skills will set you apart. Many junior engineers get promoted early because they can **diagnose faults calmly during emergencies**. Treat every fault as a learning opportunity—this mindset builds a strong engineering career.

Student AI Toolkit – Unit 3: Commissioning of Transformer

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

1. “Explain in simple terms what transformer commissioning is and why it is important.”
2. “List and define the different types of tests performed during transformer commissioning.”
3. “Describe the main purposes of transformer foundations for static and rotating machines.”
4. “Summarize the steps involved in final commissioning checks of a transformer.”
5. “Define insulation resistance testing and explain why it is done during transformer commissioning.”
6. “Explain the difference between mechanical inspection and electrical testing of transformers.”
7. “List the main safety precautions to follow during transformer energization.”
8. “Describe the function of a Buchholz relay in transformer protection in simple words.”
9. “Explain what no-load energization of a transformer is and why it is important.”
10. “Summarize the key checks performed before connecting a transformer to the load.”

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

11. “Compare rigid and flexible foundations for electrical machines and give examples of each.”
12. “Given a transformer showing unusual vibration after installation, analyze possible causes based on commissioning checks.”
13. “Explain step-by-step how you would perform a turns ratio test and interpret the results.”

14. “Describe a scenario where improper grounding during energization could cause problems, and explain how to prevent it.”
15. “Analyze why progressive loading of a transformer is safer than connecting full load immediately.”
16. “Compare mechanical inspection and electrical testing: which issues can each detect, and why are both necessary?”
17. “Explain how protection relays and circuit breakers work together during commissioning to ensure safety.”
18. “Given readings of voltage, current, and temperature during no-load energization, determine if the transformer is operating normally.”
19. “Describe how transformer commissioning practices help in avoiding costly downtime in industrial or utility applications.”
20. “Analyze the impact of skipping final commissioning checks on transformer performance and safety.”

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

21. “Design a step-by-step workflow for commissioning a medium-sized transformer, including mechanical, electrical, protection, and energization checks.”
22. “Create a checklist for transformer energization that ensures safety, correct measurements, and protection verification.”
23. “Propose a method to detect alignment and vibration issues in a rotating machine foundation using simple engineering reasoning.”
24. “Design a problem-solving approach for identifying the cause of abnormal temperature rise during transformer commissioning.”
25. “Create a visual diagram showing the full commissioning process of a transformer from foundation inspection to gradual load connection, labeling all key steps.”

✓ Notes for Students:

- These prompts are **copy-paste-ready** for ChatGPT, Gemini, or other AI platforms.
- Use **Low-Level prompts** to strengthen memory and understanding.
- Use **Moderate-Level prompts** to practice problem-solving, analysis, and applications.
- Use **High-Level prompts** to develop design skills, critical thinking, and exam distinction.
- Students can **adapt these prompts to diagrams, flowcharts, or simulation exercises** to reinforce learning.

Unit 3: Commissioning of Transformer – Mastery Check

1. Key Definitions / Glossary

Term	Definition (Diploma-level)
1. Transformer Commissioning	The process of testing and verifying a transformer before it is connected to the system.
2. Mechanical Inspection	Checking the physical structure, alignment, bolts, and bushings of a transformer.
3. Electrical Testing	Measurement of insulation, voltage ratios, polarity, and other electrical parameters.
4. Insulation Resistance Test	Test to measure the resistance of transformer windings to detect insulation health.
5. Turns Ratio Test	Test to verify the voltage transformation ratio between primary and secondary windings.
6. Polarity Test	Test to ensure the correct phase relationship between primary and secondary windings.
7. No-Load Energization	Applying supply to a transformer without connecting the load to check operation.
8. Gradual Load Application	Stepwise connection of the transformer to the load to prevent sudden stress.
9. Foundation	The base or plinth supporting a transformer or rotating machine to ensure stability.
10. Vibration Damping	Measures taken to reduce oscillations in machines to avoid damage.
11. Buchholz Relay	A gas-actuated relay that detects faults in oil-filled transformers.
12. Protection Relay	Device that detects abnormal conditions and trips circuit breakers to protect equipment.
13. Circuit Breaker	Switch that automatically disconnects a circuit in case of overload or fault.
14. Conservator Tank	Tank in oil-filled transformers that stores expansion oil and maintains oil level.
15. Final Commissioning Checks	Comprehensive mechanical, electrical, and safety verification before energization.

2. FAQ & Assessment Section**A. Multiple Choice Questions (MCQs)**

Instructions: Choose the correct option (A, B, C, or D) for each question.

1. What is the main purpose of transformer commissioning?
 - A) Increase voltage rating
 - B) Test and verify safe operation before use
 - C) Reduce load on the system
 - D) Measure current in circuits
2. Which test verifies the correct voltage transformation ratio?
 - A) Insulation Resistance Test
 - B) Turns Ratio Test

- C) Polarity Test
 - D) No-Load Test
3. What is the first step in final commissioning checks?
- A) Electrical Testing
 - B) Mechanical Inspection
 - C) Energization
 - D) Load Connection
4. The Buchholz relay is used to detect:
- A) Overvoltage
 - B) Winding short-circuits or oil faults
 - C) Excess current
 - D) Incorrect polarity
5. No-load energization is performed to:
- A) Measure current under full load
 - B) Check transformer operation without load
 - C) Determine foundation stability
 - D) Test mechanical alignment
6. Why is gradual load application important?
- A) Reduces mechanical stress
 - B) Prevents insulation heating
 - C) Ensures voltage stability
 - D) All of the above
7. Which of the following is NOT part of mechanical inspection?
- A) Checking bolts and clamps
 - B) Verifying tap changer alignment
 - C) Measuring insulation resistance
 - D) Inspecting bushings
8. Polarity test ensures:
- A) Winding resistance is low
 - B) Correct phase relationship between windings
 - C) Oil level is adequate
 - D) Transformer is grounded
9. Which component absorbs transformer vibrations?
- A) Conservator tank
 - B) Foundation
 - C) Circuit breaker
 - D) Protection relay
10. A flexible foundation is usually provided for:
- A) Large transformers
 - B) Rotating machines

- C) Static machines
- D) Oil storage tanks

11. Which instrument is used in insulation resistance testing?
- A) Ammeter
 - B) Megger
 - C) Voltmeter
 - D) Ohmmeter
12. During energization, abnormal heating indicates:
- A) Normal operation
 - B) Potential faults or loose connections
 - C) Proper loading
 - D) Correct grounding
13. Which is the correct sequence for transformer commissioning?
- A) Electrical tests → Mechanical inspection → Energization
 - B) Mechanical inspection → Electrical tests → Final checks → Energization
 - C) Energization → Load connection → Mechanical inspection
 - D) Load connection → Electrical testing → Mechanical inspection
14. What is the function of a conservator tank?
- A) Store oil and accommodate expansion
 - B) Protect from overvoltage
 - C) Reduce vibration
 - D) Trip the breaker
15. Circuit breakers in commissioning are used to:
- A) Measure current
 - B) Disconnect the transformer during fault conditions
 - C) Stabilize voltage
 - D) Monitor temperature
16. Which test detects winding insulation deterioration?
- A) Polarity Test
 - B) Insulation Resistance Test
 - C) Turns Ratio Test
 - D) No-Load Test
17. What does final commissioning check ensure?
- A) Transformer is aesthetically clean
 - B) Mechanical and electrical readiness and safety
 - C) Only voltage rating is correct
 - D) Only load connection is proper
18. Vibrations in a transformer may be caused by:
- A) Loose bolts
 - B) Misaligned foundation

- C) Electrical faults
- D) All of the above

19. Grounding is checked during:

- A) Mechanical inspection
- B) Electrical testing
- C) Load application
- D) Foundation design

20. Which statement is correct regarding energization?

- A) Full load is connected immediately
- B) Transformer should be energized stepwise and observed
- C) Mechanical checks are skipped
- D) Only insulation is tested

Answer Key (MCQs 1–20):

1-B, 2-B, 3-B, 4-B, 5-B, 6-D, 7-C, 8-B, 9-B, 10-B, 11-B, 12-B, 13-B, 14-A, 15-B, 16-B, 17-B, 18-D, 19-B, 20-B

B. Short Answer / Viva Questions

1. Explain why foundation design is important for transformer and rotating machines.
2. What is the purpose of insulation resistance testing in transformer commissioning?
3. Describe the sequence of steps involved in final commissioning checks.
4. How is no-load energization performed and why is it necessary?
5. Explain the role of a Buchholz relay in transformer protection.
6. Why is gradual load application preferred over full-load energization?
7. What safety precautions must be taken during transformer energization?
8. Describe the difference between mechanical inspection and electrical testing.
9. Explain how improper grounding can affect transformer operation.
10. Discuss the importance of protection relays and circuit breakers in the commissioning process.

✓ Usage Notes for Students:

- Glossary helps **memorize key technical vocabulary** for exams and viva.
- MCQs reinforce **conceptual understanding and application**.
- Short-answer questions develop **reasoning, justification, and exam-ready answers**.
- This Mastery Check can be used for **self-assessment, peer discussion, or AI-assisted practice**.

UNIT-4 STUDY PLAN

Commissioning of Rotating Machines

(Synchronous Machine, Induction Motor, DC Machine)

Total Teaching Hours: 8 Hours

Theory Weightage: 18%

Mapped Course Outcome: CO-4

“Perform standard tests and commissioning of rotating machines with adherence to safety standards.”

Bloom’s Taxonomy Focus:

- Understanding (U)
- Application (A)

Logical Teaching Sequence (Mentor's Perspective)

☉ "Before you switch ON a machine worth lakh of rupees, you must think like a commissioning engineer."

The unit is logically structured as:

1. Inspection before power is applied (visual & mechanical readiness)
2. Electrical safety & health checks (pre-start tests)
3. Controlled energization (trial start & no-load run)
4. Condition monitoring (vibration, abnormal behavior)
5. Fault diagnosis & troubleshooting

This mirrors real industrial commissioning practice.

Topic-Wise Detailed Study Plan (Strictly as per Syllabus)

♦ UNIT-4: Commissioning of Rotating Machines (8 Hours)

Sr. No.	Syllabus Topic (GTU)	Topic Nature	Key Learning Focus (Diploma Level)	Suggested Lecture Hours	Exam Importance	Practical / Industry Relevance
4.1	Pre-Commissioning Inspection Checks for Rotating Machines	Core	Nameplate verification, foundation, alignment, earthing, cooling, lubrication, coupling, safety checks	1.5 hrs	★★★★☆	★★★★★
4.2	Pre-Start Tests on Rotating Machines (Overview)	Core	Purpose of tests, safety precautions, sequence before energization	0.5 hr	★★★★☆	★★★★★
4.2.1	Winding Resistance Measurement	Core + Application	Test procedure, instruments, significance, abnormal values	1.0 hr	★★★★☆	★★★★★
4.2.2	Insulation Resistance Measurement of Windings	Core + Application	Megger test, acceptable values, temperature effect, safety	1.0 hr	★★★★★	★★★★★
4.2.3	High Voltage Tests (Power Frequency Test)	Supporting	Purpose, precautions, pass/fail criteria (conceptual level)	0.75 hr	★★★★☆	★★★★☆
4.2.4	Trial Start	Application-Oriented	Direction of rotation, abnormal sound, current, vibration	0.75 hr	★★★★☆	★★★★★
4.2.5	No-Load Test	Core + Application	No-load current, losses, speed, temperature rise	1.0 hr	★★★★☆	★★★★★
4.2.6	Vibration	Supporting +	Causes of vibration,	0.75 hr	★★★★☆	★★★★★

Sr. No.	Syllabus Topic (GTU)	Topic Nature	Key Learning Focus (Diploma Level)	Suggested Lecture Hours	Exam Importance	Practical / Industry Relevance
	Measurement	Application	basic limits, instruments, interpretation			
4.3	Faults and Troubleshooting of Rotating Machines (SM, IM, DC)	Core + Application	Common electrical & mechanical faults, symptoms, remedies	1.75 hrs	★★★★★	★★★★★

Total = 8 Hours

Topic Classification for Teaching Strategy

● Core Topics (High Priority)

- Pre-commissioning inspection
- IR & winding resistance tests
- No-load test
- Faults and troubleshooting

→ Frequently asked in exams & essential for industry

● Supporting Topics

- High-voltage test
- Vibration measurement theory

→ Conceptual clarity, usually short-answer questions

● Application-Oriented Topics

- Trial start
- Fault diagnosis
- Condition monitoring

→ Directly linked to lab experiments & site work

🔗 OBE Alignment (Outcome Mapping)

Element	Alignment
Course Outcome (CO-4)	Fully addressed through tests, trial run & troubleshooting
Program Outcome	Technical competency, safety compliance
NEP-2020 Focus	Experiential learning, employability skills, industry readiness

Integration with Practical Curriculum (Very Important)

Directly linked GTU Practicals:

- No-load & trial run test of induction motor
- Vibration measurement of rotating machine

“Theory is successful only when the student can confidently stand in front of a running machine.”

Exam-Oriented Guidance for Students (Mentor Talk)

- Draw neat flowcharts for commissioning steps
- Write test procedure + significance + safety

- Troubleshooting questions = high-scoring answers
- Use machine-specific examples (IM, DC, SM)

Mentor's Note

This Unit is highly scoring, highly practical, and directly linked to industry jobs (maintenance engineer, commissioning technician, plant operator).

If taught and studied properly, Unit-4 alone can boost confidence for site work.

Lecture Topic 4.1: Pre-Commissioning Inspection Checks for Rotating Machines

(Synchronous Machine, Induction Motor, DC Machine)

Hook / Introduction (≈ 5 minutes)

“If a brand-new motor fails within 5 minutes of starting, is the machine faulty... or the engineer?”

In most real industries, the answer is the process, not the machine.

Many rotating machines fail not because of design issues, but because basic pre-commissioning inspection checks were skipped.

You have already studied construction and working principles of motors and generators. Today, we move one step closer to real engineering practice—the moment *before* switching ON the supply.

This stage is called Pre-Commissioning Inspection, and it decides whether the machine will run smoothly for years or fail on Day-1.

Core Concepts (≈ 40 minutes)

What is Pre-Commissioning Inspection?

Pre-commissioning inspection is a systematic physical and safety check carried out before any electrical test or energization of a rotating machine.

Think of it like a medical check-up before surgery.

If basics are not checked, advanced tests become meaningless.

Objectives of Pre-Commissioning Inspection

1. To ensure mechanical safety
2. To confirm correct installation
3. To avoid accidents, vibrations, and premature failure
4. To protect costly electrical windings

Main Inspection Checks (Step-by-Step)**1. Visual Inspection**

Check:

- Cracks on frame
- Loose bolts and nuts
- Signs of moisture, rust, or dust
- Damage during transportation

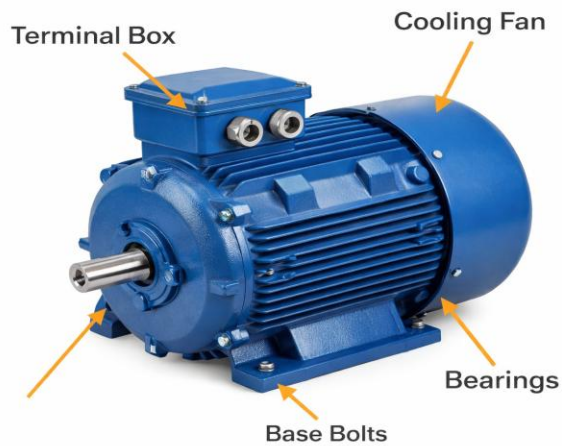


Figure: Motor with arrows pointing to terminal box, cooling fan, bearings, and base bolts.

2. Foundation & Mounting Check

- Machine should be firmly mounted
- No rocking or uneven base
- Foundation bolts properly tightened

Poor foundation = vibration + noise + bearing damage

3. Shaft, Coupling & Alignment

- Shaft should rotate freely by hand
- No rubbing sound
- Coupling aligned properly with load (pump/fan)



Flowchart for Inspection → Free rotation → Alignment → Safe for testing

4. Bearing & Lubrication Check

- Bearings should be clean
- Correct grade and quantity of grease/oil
- No leakage

More machines fail due to wrong lubrication than electrical faults!

5. Cooling System Check

- Cooling fan intact
- Air passages clean
- No obstruction to airflow

⚠ Overheating starts even before loading if cooling is blocked.

6. Terminal Box & Connections

- Terminals tight
- No exposed conductor
- Proper cable lugs used
- Earthing connection verified

Earthing must be checked before any electrical test.

7. Nameplate Verification

Confirm:

- Rated voltage
- Current
- Speed (RPM)
- Connection (Star/Delta)
- Duty type

Mismatch between supply and nameplate = guaranteed failure.

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

In industries like:

- Power plants
- Pumping stations
- Textile and cement industries

Pre-commissioning inspection is mandatory and recorded in a checklist signed by the engineer.

🔧 Example:

A 50 HP induction motor installed correctly but with:

- Loose foundation bolt

Result: High vibration → bearing failure → shutdown loss in lakhs.

A 10-minute inspection could have saved it.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Pre-commissioning inspection is non-electrical but critical
- Focus areas: visual, mechanical, cooling, earthing
- Prevents accidents and costly damage

- Always done before electrical tests

Typical Student Doubts

- “Can we skip inspection for new machines?” → ❌ Never
- “Is inspection part of commissioning?” → ✅ First step
- “Is it asked in exams?” → ✅ Yes, short & long answers

Mentorship & Career Note

Mastering pre-commissioning inspection turns you from a theory student into a site-ready engineer. In interviews, supervisors don’t ask formulas first—they ask: “What will you check before starting a motor?” If you can confidently answer this, you already stand one step ahead in your engineering career.

4.2 Pre-Start Tests on Rotating Machines-

Topic 4.2.1: Winding Resistance Measurement (Pre-Start Test)

Hook / Introduction (≈ 5 minutes)

Let me ask you a simple question before we begin:

“If all three phases of a motor look healthy from outside, how do we know the windings inside are actually safe?”

You cannot *see* winding condition with your eyes.

But before switching ON any rotating machine, an engineer must talk to the windings—and the language they speak is resistance.

You already know from basic electrical theory that every conductor has resistance.

Today, we will learn how measuring this small resistance can prevent major failures, detect hidden faults, and protect expensive machines.

Core Concepts (≈ 40 minutes)

What is Winding Resistance Measurement?

Winding resistance measurement is a pre-start electrical test used to measure the DC resistance of machine windings before energization.

It is performed on:

- Induction motors
- Synchronous machines
- DC machines

Think of it like checking the pulse rate of a patient before starting treatment.

Objectives of Winding Resistance Measurement

1. To check uniformity of windings
2. To detect loose connections
3. To identify open circuits or shorted turns
4. To verify manufacturing or installation defects

Basic Principle (Simple Language)

If a machine is healthy:

- All phase windings should have nearly equal resistance
- Small variation is allowed due to temperature and length

△ Large difference = fault

Instruments Used

- Digital low-resistance ohmmeter
- Micro-ohmmeter (for large machines)
- Digital multimeter (for small motors)

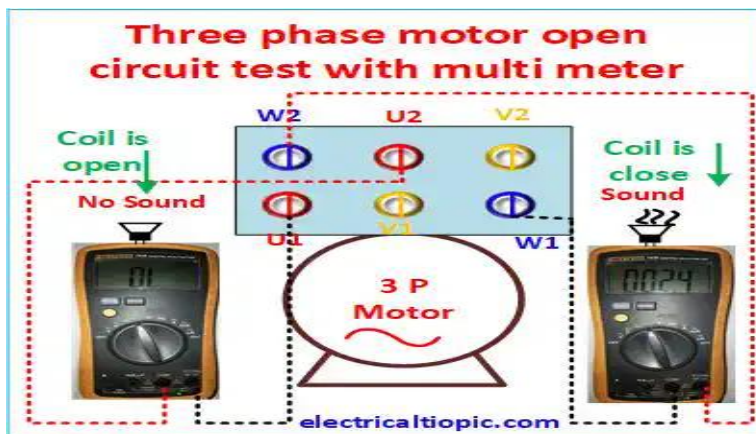


Figure: Three stator terminals (U-V-W) connected to a resistance meter one pair at a time.

Test Procedure (Step-by-Step)

1. Ensure machine is isolated from power supply
2. Discharge stored energy (important for large machines)
3. Identify terminals:
 - Three-phase motor: R-Y-B or U-V-W
4. Measure resistance:
 - R-Y
 - Y-B
 - B-R
5. Record readings
6. Compare values

Expected Results & Interpretation

Observation	Meaning
All values nearly equal	Healthy winding
One phase very high	Open circuit
One phase very low	Shorted turns
Large imbalance	Loose joint / damaged winding

Even a slightly loose terminal can increase resistance and cause overheating during operation.

Important Precautions


- Test at **ambient temperature**
- Clean terminals before testing
- Do not touch probes during measurement
- Record temperature for reference

Real-World / Industry Applications (≈ 10 minutes)

In industries:

- Power plants
- Pumping stations
- Manufacturing units

Winding resistance measurement is compulsory and recorded in commissioning reports.

 Example from industry:

A 30 HP motor showed **10% higher resistance in one phase**.

Result: Found loose lug → corrected → motor saved from future burnout.

Without this test, the motor would have failed within weeks.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Winding resistance test is a **basic but critical pre-start test**
- Confirms electrical symmetry of windings
- Detects hidden faults before energization
- Simple test, powerful result

Common Student Doubts

- *Is this test done with AC?* → ❌ DC only
- *Can resistance be exactly equal?* → ❌ Nearly equal is acceptable
- *Is this asked in exams?* → ✅ Yes (procedure + purpose)

Mentorship & Career Note

Every site engineer is trusted based on how carefully they test before starting a machine. Mastering winding resistance measurement shows that you understand electrical health, safety, and

discipline—qualities that supervisors look for during jobs, apprenticeships, and interviews.

Remember:

A good engineer does not rush to start a motor.

A great engineer checks its windings first.

Topic 4.2.2: Insulation Resistance Measurement of Windings (Pre-Start Test)

Hook / Introduction (≈ 5 minutes)

Let begin with a situation from real industry:

A motor passed the winding resistance test perfectly.

Still, it failed immediately when energized.

Why?

Because conductors were healthy, but insulation was weak.

In electrical machines, copper carries current, but insulation protects life and equipment.

Today's topic—Insulation Resistance (IR) Measurement—is one of the most important safety tests performed before starting any rotating machine.

You already know from basic theory that insulation should oppose current flow.

Now we will learn how to measure insulation health practically, before the machine is switched ON.

Core Concepts (≈ 40 minutes)

What is Insulation Resistance Measurement?

Insulation Resistance Measurement is a pre-start electrical test used to measure the resistance offered by insulation between:

- Winding to earth (body)
- Winding to winding (phase to phase)

The resistance is measured in Mega Ohms (MΩ).

Think of insulation like the rubber covering of a wire—if it is weak, leakage current flows and causes shock, heating, or failure.

Why IR Measurement is Necessary

1. To detect moisture in windings
2. To identify insulation deterioration
3. To ensure safety of personnel
4. To prevent short circuits and earth faults

⚠ A motor with low IR value is dangerous to energize.

Instrument Used – Megger

- Insulation Resistance Tester (Megger)
- Applies high DC voltage (typically 500 V or 1000 V)
- Measures leakage current and displays resistance

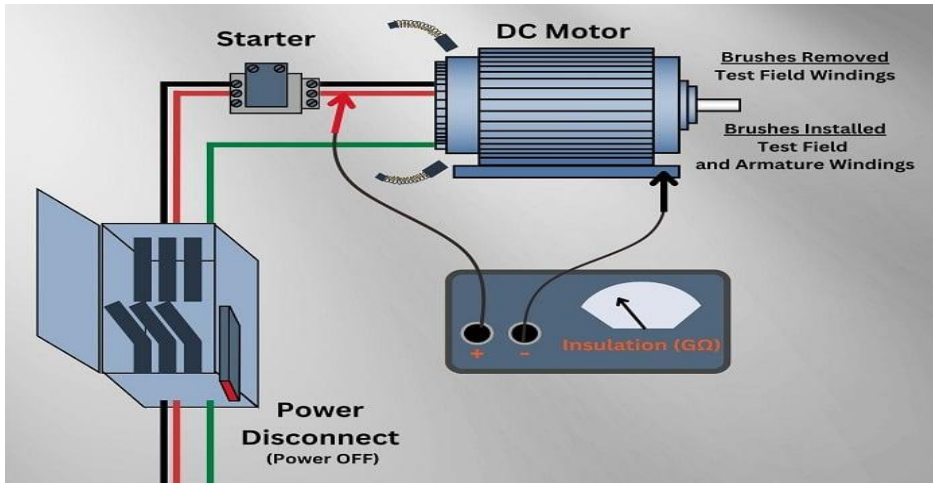


Figure: Motor body grounded, Megger connected between winding terminal and frame.

Test Connections

1. Phase to Earth Test

- One Megger lead to winding
- Other lead to motor body (earth)

2. Phase to Phase Test

- Megger between two winding terminals

Test Procedure (Step-by-Step)

1. Ensure machine is isolated from supply
2. Clean terminals and remove dust/moisture
3. Properly earth the machine body
4. Select suitable test voltage (as per rating)
5. Apply Megger voltage for minimum 1 minute
6. Note IR value
7. Discharge windings after test

Acceptable IR Values (General Guideline)

- New machine: Very high (hundreds of MΩ)
- Minimum acceptable:

$$IR (M\Omega) \geq (\text{Rated Voltage in kV} + 1)$$

⚠ Low IR indicates:

- Moisture
- Dirt
- Damaged insulation

Important Safety Precautions

- Never touch terminals during test
- Always discharge windings after test
- Do not test when machine is hot
- Follow proper PPE practices

Many motors fail during rainy season due to **moisture-reduced insulation resistance**.

Real-World / Industry Applications (≈ 10 minutes)

In industries like:

- Power plants
- Water pumping stations
- Textile and cement plants

IR measurement is mandatory before:

- First energization
- Restart after long shutdown
- Maintenance completion

 Industry example:

A standby motor showed low IR after 6 months of non-operation.

Solution: Drying with heaters → IR improved → safe commissioning.

Without IR testing, energization could have caused earth fault or fire.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- IR test checks health of insulation, not conductor
- Performed using Megger
- Measured in Mega Ohms
- Low IR = unsafe to energize
- Always discharge after testing

Common Student Doubts

- *Is IR test done with AC supply?* → ❌ DC only
- *Can we skip IR if motor is new?* → ❌ Never
- *Is this asked in exams?* → ✅ Very important

Mentorship & Career Note

In real engineering jobs, **safety responsibility comes first.**

An engineer who understands insulation resistance is trusted with high-value machines and human safety.

Mastering IR measurement helps you:

- Perform confident commissioning
- Handle maintenance jobs
- Answer viva & interview questions effectively

Remember:

Copper carries power,
but insulation protects life.

If you want next:

- ✓ Comparison of IR vs PI test
 - ✓ Viva questions & numerical logic
 - ✓ Lab-manual format answer
 - ✓ PPT slide structure
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Topic 4.2.3: High Voltage Test (Power Frequency) on Rotating Machines

Hook / Introduction (≈ 5 minutes)

Let begin with a reality check from industry:

“A motor may pass insulation resistance test today...
but can it survive operating voltage for years?”

Insulation Resistance (IR) tells us *how dry and clean* the insulation is.

But High Voltage (HV) Power Frequency Test tells us something deeper:

Can the insulation withstand stress without breaking down?

This test is like a stress test for insulation, performed before the first energization of important rotating machines.

Core Concepts (≈ 40 minutes)

What is High Voltage (Power Frequency) Test?

High Voltage Test is a pre-start dielectric test in which an AC voltage higher than rated value is applied between:

- Winding and earth
- Sometimes between windings

The voltage is applied at power frequency (50 Hz) for a specified duration.

♦ This test checks the dielectric strength of insulation.

Why HV Test is Required

1. To ensure insulation can withstand electrical stress
2. To detect weak spots, cracks, or manufacturing defects
3. To avoid insulation breakdown during operation

4. To ensure safe commissioning of critical machines

💡 *Analogy:*

IR test checks the *health report*, HV test checks *fitness under pressure*.

Equipment Used

- AC High Voltage Test Set
- Control panel with voltmeter and current indicator
- Proper earthing arrangement

Test Connections

- One terminal of HV test set connected to machine winding
- Other terminal connected to earth
- Machine body solidly earthed

⚠ Proper earthing is mandatory before applying HV.

Test Procedure (Step-by-Step)

1. Ensure machine is isolated and inspected
2. Clean windings and terminals
3. Connect HV test set properly
4. Increase voltage gradually up to specified value
5. Maintain voltage for 1 minute
6. Observe leakage current and sound
7. Reduce voltage to zero
8. Disconnect and discharge windings

Test Voltage (General Idea)

- Usually $2 \times$ rated voltage + 1000 V (as per standards)
- Exact value depends on machine rating and standards

⚠ Sudden voltage rise can damage insulation—always increase gradually.

Interpretation of Results

Observation	Meaning
No spark, no noise	Insulation healthy
Sparking / flashover	Insulation weak
Sudden current rise	Breakdown likely

Failing HV test means machine is unsafe to energize.

Safety Precautions


- Authorized personnel only
- Warning boards displayed
- Safe distance maintained
- PPE mandatory
- Never touch terminals after test without discharge

Many industrial accidents happen due to stored charge after HV testing, not during the test itself.

Real-World / Industry Applications (≈ 10 minutes)

HV tests are performed on:

- Large motors in power plants
- Synchronous generators
- Critical standby machines
- Repaired or rewound motors

 Industry example:

A rewound motor passed IR test but failed HV test due to poor insulation varnish.
Rework saved the plant from future breakdown and fire risk.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- HV test checks dielectric strength, not resistance
- Uses AC voltage at power frequency
- Done after IR test
- Mandatory for high-rating machines
- Safety is non-negotiable

Common Student Doubts

- *Is HV test compulsory for all motors?* → Mainly for large/critical machines
- *Is this test destructive?* → ❌ If done correctly
- *Is it asked in exams?* → ✅ Concept + purpose

Mentorship & Career Note

High Voltage testing is a specialized skill.

Engineers who understand HV tests are trusted with power plants, substations, and critical machinery.

Mastering this topic helps you:

- Work confidently in commissioning teams
- Understand insulation failure causes
- Prepare for higher studies in High Voltage Engineering

Remember:

Resistance shows condition,
but voltage reveals strength.

Topic 4.2.4: Trial Start of Rotating Machines

Hook / Introduction (≈ 5 minutes)

Let me start with a practical question:

“After all tests are completed, is it safe to immediately load the machine?”

The answer is No.

Between testing and full operation lies a critical step called Trial Start—the *first controlled energization* of the machine without load.

Think of a trial start like starting a new bike engine gently before racing.

This step ensures that all previous inspections and tests truly translate into safe and smooth operation.

Core Concepts (≈ 40 minutes)

What is Trial Start?

A Trial Start is the initial switching ON of a rotating machine under no-load or minimum load conditions to observe its basic behavior.

It is performed after:

- Pre-commissioning inspection
 - Winding resistance test
 - Insulation resistance test
 - High voltage test (if applicable)
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Objectives of Trial Start

1. To verify correct rotation direction
 2. To observe starting current and sound
 3. To detect abnormal vibration or heating
 4. To confirm control and protection operation
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Pre-Trial Start Checklist

Before energizing:

- All electrical tests completed satisfactorily
- Machine properly earthed
- Coupling disengaged or load removed
- Cooling system ready
- Protection devices set correctly

⚠ Skipping this checklist can damage the machine instantly.

Trial Start Procedure (Step-by-Step)

1. Ensure no mechanical load

2. Inform all personnel and clear the area
3. Switch ON supply briefly
4. Observe:
 - o Direction of rotation
 - o Smooth acceleration
 - o Sound and vibration
5. Switch OFF immediately if abnormality observed
6. Repeat short runs if required
7. Allow machine to reach rated speed
8. Record observations

Parameters Observed During Trial Start

- Direction of rotation
(Very important for pumps and compressors)
- Noise
Grinding or knocking indicates mechanical issue
- Vibration
Excess vibration means misalignment or foundation problem
- Starting current
Should be within expected limits
- Temperature rise
No rapid heating should occur
Many faults appear within the first 10 seconds of trial start.

Common Abnormalities & Causes


Observation	Possible Cause
Wrong rotation	Phase sequence wrong
Loud noise	Bearing or alignment issue
High vibration	Loose foundation
High current	Electrical imbalance

Real-World / Industry Applications (≈ 10 minutes)

In industries like:

- Water pumping stations
- Power plants
- Manufacturing units

Trial start is mandatory and logged in commissioning reports.

 Industry example:

A motor passed all tests, but during trial start showed reverse rotation. Immediate correction saved the pump from mechanical damage.

Trial start is also used after:

- Long shutdowns
- Major maintenance
- Rewinding or repair


Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Trial start is the first controlled energization
- Always done without load
- Focus on rotation, sound, vibration, and current
- Stop immediately if abnormal behavior observed
- Acts as a bridge between testing and operation

Common Student Doubts

- *Is trial start same as no-load test?* → ❌ No, it is shorter and more observational
- *Can load be connected immediately?* → ❌ Only after successful trial start
- *Is this asked in exams?* → ✅ Yes (procedure & purpose)

 **Mentorship & Career Note**

In real plants, supervisors judge engineers by how safely they start machines.

Mastering trial start procedures builds:

- Operational confidence
- Safety awareness
- Troubleshooting skills

This knowledge helps you in:

- Site jobs
- Maintenance roles
- Practical exams and interviews

Remember:

A careful first start prevents years of breakdowns.

Topic 4.2.5: No-Load Test of Rotating Machines

Hook / Introduction (≈ 5 minutes)

Imagine you buy a new two-wheeler.

Do you immediately ride it with a pillion and luggage? Never.

You first start it, let it idle, listen to the engine, and feel the vibration.

In the same way, after a trial start, engineers perform a No-Load Test.

This test allows the machine to run freely so that we can observe its natural behavior without the stress of load.

Today's lecture focuses on how a simple no-load run can reveal hidden electrical and mechanical problems before they become costly failures.

Core Concepts (≈ 40 minutes)

What is a No-Load Test?

A No-Load Test is a test in which a rotating machine is operated at rated voltage and frequency with no mechanical load connected.

The machine is allowed to run continuously for a certain duration while key parameters are observed and recorded.

Objectives of No-Load Test

1. To check smooth and stable operation
2. To observe no-load current
3. To detect abnormal noise, vibration, or heating
4. To verify cooling effectiveness
5. To confirm rated speed attainment

This test gives confidence that the machine is fit for loading.

Pre-Conditions for No-Load Test

Before starting:

- Trial start completed successfully
- Correct direction of rotation confirmed
- Load disconnected (pump uncoupled, belt removed)
- Measuring instruments connected
- Cooling system operational

⚠ Never conduct a no-load test without completing the trial start.

Test Procedure (Step-by-Step)

1. Switch ON the machine at rated supply
2. Allow it to reach rated speed
3. Run continuously for 20–30 minutes
4. Measure and observe:
 - Line voltage
 - No-load current
 - Speed (using tachometer)
 - Sound and vibration
 - Temperature rise
5. Record readings

6. Switch OFF and inspect

Parameters Observed & Their Meaning

- No-Load Current
Indicates magnetic condition and losses
Excess current → winding fault or air-gap issue
- Speed
Near synchronous speed (induction motor)
Low speed → electrical or mechanical issue
- Noise & Vibration
Humming is normal, knocking is not
- Temperature Rise
Should be gradual and within limits
Even at no load, a motor consumes power due to **iron loss, friction, and windage**.

Common Abnormalities & Causes


Observation	Possible Cause
High no-load current	Shorted turns
Excess vibration	Misalignment
Rapid heating	Cooling problem
Unusual noise	Bearing defect

Real-World / Industry Applications (≈ 10 minutes)

In industries such as:

- Water supply systems
- Power plants
- Manufacturing units

No-load test is mandatory before connecting load.

 Industry example:

A motor ran fine during trial start, but during no-load test showed abnormal heating.

Cause: Cooling fan installed incorrectly.

Correction avoided future winding failure.

No-load tests are also performed after:

- Rewinding
- Long shutdown
- Major maintenance

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- No-load test runs machine at rated supply without load

- Helps detect hidden faults
- Observes current, speed, vibration, and temperature
- Acts as final check before loading

Common Student Doubts

- *Is no-load test same as trial start?* → ❌ No, it is longer and more detailed
- *Does motor consume power at no load?* → ✅ Yes

👤 Mentorship & Career Note

In real plants, engineers who carefully analyze no-load behavior are trusted with commissioning responsibility.

This skill helps you:

- Understand machine losses
- Prevent premature failures
- Perform confidently in labs, viva, and site jobs

Remember:

A machine that behaves well at no load will serve reliably under load.

Topic 4.2.6: Vibration Measurement of Rotating Machines

Hook / Introduction (≈ 5 minutes)

Let me start with a question you may not expect:
“If a motor is electrically perfect, can it still fail?”

Yes—very easily.

Many machines fail not because of electrical problems, but because of excessive vibration.

You may have noticed a ceiling fan that shakes or makes noise. Even if it runs, you know something is wrong.

In industries, such “small vibration” can lead to bearing damage, shaft bending, insulation failure, and shutdowns costing lakhs.

That is why vibration measurement is included as an important pre-start test before declaring a rotating machine fit for service.

Core Concepts (≈ 40 minutes)

What is Vibration in Rotating Machines?

Vibration is the oscillatory motion of a machine or its parts around a mean position during operation.

In simple words:

Vibration = unwanted movement

Some vibration is normal, but excess vibration is dangerous.

Why Vibration Measurement is Necessary

1. To detect mechanical defects
2. To ensure smooth and safe operation
3. To prevent bearing and shaft failure

4. To increase machine life
5. To reduce noise and maintenance cost

Vibration measurement tells us the mechanical health of the machine.

Common Causes of Vibration

- Rotor unbalance
- Misalignment between motor and load
- Loose foundation bolts
- Bearing defects
- Bent shaft
- Electrical unbalance (unequal air gap)

Even a slightly loose bolt can double vibration levels.

Instruments Used for Vibration Measurement

- Vibration meter / vibration analyzer
- Accelerometer sensor
- Sometimes portable vibration testers

Measurements are usually taken in:

- Vertical direction
- Horizontal direction
- Axial direction

Parameters Measured

- Vibration amplitude (mm or microns)
- Vibration velocity (mm/s) – most commonly used
- Vibration acceleration (m/s^2)

For Diploma level, focus mainly on vibration velocity.

Procedure for Vibration Measurement

1. Ensure machine is running at no-load condition
2. Place vibration sensor firmly on bearing housing
3. Take readings in three directions
4. Compare values with acceptable limits
5. Record readings for future reference

Acceptable Vibration Levels (General Idea)

- Low vibration → Machine healthy
- Moderate vibration → Monitor closely

- High vibration → Stop machine and correct fault

△ Exact limits depend on machine size and standards, but sudden increase is always a warning sign.

Interpretation of Results

Observation	Possible Cause
High vibration at startup	Unbalance
Increasing vibration over time	Bearing wear
Axial vibration high	Misalignment
Random vibration	Loose parts

Real-World / Industry Applications (≈ 10 minutes)

In power plants, refineries, and large industries:

- Vibration measurement is done during commissioning
- Also used for condition monitoring

🔧 Industry example:

A motor passed no-load test but showed high vibration.

Reason: Improper foundation grouting.

Correction prevented bearing failure within months.

Today, many plants use vibration data for predictive maintenance—repairing machines *before* breakdown occurs.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Vibration measurement checks mechanical condition
- Excess vibration leads to early failure
- Measurement is done in three directions
- Helps detect unbalance, misalignment, and loose parts
- Essential before full-load operation

Common Student Doubts

- *Is some vibration normal?* → Yes, but within limits
- *Can vibration damage windings?* → Yes, indirectly

🎓 Mentorship & Career Note

Modern maintenance is moving from “**repair after failure**” to “**predict before failure.**”

Vibration measurement is a key skill in:

- Power plants
- Heavy industries
- Predictive maintenance roles

By mastering this topic, you move closer to becoming a smart, future-ready Diploma Engineer.

Remember:

Machines speak through vibration.

A good engineer knows how to listen.

Topic 4.3: Faults and Troubleshooting of Synchronous Machines

Hook / Introduction (≈ 5 minutes)

Let me begin with a practical question:

“Why is a synchronous machine considered powerful yet sensitive?”

A synchronous machine can deliver large power at constant speed, which is why it is widely used as alternators in power plants and synchronous motors in industries.

But at the same time, it is less forgiving than an induction motor. A small mistake in excitation, loading, or synchronization can lead to serious faults.

Today’s lecture will help you understand what can go wrong in a synchronous machine, how to identify the fault from symptoms, and how to correct it safely—just like a real maintenance engineer.

Core Concepts (≈ 40 minutes)

Types of Faults in Synchronous Machines

Faults in synchronous machines can be broadly divided into:

1. Electrical faults
2. Mechanical faults
3. Operational / control-related faults

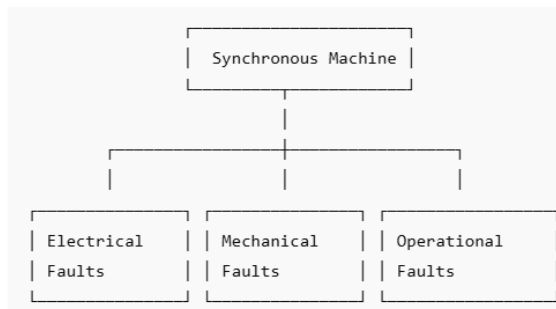


Figure: A block diagram showing “Synchronous Machine” → Electrical / Mechanical / Operational faults.

A. Electrical Faults

1. Field Winding Faults

- Open circuit in field winding
- Short circuit in field winding
- Poor brush or slip-ring contact

Symptoms:

- Loss of excitation
- Low terminal voltage (alternator)
- Machine pulls out of synchronism

Causes:

- Worn brushes
- Loose field connections
- Overheating of field winding

Remedies:

- Check continuity of field winding
 - Clean slip rings and brushes
 - Correct excitation supply
-

2. Stator Winding Faults

- Phase-to-phase short circuit
- Phase-to-earth fault

Symptoms:

- Excessive current
- Tripping of protection
- Heating and burning smell

Remedies:

- Insulation resistance test
 - Winding repair or rewinding
-

B. Mechanical Faults

Common Mechanical Faults

- Bearing wear
- Shaft misalignment
- Rotor unbalance

Symptoms:

- Abnormal noise
- Excessive vibration
- Heating near bearings

Remedies:

- Bearing replacement
- Proper alignment
- Rotor balancing

Many “electrical-looking” problems in synchronous machines actually start from mechanical vibration.

C. Operational / Control Faults (Very Important)

1. Failure to Synchronize

Occurs when:

- Voltage not matched
- Frequency not matched
- Phase sequence incorrect

Symptoms:

- Heavy current surge
- Mechanical jerks

Remedy:

- Follow proper synchronization procedure using synchroscope or lamps

2. Hunting

Hunting is **oscillation of rotor speed around synchronous speed.**

Causes:

- Sudden load change
- Weak damper winding
- Poor governor response

Effects:

- Mechanical stress
- Voltage fluctuation

Remedy:

- Use damper windings
- Improve load control

Systematic Troubleshooting Steps

Instead of guessing, follow this order:

1. Observe symptoms (voltage, current, sound, vibration)
2. Check excitation system
3. Check stator and rotor electrical parameters
4. Inspect mechanical parts
5. Identify root cause
6. Rectify and re-test

Real-World / Industry Applications (≈ 10 minutes)

In **power plants**, synchronous machines work as alternators supplying electricity to the grid. A small excitation fault can lead to **voltage instability of the entire system.**

Industry example:

An alternator showed fluctuating voltage.

Cause: Loose field connection.

Correction restored stable supply and avoided shutdown.

In industries, synchronous motors are used for **power factor improvement**, so excitation faults directly affect plant efficiency.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Synchronous machines are powerful but sensitive
- Common faults: field winding, stator winding, mechanical, synchronization
- Symptoms guide fault identification
- Troubleshooting must be systematic
- Excitation system plays a critical role

Common Student Doubts

- *Can synchronous motor run without excitation?* → ❌ No
- *Is hunting dangerous?* → ✅ Yes, if continuous

Mentorship & Career Note

Understanding faults of synchronous machines prepares you for power plant, utility, and industrial maintenance roles.

Engineers who can diagnose excitation and synchronization problems are highly trusted and valued.

Remember:

Induction motors forgive mistakes.

Synchronous machines teach discipline.

Topic 4.3: Faults and Troubleshooting of Induction Motors

Hook / Introduction (≈ 5 minutes)

Let me begin with a very common industrial question:

“If induction motors are so rugged and reliable, why do they fail so often in industries?”

Induction motors are called the workhorses of industry. They are simple, strong, and require less maintenance than many other machines.

Yet, more than 80% of industrial breakdowns involve induction motors.

The reason is not poor design—it is faults caused by wrong operation, poor maintenance, or delayed troubleshooting.

Today’s lecture will train you to identify faults quickly, understand their causes, and apply correct remedies, just like a real maintenance engineer.

Core Concepts (≈ 40 minutes)

Classification of Faults in Induction Motors

Induction motor faults can be classified into:

1. Electrical faults
2. Mechanical faults
3. Supply-related faults
4. Operational / environmental faults

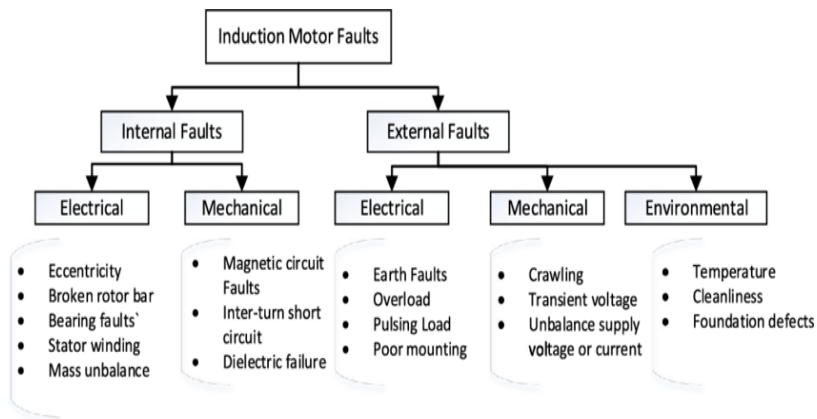


Figure: Block diagram with “Induction Motor” at center and four branches showing fault types.

A. Electrical Faults

1. Stator Winding Faults

- Phase-to-phase short circuit
- Phase-to-earth fault
- Open circuit in winding

Symptoms:

- Excessive current
- Overheating
- Tripping of protection devices

Causes:

- Insulation failure
- Moisture and dust
- Overloading

Remedies:

- Insulation resistance test
- Drying of windings
- Rewinding if damage is severe

2. Rotor Faults (Especially in Squirrel Cage Motors)

- Broken rotor bars
- Cracked end rings

Symptoms:

- Low starting torque
- Jerky acceleration

- Abnormal noise

Remedy:

- Rotor repair or replacement

Rotor bar faults often increase vibration, even when current appears normal.

B. Mechanical Faults

Common Mechanical Problems

- Bearing failure
- Shaft misalignment
- Rotor unbalance
- Loose foundation

Symptoms:

- Excessive vibration
- Noise
- Heating near bearings

Remedies:

- Bearing replacement
- Proper alignment
- Tightening foundation bolts

Bearings are the **most frequent cause** of induction motor failure.

C. Supply-Related Faults

- Single phasing
- Voltage unbalance
- Low or high supply voltage

Symptoms:

- Motor fails to start
- Overheating
- Reduced torque

Remedies:

- Check supply lines
 - Correct phase balance
 - Use proper protection (phase failure relay)
-

D. Operational / Environmental Faults

- Overloading
- Frequent starting

- Poor ventilation
- Dust or moisture

Effects:

- Insulation breakdown
- Reduced motor life

Systematic Troubleshooting Approach


Never guess. Follow a **logical sequence**:

1. Observe symptoms (noise, vibration, current)
2. Check supply condition
3. Perform electrical tests (IR, winding resistance)
4. Inspect mechanical components
5. Identify root cause
6. Rectify fault and test again

Real-World / Industry Applications (≈ 10 minutes)

Induction motors are used in:

- Pumps
- Fans
- Compressors
- Conveyors

 *Industry example:*

A motor overheated repeatedly.

Electrical tests were normal.

Root cause: Single phasing due to loose supply connection.

Correction saved the motor from burnout.

This shows that correct troubleshooting saves time, money, and production loss.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Induction motor faults can be electrical, mechanical, supply-related, or operational
- Symptoms guide fault identification
- Bearings and supply problems are common failure points
- Systematic troubleshooting is essential
- Testing confirms successful repair

Common Student Doubts

- *Is rewinding always needed?* → ❌ No
- *Can single phasing burn the motor?* → ✅ Yes

Mentorship & Career Note

Industries don't just need motor operators—they need motor problem solvers.

If you master induction motor troubleshooting:

- You become valuable in maintenance teams
- You perform confidently in interviews
- You reduce downtime and protect equipment

Remember:

A motor may be simple,
but maintaining it requires intelligence.

Topic 4.3: Faults and Troubleshooting of DC Machines

(DC Motors and DC Generators)

Hook / Introduction (≈ 5 minutes)

Let me start with a question that every maintenance engineer has faced:

“Why does a DC motor give excellent speed control, yet demand so much attention?”

DC machines are powerful, precise, and controllable, which is why they are still used in:

- Rolling mills
- Cranes
- Elevators
- Electric traction (older systems)

But unlike AC motors, DC machines have brushes and commutators, making them more sensitive to faults.

Today, we will learn how to identify common DC machine faults, understand their causes, and apply correct troubleshooting methods—a vital skill for any electrical engineer.

Core Concepts (≈ 40 minutes)

Classification of Faults in DC Machines

Faults in DC machines can be classified as:

1. Electrical faults
2. Mechanical faults
3. Commutator and brush faults
4. Operational faults

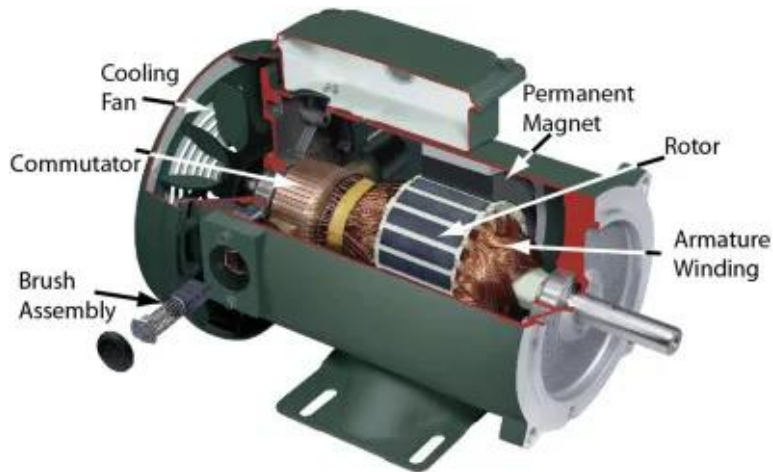


Figure: DC machine diagram showing armature, field winding, commutator, and brushes.

A. Electrical Faults

1. Armature Winding Faults

- Open circuit in armature
- Short circuit between armature coils
- Earth fault

Symptoms:

- Sparking at brushes
- Excessive current
- Loss of torque

Causes:

- Insulation failure
- Overloading
- Mechanical damage

Remedies:

- Insulation resistance test
- Armature repair or rewinding

2. Field Winding Faults

- Open field circuit
- Shorted field turns

Symptoms:

- Excessive speed (in shunt motor)
- Poor flux control

- Voltage instability (in generators)

⚠ *Dangerous condition:*

Open field in shunt motor can cause **runaway speed**.

Remedy:

- Never start motor without field circuit
- Check field continuity

B. Commutator and Brush Faults (Most Common)

Common Issues

- Excessive sparking
- Rough or burnt commutator
- Uneven brush wear

Causes:

- Incorrect brush pressure
- Wrong brush grade
- Misaligned brushes
- Dirty commutator

Remedies:

- Correct brush pressure
- Proper brush positioning
- Cleaning and polishing commutator

More than 50% DC motor complaints are related to brush and commutator issues.

C. Mechanical Faults

- Bearing failure
- Shaft misalignment
- Rotor unbalance

Symptoms:

- Noise
- Vibration
- Heating

Remedies:

- Bearing replacement
- Proper alignment and balancing

D. Operational Faults

- Overloading
- Frequent starting

- Poor ventilation

Effects:

- Rapid heating
- Insulation damage

Systematic Troubleshooting Approach


1. Observe symptoms (sparking, noise, speed change)
2. Check supply and field circuit
3. Inspect brushes and commutator
4. Perform electrical tests
5. Check mechanical condition
6. Rectify fault and re-test

Real-World / Industry Applications (≈ 10 minutes)

In industries such as:

- Steel rolling mills
- Lifts and cranes
- Paper and textile machines

DC motors are still preferred for high starting torque and precise speed control.

 *Industry example:*

A crane motor showed heavy sparking.

Cause: Incorrect brush grade after maintenance.

Correction prevented commutator damage worth lakhs.

This shows why proper troubleshooting saves cost and downtime.


Summary & Q&A (≈ 5 minutes)

Key Takeaways

- DC machines require careful maintenance
- Brush and commutator faults are most common
- Field winding faults can be dangerous
- Systematic troubleshooting prevents major damage

Common Student Doubts

- *Can DC motor run without field?* → ❌ No (dangerous)
- *Is sparking always bad?* → ❌ Small sparking is normal

 **Mentorship & Career Note**

Though AC drives are increasing, DC machine knowledge is still valued in heavy industries and maintenance roles.

Engineers who understand DC motor faults are respected because few people truly master

commutation problems.

Remember:

DC machines reward precision.

Careless handling leads to costly failures.

STUDENT AI TOOLKIT

◆ A. LOW-LEVEL PROMPTS

(Remember & Understand – 10 Prompts)

1. “Explain the concept of commissioning of rotating machines in very simple language suitable for Diploma students.”
2. “Define pre-commissioning inspection checks for rotating machines and list their objectives.”
3. “Explain winding resistance measurement: purpose, basic principle, and importance.”
4. “What is insulation resistance of windings? Explain why it is measured before starting a machine.”
5. “Explain the term ‘High Voltage Power Frequency Test’ in simple words with its purpose.”
6. “What is meant by trial start of a rotating machine? Why is it done?”
7. “Explain no-load test of rotating machines and what parameters are observed.”
8. “What is vibration in rotating machines? Explain its meaning and importance.”
9. “List common electrical and mechanical faults in rotating machines.”
10. “Summarize Unit-4 Commissioning of Rotating Machines in short bullet points for exam revision.”

◆ B. MODERATE-LEVEL PROMPTS

(Apply & Analyze – 10 Prompts)

11. “Compare winding resistance test and insulation resistance test with respect to purpose, method, and outcome.”
12. “Explain step-by-step procedure of insulation resistance measurement and interpret possible results.”
13. “Analyze why a machine may pass IR test but fail during high voltage test.”
14. “Explain the difference between trial start and no-load test with practical examples.”
15. “A rotating machine shows high vibration during no-load test. Analyze possible causes and remedies.”
16. “Explain common faults in induction motors and how symptoms help in troubleshooting.”
17. “Explain typical faults of synchronous machines related to excitation and synchronization.”
18. “Analyze the causes of sparking in DC machines and suggest corrective actions.”

19. “Prepare a cause–effect–remedy table for electrical and mechanical faults of rotating machines.”

20. “Explain how improper commissioning can reduce the life of rotating machines.”

◆ C. HIGH-LEVEL PROMPTS

(Design & Create – 5 Prompts)

21. “Design a logical flowchart for commissioning of a rotating machine from inspection to full-load operation.”

22. “Create a systematic troubleshooting workflow for rotating machines based on symptoms, tests, and corrective actions.”

23. “Develop an exam-oriented checklist for pre-start tests of rotating machines with safety emphasis.”

24. “Create a comparison chart showing faults and troubleshooting methods for induction motor, synchronous machine, and DC machine.”

25. “Design a sample commissioning report format for a rotating machine including all pre-start and test observations.”

✓ How Students Should Use This Toolkit

- 📩 Use A-level prompts before lectures or exams for quick understanding
 - 🗣️ Use B-level prompts for numericals, viva, and application-based questions
 - 🏆 Use C-level prompts for distinction, interviews, projects, and lab exams
-

🎯 Learning Coach Tip for Students

If you can ask the right question, AI becomes your personal tutor.

These prompts train you not just to *memorize*, but to think like a commissioning and maintenance engineer.

Students who practice with good prompts don’t fear exams—they master them.

If you want next:

- ✓ AI prompts for numerical & viva
 - ✓ Prompt set for lab experiments
 - ✓ Faculty version of this toolkit
-

🎯 Mastery CHECK –

📖 Key Definitions / Glossary (15 Terms)

(One-line, Diploma-level, exam & viva focused)

1. **Commissioning** – The process of checking, testing, and putting a machine into service safely.

2. **Pre-commissioning inspection** – Visual and mechanical checks done before electrical testing.
3. **Pre-start test** – Electrical and mechanical tests performed before energizing a machine.
4. **Winding resistance** – DC resistance of machine windings used to check uniformity and continuity.
5. **Insulation resistance (IR)** – Resistance offered by insulation to leakage current, measured in mega-ohms.
6. **Megger** – An instrument used to measure insulation resistance using high DC voltage.
7. **High voltage (power frequency) test** – Application of AC voltage above rated value to check insulation strength.
8. **Trial start** – First short energization of a machine under no-load condition.
9. **No-load test** – Running a machine at rated supply without mechanical load to observe behavior.
10. **No-load current** – Current drawn by a machine when operating without load.
11. **Vibration** – Unwanted mechanical oscillation of a rotating machine during operation.
12. **Single phasing** – Condition where one phase supply is lost in a three-phase system.
13. **Hunting** – Speed oscillation of a synchronous machine around synchronous speed.
14. **Commutator** – Mechanical rectifier in a DC machine that converts AC to DC.
15. **Troubleshooting** – Systematic method of identifying and correcting faults in machines.

2 FAQ & Assessment Section

A. Multiple Choice Questions (MCQs)

(20 questions – concept + basic application)

1. The main purpose of commissioning is to:
 - A) Increase speed
 - B) Reduce losses
 - C) Ensure safe and correct operation
 - D) Improve appearance
2. Which check is done first before starting any rotating machine?
 - A) No-load test
 - B) Trial start
 - C) Pre-commissioning inspection
 - D) Vibration test
3. Winding resistance is measured using:
 - A) AC supply
 - B) DC supply
 - C) Megger
 - D) Wattmeter
4. Insulation resistance is measured in:
 - A) Ohms
 - B) Kilo-ohms

- C) Mega-ohms
 - D) Micro-ohms
5. Which instrument is used for IR measurement?
- A) Voltmeter
 - B) Ammeter
 - C) Megger
 - D) Tachometer
6. High voltage test checks the:
- A) Continuity of winding
 - B) Dielectric strength of insulation
 - C) Speed of machine
 - D) Efficiency of machine
7. Trial start of a motor is done under:
- A) Full load
 - B) Overload
 - C) No-load
 - D) Short circuit
8. During no-load test, which parameter is most important?
- A) Output power
 - B) No-load current
 - C) Shaft torque
 - D) Efficiency
9. Excessive vibration mainly indicates:
- A) Electrical insulation failure
 - B) Mechanical problems
 - C) High efficiency
 - D) Proper alignment
10. Vibration measurement is mainly used to detect:
- A) Moisture in windings
 - B) Mechanical imbalance
 - C) Overvoltage
 - D) Earth fault
11. Single phasing in induction motor causes:
- A) Reduced speed only
 - B) Overheating
 - C) Improved efficiency
 - D) Reduced vibration
12. Which machine fault can cause hunting?
- A) Induction motor fault
 - B) DC motor brush fault
 - C) Synchronous machine fault
 - D) Transformer fault
13. Sparking at brushes is commonly related to:
- A) Induction motor
 - B) Synchronous motor
 - C) DC machine
 - D) Transformer
14. High no-load current indicates:
- A) Healthy motor
 - B) Over-excitation
 - C) Possible winding fault

D) Proper alignment

15. Which test confirms direction of rotation?

A) IR test

B) Winding resistance test

C) Trial start

D) HV test

16. Bearing failure mainly causes:

A) Electrical short circuit

B) Excessive vibration

C) High insulation resistance

D) Reduced voltage

17. HV test is performed using:

A) DC voltage

B) AC power frequency voltage

C) Battery

D) Pulse voltage

18. Loss of excitation in synchronous motor leads to:

A) Overspeed

B) Pulling out of synchronism

C) Reduced vibration

D) Higher power factor

19. Which fault is most common in induction motors?

A) Rotor winding open

B) Bearing failure

C) Field failure

D) Commutator fault

20. Troubleshooting should always start with:

A) Rewinding

B) Replacing parts

C) Observing symptoms

D) Increasing supply voltage

Answer Key (MCQs)

1-C, 2-C, 3-B, 4-C, 5-C, 6-B, 7-C, 8-B, 9-B, 10-B,

11-B, 12-C, 13-C, 14-C, 15-C, 16-B, 17-B, 18-B, 19-B, 20-C

B. Short Answer / Viva Questions (10)

1. Why is pre-commissioning inspection necessary before electrical tests?
2. Why should winding resistance of all phases be nearly equal?
3. What is the importance of insulation resistance measurement?
4. Why is HV test performed after IR test?
5. Why is trial start done without load?
6. What information does no-load current give about a machine?
7. How does vibration affect machine life?
8. Why is single phasing dangerous for induction motors?
9. Why is loss of field dangerous in DC shunt motors?

10. Why is troubleshooting always done systematically and not by guesswork?

DIGITAL RESOURCE LIBRARY

AI Tools & Digital Learning Tools

1. AI Conversational Tutor (Chat-based AI tools)

Purpose / Use-case:

- Concept explanation, doubt clearing, summaries, viva practice

How it helps in this unit:

- Explains commissioning steps, tests, and faults in simple Diploma-level language
 - Helps convert syllabus points into exam-ready answers
 - Useful for revision before viva and theory exams
-

2. Virtual Electrical Machines Simulator

Purpose / Use-case:

- Visualize rotating machine operation and test conditions

How it helps in this unit:

- Understand trial start, no-load test behavior, speed, and current
 - Visualizes effects of faults like single phasing, overload, or imbalance
 - Builds intuition before real lab experiments
-

3. Virtual Lab Platforms (Govt./Academic)

Purpose / Use-case:

- Perform simulated experiments online

How it helps in this unit:

- Practice no-load test, vibration measurement, IR test virtually
 - Reinforces lab experiments listed in syllabus (Unit-4 practicals)
 - Very useful for slow or average learners
-

4. Digital Measurement Visualizers

Purpose / Use-case:

- Simulate instruments like Megger, tachometer, vibration meter

How it helps in this unit:

- Understand instrument connections and readings
 - Reduces fear of real instruments during practical exams
 - Supports concepts like IR values, speed, vibration
-

5. Diagram & Flowchart Generators

Purpose / Use-case:

- Create flowcharts, checklists, and troubleshooting steps

How it helps in this unit:





- Prepare commissioning flowcharts and fault-finding logic
- Helps in 5-mark / 10-mark answers and project work
- Aligns with NEP focus on concept clarity and design thinking

2 Video Learning Repository

(Use search keywords instead of direct links for easy access)

Topic Name	Recommended Channel / Course / Lecturer Name	Search Keywords
Commissioning of Rotating Machines (Overview)	NPTEL – Electrical Engineering	“NPTEL commissioning of electrical machines”
Pre-commissioning Inspection of Motors	Electrical4U	“Electrical4U motor pre commissioning checks”
Winding Resistance & IR Test	Learn Engineering / Engineering Explained	“winding resistance test motor IR test”
High Voltage Power Frequency Test	NPTEL – High Voltage Engineering	“power frequency high voltage test machines”
Trial Start & No-Load Test of Induction Motor	NPTEL / Polytechnic Channels	“trial run no load test induction motor”
Vibration Measurement in Machines	NPTEL – Maintenance / Condition Monitoring	“vibration measurement rotating machines”
Faults in Induction Motor	Gate Smashers / Electrical Subjects	“induction motor faults and troubleshooting”
Faults in Synchronous Machine	NPTEL – Electrical Machines	“synchronous machine faults hunting excitation”
DC Machine Faults & Sparking	Engineering Funda / Polytechnic Channels	“DC motor sparking commutator faults”
Troubleshooting of Electrical Machines	NPTEL / Industrial Maintenance Lectures	“troubleshooting electrical machines”

How Students Should Use This Library

-  Before lecture: Watch overview videos for concept familiarity
-  After lecture: Use AI tools for summaries and doubt clearing
-  Before practical/viva: Use simulators and visualizers
-  Before exam: Use flowchart tools + AI for structured answers

Learning Coach Tip for Students

Don't use digital tools only to read answers.

Use them to:

- Visualize,
- Question, and

- Re-explain in your own words.

When technology supports thinking, learning becomes permanent.

PREDICTED QUESTION BANK

1 Most Repeated / High-Probability Questions

(Based on Diploma exam trends: 2-mark, 4-mark, 6-mark, diagram-based)

A. Core Definitions & Short Questions

1. Define commissioning of rotating machines.
2. What is meant by pre-commissioning inspection? State its importance.
3. Define winding resistance. Why is it measured before starting a machine?
4. What is insulation resistance? Mention acceptable limits in brief.
5. Define trial start of a rotating machine.
6. What is a no-load test? State its purpose.
7. Define vibration in rotating machines.
8. What is single phasing in an induction motor?
9. Define hunting in synchronous machines.
10. What is sparking at commutator in DC machines?

B. Explanatory / Descriptive Questions

11. Explain pre-commissioning inspection checks for rotating machines.
12. Describe the procedure for winding resistance measurement with neat sketch.
13. Explain insulation resistance measurement of windings using a Megger.
14. Explain high-voltage power frequency test and its necessity.
15. Describe the trial start procedure of a rotating machine.
16. Explain the no-load test of an induction motor and observations made.
17. Explain vibration measurement and its importance in commissioning.

C. Diagram-Based / Concept-Focused Questions

18. With a neat diagram, explain IR test connection of a rotating machine.
19. Draw and explain a flowchart for commissioning of a rotating machine.
20. Draw a cause–effect chart for vibration in rotating machines.

D. Faults & Troubleshooting (Very High Probability)

21. List common electrical and mechanical faults in rotating machines.
22. Explain faults and troubleshooting of induction motor.
23. Explain faults and troubleshooting of synchronous machine.
24. Explain faults and troubleshooting of DC machine.

25. Write a symptom–cause–remedy table for rotating machine faults.

2 Application & Logical Thinking Questions

(5 questions – differentiate average vs distinction answers)

1. A three-phase induction motor shows unequal winding resistance values.
 - Identify the possible fault
 - Explain why the motor should not be energized
 - Suggest corrective action
 2. A motor passes IR test but fails during high-voltage test.
 - Analyze the reason
 - Explain what this indicates about insulation quality
 3. During trial start, a motor rotates in the wrong direction.
 - What is the cause?
 - What immediate corrective step should be taken?
 4. A rotating machine shows high vibration during no-load test.
 - List possible mechanical causes
 - Explain how vibration affects machine life
 5. A DC shunt motor suddenly runs at very high speed.
 - Identify the fault
 - Explain why it is dangerous
 - Suggest preventive measures
-

Unit-5: Commissioning of Switchgear and Power Cable

Subject: Commissioning & Maintenance of Electrical Equipments (DI04009031)

Semester: 4th | Total Unit Hours: 8 | Weightage: 18%

Pedagogical Intent (Faculty Note)

“This unit transforms students from passive learners into site-ready technicians. The focus is on safety, standard test procedures, interpretation of results, and documentation, which are critical industry skills.”

Topic-Wise Detailed Study Plan (As per Syllabus)

Legend

- CT – Core Topic
 - ST – Supporting Topic
 - AT – Application-Oriented Topic
-

1. Pre-Commissioning Checks of Switchgear (5.1)

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
5.1.1	ST	0.5	Medium	High

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
Visual Inspection (Nameplate, Interlocks)				
5.1.2 Insulation Resistance (IR) Measurement	CT	0.5	High	Very High
5.1.3 Contact Resistance Test of CBs & Isolators	CT	0.5	High	Very High
5.1.4 CTs, PTs & Protection Relay Connection	CT	0.5	High	Very High

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
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Teaching Focus:

- ✓ Safety compliance
- ✓ Understanding manufacturer data & wiring correctness

2. Functional Tests of Switchgear (5.2)

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
5.2.1 Mechanical Operation Test	ST	0.5	Medium	High
5.2.2 Protection Relay & Control	CT	0.5	High	Very High

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
Circuit Testing				
5.2.3 Interlock Verification (Electric & Mechanical)	CT	0.5	High	Very High
5.2.4 SF ₆ Gas / Vacuum Integrity Test	AT	0.5	Medium	High

Teaching Focus:

- ✓ “Fail-safe” operation philosophy
- ✓ Importance of interlocks in accident prevention

3. On-Site Commissioning Tests of Switchgear (5.3)

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
5.3.1 High-Voltage	CT	0.5	High	Very High

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
Withstand Test (IS/IEC)				
5.3.2 Partial Discharge Test (GIS)	AT	0.25	Low–Medium	Medium
5.3.3 Breaker Timing Test	CT	0.25	High	Very High

Teaching Focus:

- ✓ Interpretation of test values
 - ✓ Consequences of insulation failure
-

4. Pre-Commissioning Checks of Power Cable (5.4)

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
5.4.1 Physical Inspection (Joints, Termination, Bending Radius)	ST	0.5	Medium	High
5.4.2 Conductor Resistance & Continuity Test	CT	0.5	High	Very High
5.4.3 Insulation Resistance Measurement (Megger Test)	CT	0.5	High	Very High

Teaching Focus:

- ✓ Cable handling & installation discipline
 - ✓ Safety before energization
-

5. Site Acceptance Tests of Power Cable (5.5)

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
5.5.1 High-Voltage Withstand Test	CT	0.5	High	Very High
5.5.2 Sheath Integrity Test	AT	0.25	Medium	High
5.5.3 Capacitance & Tan δ Measurement	AT	0.25	Medium	Medium

Teaching Focus:

- ✓ Cable insulation health

✓ Long-term reliability

6. Post-Commissioning Activities (5.6)

Sub-Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
5.6.1 Load Test Under Service Conditions	AT	0.25	Medium	High
5.6.2 Temperature Monitoring During Initial Energization	AT	0.25	Medium	High
5.6.3 Documentation of Test Results	CT	0.5	High	Very High

Teaching Focus:

✓ Importance of records in audits & troubleshooting

7. Faults & Troubleshooting (5.7)

Topic	Level	Lecture Hours	Exam Importance	Practical Relevance
Switchgear & Power Cable Faults	CT	0.75	Very High	Very High

Teaching Focus:

✓ Symptom → Cause → Remedy approach

✓ Industry-based fault scenarios

Logical Learning Progression

1. Safety & Visual Checks →
2. Electrical Testing (IR, Resistance) →
3. Functional & Protection Testing →
4. High-Voltage & Acceptance Tests →
5. Post-Commissioning Monitoring →

6. Fault Diagnosis & Troubleshooting

OBE & NEP-2020 Alignment

- **CO Mapping:** Directly supports CO-5 (Commission switchgear & power cable)
 - **RBT Levels:**
 - Remember & Understand → Procedures, standards
 - Apply (50%) → Testing, commissioning, troubleshooting
 - Skill Orientation: Industry-ready, site-oriented learning
 - Experiential Learning: Lab tests, site visit correlation, report writing
-

Exam-Focused Guidance for Students

- Very High Priority:
 - IR test, Contact resistance test
 - HV withstand test (switchgear & cable)
 - Faults & troubleshooting
- Likely 5–7-mark questions:
 - Stepwise commissioning procedure
 - Test purpose + standard values
- Practical Viva Focus:
 - Safety precautions
 - Instrument used & connections

Motivational Note to Students

“If you can commission a breaker or cable safely, you are already an industry asset. Master the tests, respect safety, and document everything—this is how professionals work.”

Topic 5.1.1: Pre-Commissioning Checks of Switchgear – Visual Inspection (Nameplate & Interlocks)

1 Hook / Introduction (≈ 5 minutes)

Let me begin with a simple but powerful question:

“If a switchgear panel looks new, does that mean it is safe to energize?”

In real substations, many failures happen not because of electrical defects, but because basic visual checks were ignored.

A missing interlock or a wrong nameplate rating can cause wrong operation, equipment damage, or even fatal accidents.

You already know that switchgear controls and protects the power system.

Today, we learn the first and most important step of commissioning—visual inspection, which costs zero money but saves lives and equipment.

2 Core Concepts (≈ 40 minutes)

What is Visual Inspection in Switchgear Commissioning?

Visual inspection is a systematic physical examination of switchgear before any electrical test or energization.

It ensures:

- Correct equipment is installed
- Safety features are intact
- No visible abnormality exists

Never test or energize switchgear without visual inspection.

A. Nameplate Inspection

Every switchgear component—circuit breaker, isolator, relay panel—has a nameplate.

What to Check on Nameplate

- Rated voltage (kV)
- Rated current (A)
- Short-circuit breaking capacity
- Frequency (50 Hz)
- Make, model, and year
- Standard reference (IS/IEC)

✦ *Why it matters:*

If switchgear rating does not match the system, it may **fail during fault conditions**.

✦ *Visual to draw:*

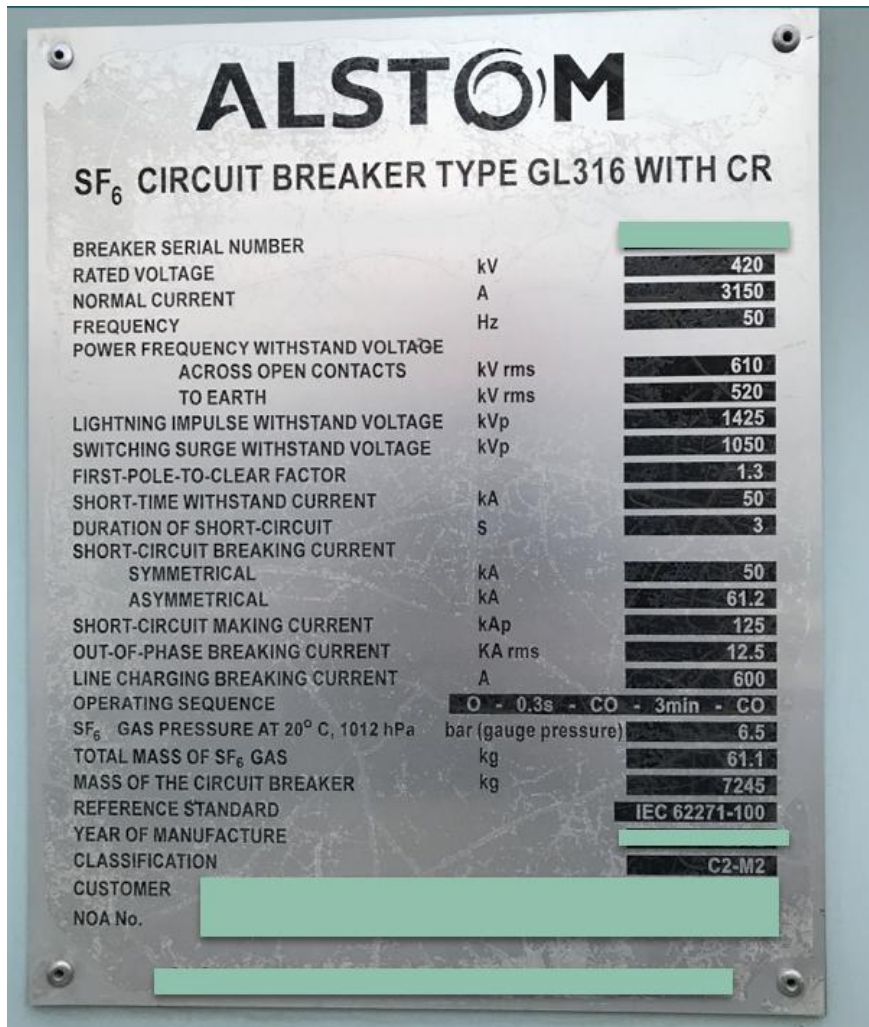


Figure : Front view of a circuit breaker with nameplate

B. Physical Condition Check

Inspect for:

- Cracks or damage on enclosure
- Rust, dust, or moisture

- Loose bolts and screws
- Broken indicators or handles

Moisture visible outside often means insulation weakness inside.

C. Interlocks – The Safety Guards

Interlocks are mechanical or electrical safety arrangements that prevent wrong sequence operation.

Purpose of Interlocks

- Prevent closing breaker when isolator is open
- Prevent access to live parts
- Ensure safe maintenance

Types of Interlocks

1. **Mechanical interlocks** – Linkages, locks, shutters
2. **Electrical interlocks** – Control circuit logic, relays

D. Interlock Verification Checks

- Breaker should not close if isolator is open
- Earthing switch should not close when breaker is ON
- Panel door should not open when equipment is live

⚠ If any interlock fails, energization must be stopped immediately.

E. Labelling & Indications


Check:

- Phase identification (R-Y-B)
- ON/OFF indication
- Danger and safety labels
- Control wiring tags

Clear labeling prevents human error, which is the most common cause of accidents.

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

In substations, industries, and power plants, visual inspection is done using a standard checklist and signed by the commissioning engineer.

 *Industry example:*

A breaker was installed with correct electrical tests passed. During visual inspection, a missing interlock pin was noticed. Correction prevented unsafe earthing during live condition. This shows why visual inspection is not optional—it is mandatory.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Visual inspection is the first step of switchgear commissioning
- Nameplate ensures correct rating and compatibility

- Interlocks protect equipment and human life
- Never bypass or ignore interlocks
- Always use a checklist approach

Common Student Doubts

- *Can we skip visual check if equipment is new?* → ❌ Never
- *Are interlocks really necessary?* → ✅ Yes, for safety

Mentorship Note (Career Connection)

Engineers who master visual inspection and interlock logic are trusted with substations, panels, and protection systems.

In interviews, supervisors often ask:

“What do you check before energizing switchgear?”

If you answer confidently, you already stand out as a site-ready engineer.

Remember:

Good engineers test equipment.

Great engineers inspect it first.

Topic 5.1.2: Pre-Commissioning Checks of Switchgear – Insulation Resistance (IR) Measurement

Hook / Introduction (≈ 5 minutes)

Let me start with a real-life site question:

“The breaker is new, panels are clean, wiring looks perfect... so why did it trip immediately after energization?”

In many such cases, the answer is simple: poor insulation.

Insulation is like the skin of an electrical system—if it is weak, current leaks, protection operates, and equipment fails.

You have already studied IR testing for machines and transformers.

Today, we apply the same fundamental concept to switchgear, which is the first line of protection in any power system.

Core Concepts (≈ 40 minutes)

What is Insulation Resistance (IR)?

Insulation Resistance is the resistance offered by insulating material against leakage current between:

- Phase to earth
- Phase to phase

It is measured in **mega-ohms (MΩ)**.

Purpose of IR Measurement in Switchgear

- To ensure insulation health before energization
- To prevent short circuits and earth faults
- To ensure safety of personnel and equipment

Equipment Used – Megger

IR measurement is done using an Insulation Resistance Tester (Megger).

Typical test voltages:

- LT switchgear → 500 V / 1000 V DC
- HT switchgear → 2.5 kV / 5 kV DC

Preparation Before IR Test

Before testing, always ensure:

- Switchgear is isolated from supply
- Control and auxiliary circuits are disconnected
- Earthing switch is open
- Panel is clean and dry

⚠ Safety rule:

Never touch terminals during or immediately after testing—stored charge may remain.

IR Measurement Procedure (Step-by-Step)

1. Identify test points (phase-earth, phase-phase)
2. Connect Megger leads properly
3. Apply test voltage for **1 minute**
4. Note the steady IR value
5. Discharge the circuit after test

Acceptable IR Values (General Guideline)

- LT switchgear: $\geq 1 \text{ M}\Omega$
- HT switchgear: $\geq 100 \text{ M}\Omega$ (or as per IS/IEC / manufacturer)

Key teaching point:

Higher IR value = healthier insulation

Causes of Low IR Value

- Moisture or humidity
- Dust and contamination
- Aging insulation
- Improper storage

Corrective actions:

- Cleaning
- Drying using heaters or blowers
- Retesting after rectification

Why IR Test is Done Before Other Tests

- IR test is non-destructive
- It identifies insulation weakness early

- Other tests (HV test) depend on good IR results

IR test is always performed before high-voltage tests.

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

In substations and industries, IR measurement is mandatory before:

- First energization
- After maintenance
- After long shutdown

Industry example:

A panel stored for 6 months showed low IR due to moisture.

After drying and retesting, IR improved and commissioning was successful—preventing a major fault.

This shows IR testing is not just a formality—it is a decision-making test.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- IR measurement checks insulation health of switchgear
- Megger is used with appropriate DC voltage
- Test is done phase-earth and phase-phase
- Low IR must be corrected before energization
- IR test ensures safety and reliability

Common Student Doubts

- *Can IR test damage equipment?* → ❌ No (if done correctly)
- *Is one reading enough?* → ❌ Test all phases

Mentorship Note (Career Connection)

In real sites, engineers are often asked:

“Have you taken IR values before energizing?”

If you understand why, how, and what the values mean, you are no longer a student—you are a responsible commissioning engineer.

Remember:

Strong insulation knowledge protects equipment.

Strong IR testing protects your reputation.

Topic 5.1.3: Pre-Commissioning Checks of Switchgear – Contact Resistance Test of Circuit Breakers and Isolators

Hook / Introduction (≈ 5 minutes)

Let 'begin with a simple but critical question:

“If a circuit breaker is CLOSED, does it always mean current flows smoothly?”

Many students assume that a closed breaker is perfect.

But in real substations, a breaker may be mechanically closed yet electrically weak due to high contact resistance.

High contact resistance does not show sparks immediately.

Instead, it silently causes heating, energy loss, contact burning, and eventual failure.

That is why contact resistance test is an essential pre-commissioning test for circuit breakers and isolators—especially before first energization.

Core Concepts (≈ 40 minutes)

What is Contact Resistance?

Contact resistance is the resistance offered at the junction of two conducting contacts when a breaker or isolator is in the ON (closed) position.

Ideally, contact resistance should be very low (micro-ohms).

Simple analogy:

Think of two clean copper plates pressed firmly together → low resistance

Think of rusty or loose plates → high resistance and heat

Why Contact Resistance Test is Required

1. To ensure proper current flow
2. To detect loose, oxidized, or damaged contacts
3. To avoid excessive heating
4. To prevent premature failure of switchgear

This test checks the health of current-carrying joints, not insulation.

Equipment Used

- Micro-ohmmeter / Contact Resistance Tester
- Uses high DC current (100 A or more) and measures voltage drop

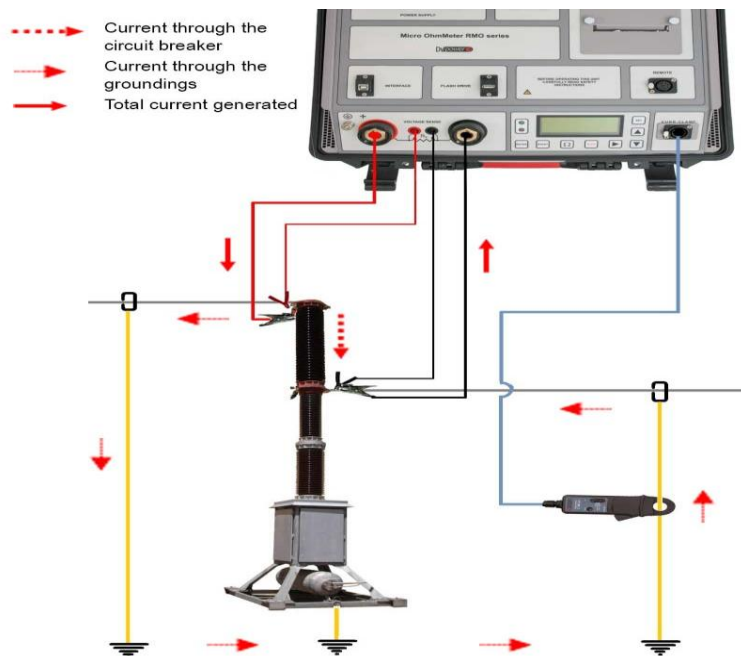


Figure: Circuit breaker poles with test leads connected across each pole (one pole at a time).

Preparation Before Test

Before testing:

- Switchgear must be isolated and de-energized
- Breaker or isolator should be in CLOSED position
- Contacts should be clean
- Control circuits isolated

⚠ Safety rule:

Never perform contact resistance test on an energized breaker.

Test Procedure (Step-by-Step)

1. Close the circuit breaker / isolator
2. Connect micro-ohmmeter probes across one pole
3. Inject specified DC current
4. Measure voltage drop
5. Instrument calculates contact resistance
6. Repeat for all poles
7. Compare results

Acceptable Values (General Idea)

- Contact resistance should be:
 - Very low
 - Nearly equal for all poles

✦ Key observation:

Large difference between poles indicates contact problem, even if absolute value seems low.

Causes of High Contact Resistance

- Oxidation or corrosion
- Improper contact pressure
- Misalignment
- Contact wear or damage

Corrective actions:

- Cleaning contacts
- Tightening joints
- Replacing damaged contacts

A small increase in contact resistance can cause large temperature rise due to I^2R loss.

Why This Test is Done After IR Test

- IR test checks insulation
- Contact resistance test checks current path
- Both together ensure safe and efficient operation

Real-World / Industry Applications (≈ 10 minutes)

In substations and industries:

- Contact resistance test is mandatory for new breakers
- Also done after maintenance or overhaul

🔧 Industry example:

A breaker passed IR test but showed unequal contact resistance in one pole.

Contacts were cleaned and aligned before energization—preventing localized overheating and future outage.

This proves that visual appearance is not enough; electrical contact quality must be verified.

Summary & Q&A (≈ 5 minutes)**Key Takeaways**

- Contact resistance test checks current-carrying ability
- Performed with breaker/isolator in closed condition
- Uses micro-ohmmeter with high DC current
- All poles must show uniform low resistance

- Prevents heating and contact failure

Common Student Doubts

- *Is contact resistance same as winding resistance?* → ❌ No
- *Can high contact resistance trip protection?* → ✅ Yes (due to heating)

📌 Mentorship Note (Career Connection)

On real sites, senior engineers often say:

“Most breaker failures start at the contacts.”

If you understand why and how contact resistance is measured, you are ready for:

- Substation commissioning
- Maintenance teams
- Protection and switchgear roles

Remember:

Good insulation prevents faults.

Good contacts prevent failures.

Topic 5.1.4: Pre-Commissioning Checks of Switchgear – CTs, PTs & Protection Relay Connections Verification

Hook / Introduction (≈ 5 minutes)

Let begin with a thought-provoking question:

“If a fault occurs in a power system, who actually ‘decides’ to trip the circuit breaker?”

It is not the breaker itself.

The decision is taken by CTs, PTs, and protection relays working together.

Even if your breaker is perfect and insulation is excellent, one wrong CT or relay connection can cause false tripping, non-tripping, or total protection failure.

That is why verification of CT, PT, and relay connections is one of the most critical pre-commissioning checks in switchgear.

Core Concepts (≈ 40 minutes)

Role of CTs, PTs, and Protection Relays

- Current Transformer (CT): Steps down high current to a safe value for relays and meters
- Potential Transformer (PT): Steps down high voltage to a measurable level
- Protection Relay: Senses abnormal conditions and gives trip command

Simple idea:

CTs & PTs are the “senses” → Relay is the “brain” → Breaker is the “muscle”.

Why Connection Verification is Required

- To ensure correct magnitude and direction of current/voltage
- To avoid mal-operation of protection
- To ensure selective and reliable fault clearing

- To protect costly equipment and maintain system stability

CT Connection Verification

Key checks:

- Correct CT ratio as per design
- Correct polarity (P1–P2 / S1–S2)
- Proper shorting of CT secondary during testing
- Correct phase connection to relay

⚠ Important safety rule:

Never keep CT secondary open-circuited—it may develop dangerously high voltage.

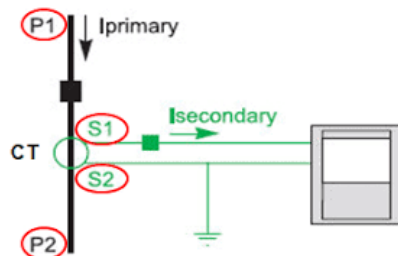


Figure: CT on a conductor with primary terminals P1-P2 and secondary S1-S2 connected to relay.

PT Connection Verification

Key checks:

- Correct voltage ratio
- Proper phase identification (R-Y-B)
- Correct earthing of PT secondary
- Proper fuse/MCB in PT circuit

PT secondary earthing is essential for safety and stable relay operation.

Protection Relay Connection Verification

Checks include:

- Correct wiring as per schematic
- Correct CT & PT inputs to relay
- Correct trip circuit wiring to breaker
- Auxiliary supply availability
- Proper labeling of terminals

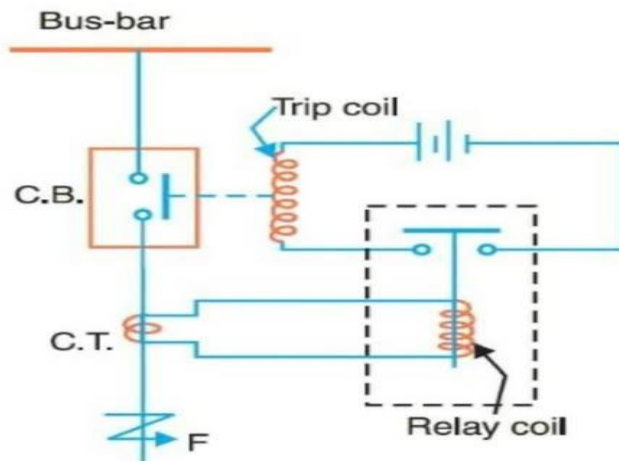


Figure: CT → Relay → Trip Coil → Circuit Breaker.

Basic Functional Verification (Before Testing)

- Relay powers ON correctly
- Indications and LEDs are healthy
- No wiring loose or interchanged
- Trip circuit continuity is healthy

Common Errors Found During Verification

- CT polarity reversed
- Wrong CT ratio connected
- PT phase sequence mismatch
- Trip coil wiring error

Result:

- False tripping
- Failure to trip during actual fault

Real-World / Industry Applications (≈ 10 minutes)

In substations, industries, and power plants, commissioning engineers always verify CT, PT, and relay connections before injecting current or voltage.

Industry example:

During commissioning, a feeder relay tripped instantly on energization.

Reason: CT polarity reversed in one phase.

After correction, the system operated normally.

This shows that a small wiring mistake can shut down an entire system.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- CTs and PTs provide correct signals to protection relays
- Relay acts as decision-making device
- Connection verification prevents false or missed tripping
- CT secondary must never be open
- This check is essential before functional and HV tests

Common Student Doubts

- *Is CT verification more important than breaker test?* → Yes, equally important
- *Can relay be tested without correct CT/PT wiring?* → No

Mentorship Note (Career Connection)

In real substations, senior engineers often say:

“Breaker trips only when relay tells it to.”

If you master CT, PT, and relay connection logic, you move closer to roles in:

- Substation commissioning
- Protection & control panels
- Utility and industrial maintenance

Remember:

Good protection starts with correct connections.

Correct connections build trust in an engineer.

Topic 5.2.1: Functional Tests of Switchgear – Mechanical Operation Test

Hook / Introduction (≈ 5 minutes)

Let me start with a very practical question:

“If a circuit breaker is electrically healthy, will it always protect the system?”

The honest answer is No.

Even with perfect insulation and correct relay wiring, a breaker that cannot open or close mechanically at the right time becomes useless.

Think of a strong door lock with a jammed handle—no matter how strong the lock is, it fails when you need it most.

That is why mechanical operation test is a crucial functional test of switchgear before commissioning.

Core Concepts (≈ 40 minutes)

What is Mechanical Operation Test?

Mechanical operation test is a functional test carried out to verify that switchgear operates smoothly and reliably without any electrical load.

It checks the mechanical health of:

- Circuit breakers
- Isolators

- Earthing switches

This test confirms that the breaker can OPEN and CLOSE correctly on command.

Purpose of Mechanical Operation Test

1. To ensure smooth closing and opening
2. To check spring, linkage, and latch mechanisms
3. To verify manual and motorized operation
4. To confirm mechanical interlocks
5. To detect sticking, jamming, or abnormal noise

Types of Mechanical Operations Checked

- Manual operation (hand lever / handle)
- Electrical operation (spring charging motor)
- Local operation (panel push buttons)
- Remote operation (control room command)

Preparation Before Test

Before performing the test:

- Ensure switchgear is isolated and de-energized
- Ensure no electrical load
- Confirm proper lubrication
- Check safety clearances

⚠ Safety rule:

Mechanical test must be done before any high-voltage or load test.

Mechanical Operation Test Procedure

1. Close the breaker manually
2. Observe smoothness and firmness
3. Open the breaker manually
4. Repeat several times (open–close cycles)
5. Perform electrical close/open using control circuit
6. Observe indicators and position flags
7. Listen for abnormal sounds

Parameters Observed

- Smoothness of operation

- Proper contact engagement
- Correct ON/OFF indication
- Proper spring charging and release
- No abnormal sound or vibration

Most breaker failures during faults occur due to mechanical sticking, not electrical problems.

Common Mechanical Problems Detected

Observation	Possible Cause
Hard closing	Poor lubrication
Delay in opening	Weak spring
Jerky movement	Misalignment
Noisy operation	Worn parts

Corrective actions:

Cleaning, lubrication, adjustment, or replacement of parts.

Why Mechanical Test Comes Before Electrical Tests

- Electrical tests assume proper movement of contacts
- A stuck breaker can fail even with perfect electrical values
- Prevents damage during HV tests

Real-World / Industry Applications (≈ 10 minutes)

In substations and industries, commissioning engineers perform multiple open–close operations before allowing a breaker to be energized.

Industry example:

A newly installed breaker failed to open during trial operation.

Cause: Transport lock not removed.

Mechanical test detected the issue and prevented a serious fault during energization.

This shows how a simple mechanical test can prevent major accidents.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Mechanical operation test checks physical movement of switchgear
- Ensures reliable opening and closing
- Detects sticking, jamming, and weak springs
- Must be done before HV and load tests
- Essential for system safety and reliability

Common Student Doubts

- *Is mechanical test enough for commissioning?* → ❌ No, but it is essential
- *Can a new breaker fail mechanically?* → ✅ Yes

Mentorship Note (Career Connection)

In real sites, senior engineers trust those who **never rush mechanical checks**.

If you master mechanical operation testing, you gain confidence in:

- Substation commissioning
- Industrial panel maintenance
- Protection and control systems

Remember:

A breaker that moves correctly
is a breaker that protects correctly.

Topic 5.2.2: Functional Tests of Switchgear – Protection Relay and Control Circuit Testing

Hook / Introduction (≈ 5 minutes)

Let me ask you a practical question you may face on site:

“During a short circuit, who actually orders the circuit breaker to trip?”

It’s not the breaker.

The decision is taken by the protection relay, and the command travels through the control circuit.

You may install the best breaker, but if the relay or control circuit fails, protection fails.

That is why protection relay and control circuit testing is a *must* before energizing any switchgear.

Today, you will learn how engineers verify that protection works exactly when it is needed most.

Core Concepts (≈ 40 minutes)

What is Protection Relay & Control Circuit Testing?

It is a functional test carried out to ensure that:

- Protection relays sense abnormal conditions correctly
- Control circuits transmit signals properly
- Circuit breaker trips and closes as designed

Simple logic:

Fault → Relay operates → Control circuit carries signal → Breaker trips

Purpose of This Test

1. To confirm correct operation of protection relays
2. To verify healthy control wiring and DC supply
3. To check trip and close circuits
4. To prevent false tripping or failure to trip
5. To ensure safe and reliable system operation

Quick Recall: Protection Relays

- Overcurrent relay – operates during excessive current
- Earth fault relay – operates during earth leakage
- Over/Under voltage relay – operates during voltage abnormality

These relays receive inputs from CTs and PTs, which you studied in Topic 5.1.4.

Control Circuit – The Signal Path

Control circuit includes:

- DC supply (battery / control transformer)
- Trip coil and close coil
- Push buttons (TRIP / CLOSE)
- Auxiliary contacts
- Wiring and terminal blocks

💡 *Analogy:*

The control circuit is like the nervous system—invisible, but critical.

Pre-Testing Checks

Before testing:

- Verify wiring with schematic diagram
- Check availability of DC control supply
- Check fuses, MCBs, and terminal tightness
- Confirm relay settings as per design

⚠ **Safety rule:**

Relay testing is done **without energizing the power circuit.**

Protection Relay Functional Testing

Basic steps:

1. Energize relay auxiliary supply
 2. Simulate fault (test button or secondary injection)
 3. Observe relay pickup / LED indication
 4. Check relay contact operation
 5. Verify breaker trip command
-

Control Circuit Testing

Control circuit testing ensures:

- Trip push button works
- Close push button works
- Local and remote-control functions correctly
- Indications (ON, OFF, TRIP) are accurate

Common tests:


- Trip circuit continuity test
- Close circuit continuity test
- Interlock logic confirmation

Common Problems Detected

- Loose or wrong wiring
- Incorrect relay contact used
- DC supply failure
- Wrong relay settings

Real-World / Industry Applications (≈ 10 minutes)

In substations, industries, and power plants, no feeder is energized unless relay and control circuit testing is successful.

 *Industry example:*

During commissioning, a relay operated correctly, but the breaker did not trip.

Cause: Trip coil wire was loose.

After correction, the system worked safely.

This proves an important rule:


Protection is only as strong as its control circuit.

Summary & Q&A (≈ 5 minutes)**Key Takeaways**

- Protection relay makes the tripping decision
- Control circuit carries trip and close commands
- Functional testing confirms actual operation
- Prevents false tripping and non-tripping
- Mandatory before energization

Common Student Doubts

- *Can relay operate but breaker not trip?* → Yes (control circuit fault)
- *Is this test done before HV test?* → Yes
- *Is this topic exam-important?* → Very high

 Mentorship Note (Career Connection)

Engineers who understand relay logic and control circuits are trusted with:

- Substation commissioning
- Protection & control panels
- Industrial electrical maintenance

Remember:

A breaker protects equipment,

but a properly tested relay–control system protects the entire power system.

platforms.

Topic 5.2.3: Functional Tests of Switchgear – Interlock Verification (Electrical & Mechanical)

Hook / Introduction (≈ 5 minutes)

Let me begin with a safety-oriented question:

“What stops an operator from opening an isolator when the circuit breaker is still ON?”

The answer is INTERLOCKS.

Interlocks are silent safety guards. They don't generate power, they don't trip faults—but they prevent human mistakes, which are one of the biggest causes of electrical accidents.

Many serious substation accidents happened not due to equipment failure, but due to wrong operation sequence.

That is why interlock verification is a compulsory functional test before commissioning switchgear.

Core Concepts (≈ 40 minutes)

What is an Interlock?

An interlock is a safety arrangement that allows or blocks an operation unless certain conditions are satisfied.

◆ Simple definition:

Interlock ensures “right operation at the right time in the right sequence.”

Why Interlocks are Required in Switchgear

- To prevent unsafe operation
 - To protect equipment and personnel
 - To ensure correct switching sequence
 - To avoid arc flash and mechanical damage
-

Types of Interlocks

1. Mechanical Interlocks

- Operate through **physical linkages, levers, keys**
- Do not require electrical supply
- Commonly used between:
 - Circuit breaker & isolator
 - Isolator & earthing switch

◆ *Example:*

Isolator cannot open unless breaker is OFF.

2. Electrical Interlocks

- Operate through auxiliary contacts, relays, control wiring
- Depend on control circuit
- Used in:
 - Remote/local operations
 - Panel-to-panel interlocking

◆ *Example:*

Closing command is blocked unless correct conditions are met.

Interlock Verification – What Does It Mean?

Interlock verification is the process of checking whether interlocks are working correctly under all operating conditions.

This test confirms:

- Correct logical operation
- Correct sequence enforcement
- No bypass or failure in interlock mechanism

Mechanical Interlock Verification Procedure

1. Keep circuit breaker ON
2. Try operating isolator
→ It should NOT operate
3. Switch OFF circuit breaker
4. Operate isolator
→ It should operate smoothly
5. Repeat for earthing switch

Electrical Interlock Verification Procedure

1. Energize control circuit
2. Try incorrect operation (e.g., closing breaker when isolator is open)
3. Observe:
 - Operation should be blocked
4. Try correct operation
5. Verify relay logic and auxiliary contacts

Common Interlock Faults Found

- Bypassed interlocks (dangerous practice)
- Wrong auxiliary contact wiring
- Mechanical wear or misalignment
- Improper installation

⚠ Important Safety Note:

Never energize switchgear with defective or bypassed interlocks.

Exam-Oriented Points

- Difference between electrical and mechanical interlocks
- Purpose of interlocks in switchgear
- Stepwise verification procedure
- Safety importance

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

In substations and industries, interlock verification is performed before giving charging permission.

Industry example:

During commissioning, isolator operated while breaker was ON.

Reason: Mechanical interlock pin missing.

Operation stopped immediately—preventing a possible arc flash accident.

This proves:

Interlocks don't improve performance,
they prevent disasters.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Interlocks prevent unsafe operations
- Mechanical interlocks use physical mechanisms
- Electrical interlocks use control logic
- Verification ensures safety and correct sequence
- Mandatory test before energization

Common Student Doubts

- *Can interlocks be bypassed temporarily?* → ❌ Never recommended
 - *Are interlocks required in all switchgear?* → ✅ Yes
-

Mentorship Note (Career Connection)

In real electrical installations, safe engineers are valued more than fast engineers.

If you master:

- Interlock logic
- Safe switching sequences

you become suitable for roles in:

- Substation operation & maintenance
- Industrial safety supervision
- Commissioning and inspection teams

Remember:

Power systems forgive no mistakes—
interlocks exist because humans can make them.

Topic 5.2.4: Functional Tests of Switchgear – SF₆ Gas / Vacuum Integrity Test

Hook / Introduction (≈ 5 minutes)

Let me start with a question that often surprises new site engineers:

“If a circuit breaker looks mechanically perfect and passes electrical tests, can it still fail during operation?”

Yes—if its arc-quenching medium is unhealthy.

Modern circuit breakers rely on SF₆ gas or vacuum to safely interrupt high fault currents. If SF₆ gas leaks or vacuum integrity is lost, the breaker may fail to quench arc, leading to severe damage or explosion. That is why SF₆ gas / vacuum integrity testing is a critical functional test before commissioning.

Core Concepts (≈ 40 minutes)

Why Arc-Quenching Medium Matters

When contacts separate under load or fault:

- An electric arc is formed
- This arc must be quickly extinguished

Different breakers use different media:

- SF₆ Circuit Breaker → Uses sulfur hexafluoride gas
- Vacuum Circuit Breaker (VCB) → Uses sealed vacuum interrupter

✦ *Key idea:*

Healthy medium = safe interruption.

SF₆ Gas – Basics

SF₆ (Sulfur Hexafluoride):

- Excellent dielectric strength
- High arc-quenching ability
- Chemically stable and non-flammable

In SF₆ breakers, gas is stored under specified pressure.

✦ *Visual to draw:*

Simple cross-section of SF₆ breaker showing contacts inside gas chamber.

Purpose of SF₆ Gas Integrity Test

- To check correct gas pressure
 - To detect gas leakage
 - To ensure adequate dielectric strength
 - To confirm breaker is safe for operation
-

SF₆ Gas Integrity Test – What is Checked

1. Gas pressure / density
2. Leakage indication
3. Alarm and lockout operation

Most SF₆ breakers have:

- Density monitor
 - Alarm contact (low gas)
 - Lockout contact (very low gas)
-

SF₆ Gas Integrity Test Procedure (Basic)

1. Check gas pressure gauge reading
2. Compare with rated pressure (temperature corrected)
3. Check alarm contact operation
4. Check lockout contact operation
5. Inspect for visible leakage

⚠ Safety Note:

Breaker **must not be operated** if gas pressure is below safe limit.

Vacuum Circuit Breaker (VCB) – Basics

In VCB:

- Contacts are sealed in **vacuum interrupter**
- No gas filling required
- Arc extinguishes very quickly due to absence of medium

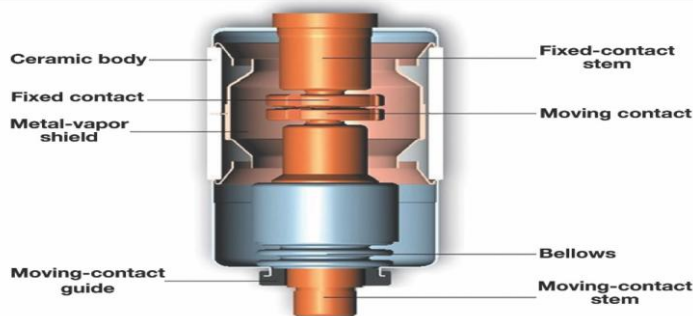


Figure: Vacuum Interrupter with fixed and moving contacts.

Vacuum Integrity Test – Purpose

- To confirm vacuum seal is intact
- To ensure no air ingress
- To maintain dielectric strength

Vacuum Integrity Test Methods (Diploma Level)

- High-voltage withstand test across open contacts
- Observation of contact gap condition
- Manufacturer-recommended test procedure

★ Exam Point:

Loss of vacuum = breaker becomes unsafe.

Common Problems Detected

- SF₆ gas leakage
- Faulty density monitor

- Cracked vacuum bottle
- Improper sealing

Corrective actions:

- Gas topping / refilling
- Replacing faulty interrupter
- Re-testing before energization

Real-World / Industry Applications (≈ 10 minutes)

In **substations, GIS installations, and industrial plants**, no SF₆ or vacuum breaker is energized without integrity verification.

Industry example:

During commissioning, SF₆ pressure was slightly below limit.

Alarm contact worked correctly, breaker operation was blocked, and gas refilling was done—**preventing internal flashover.**

This shows:

**A breaker may look strong outside,
but its real strength lies inside.**

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- SF₆ and vacuum are arc-quenching media
- Integrity test ensures safe interruption
- SF₆ test checks pressure, leakage, alarm, lockout
- Vacuum test ensures sealed interrupter
- Mandatory before energization

Common Student Doubts

- *Can breaker operate with low SF₆ pressure?* → ❌ Unsafe
- *Does vacuum breaker need gas test?* → ❌ No, but integrity test is required
- *Is this topic exam-important?* → ✅ Moderate to high

🎓 Mentorship Note (Career Connection)

Engineers who understand **SF₆ and vacuum breaker health** are valued in:

- Substations and GIS systems
- Industrial power distribution
- Modern switchgear maintenance teams

Remember:

**Contacts open the circuit,
but the arc-quenching medium saves the system.**

Topic 5.3.1: On-Site Commissioning Tests of Switchgear – High-Voltage Withstand Test (As

per IS/IEC)

1 Hook / Introduction (≈ 5 minutes)

Let me begin with a practical thought:

“The switchgear has passed IR test, contact resistance test, and functional tests. Is it now safe to energize at rated voltage?”

Not yet.

Before a switchgear is connected to the power system, it must prove one final thing:

👉 **It can withstand high voltage stress without breakdown.**

This is exactly what the **High-Voltage (HV) Withstand Test** checks.

It is like a **final stress exam** for switchgear insulation—if it passes, the equipment earns the right to be energized.

2 Core Concepts (≈ 40 minutes)

What is High-Voltage Withstand Test?

The High-Voltage Withstand Test is an **on-site commissioning test** in which a **specified high AC voltage** is applied between:

- Phase to earth
- Phase to phase

for a **specified duration**, to verify the **dielectric strength of insulation**.

🔴 Simple definition:

It checks whether insulation can survive abnormal over-voltage conditions.

Why HV Withstand Test is Necessary

- To detect **weak insulation**
- To reveal **manufacturing, transport, or installation defects**
- To ensure **safety and reliability**
- To comply with **IS/IEC standards**

💡 Key idea:

IR test shows *resistance*, HV test proves *strength*.

Standards Followed (Exam-Important)

HV Withstand Test is conducted as per:

- **Indian Standards (IS)**
- **IEC standards**

Test voltage value and duration depend on:

- Rated voltage of switchgear
- Type of insulation
- Standard reference

🔴 Exam tip:

Always mention **“As per IS/IEC”** in answers.

Equipment Used

- **AC High Voltage Test Set**

- Control panel with voltage regulator
- Measuring instruments
- Safety earthing arrangement

✦ *Visual to draw:*

Block diagram showing HV test set → switchgear → earth.

Test Preparation (Very Important for Safety)

Before testing:

- Ensure switchgear is **isolated**
- Remove sensitive devices (relays, meters)
- Ensure **proper earthing**
- Barricade the test area
- Display **DANGER – HIGH VOLTAGE** boards

⚠ Golden Rule:

Only authorized personnel should be present.

Test Procedure (Step-by-Step)

1. Connect HV test set between phase and earth
2. Gradually raise voltage to specified value
3. Maintain voltage for specified time (usually 1 minute)
4. Observe for:
 - Flashover
 - Breakdown
 - Abnormal sound or smell
5. Reduce voltage gradually and discharge circuit

✦ *Flowchart to draw:*

Connect → Increase voltage → Hold → Observe → Reduce → Discharge

Test Acceptance Criteria

- **No flashover**
- **No breakdown**
- **No abnormal noise or smell**

If any abnormality occurs:

- Test is **failed**
 - Equipment must **not be energized**
-

Difference Between IR Test and HV Test (Quick Recall)

- IR Test → Low voltage, checks insulation resistance
- HV Test → High voltage, checks insulation strength

✦ *Short exam answer point.*

Common Causes of HV Test Failure

- Moisture in insulation
- Dust or contamination
- Improper clearances
- Installation defects

Corrective actions include:

- Cleaning
- Drying
- Repair and re-testing

Real-World / Industry Applications (≈ 10 minutes)

In **substations, industries, and power plants**, HV withstand test is the **last mandatory test before charging permission**.

🔧 *Industry example:*

A panel passed all low-voltage tests, but failed HV test due to moisture.

After drying and retesting, it passed—**preventing a major insulation failure after energization**.

This proves:

**HV test may look risky,
but skipping it is far more dangerous.**

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- HV withstand test checks dielectric strength
- Conducted as per IS/IEC standards
- High AC voltage applied for fixed duration
- No breakdown means test passed
- Final test before energization

Common Student Doubts

- *Is HV test done on site or factory?* → Both (site test is mandatory)
- *Is HV test destructive?* → ❌ No, if done correctly
- *Is it exam-important?* → ✅ Yes (procedure + purpose)

🎓 Mentorship Note (Career Connection)

Engineers involved in **commissioning, testing, and substations** are trusted only when they understand **HV testing discipline**.

If you master:

- HV test purpose
- Procedure and safety rules

you become fit for roles in:

- Substation commissioning teams
- Testing & inspection agencies
- Power utility maintenance departments

Remember:

**Electricity forgives no insulation weakness—
HV testing ensures you never energize blindly.**

Topic 5.3.2: On-Site Commissioning Tests of Switchgear – Partial Discharge Test (For GIS)

1 Hook / Introduction (≈ 5 minutes)

Let me begin with a thought that every commissioning engineer should remember:

“Most insulation failures do not happen suddenly—they start silently.”

In **Gas Insulated Switchgear (GIS)**, insulation defects are often **invisible from outside**.

Before a major breakdown occurs, the insulation gives small warning signals called **partial discharges**.

The **Partial Discharge (PD) Test** is designed to detect these early warning signs.

It helps engineers **identify insulation weakness before it turns into a costly failure or outage**.

2 Core Concepts (≈ 40 minutes)

What is Partial Discharge?

Partial discharge is a **localized electrical discharge** that:

- Occurs in a small portion of insulation
- Does **not completely bridge** the insulation gap
- Happens under **high electric stress**

✦ Simple definition:

PD is a *tiny internal spark* inside insulation.

Why Partial Discharge is Critical in GIS

Gas Insulated Switchgear uses:

- **SF₆ gas** as insulating and arc-quenching medium
- Compact, enclosed metallic chambers

Because GIS is **sealed and compact**, even a small defect like:

- Dust particle
- Metal burr
- Air bubble
- Improper joint

can cause **partial discharge**.

✦ Key idea:

PD is an **early indicator of insulation failure**.

Purpose of Partial Discharge Test

- To detect **manufacturing defects**

- To identify **installation or assembly errors**
- To ensure **long-term insulation reliability**
- To prevent **sudden breakdown during service**

When PD Test is Performed

- During **on-site commissioning of GIS**
- After major **maintenance or modification**
- Before putting GIS into **continuous service**

✦ *Exam Tip:*

PD test is **mainly applicable to GIS**, not conventional air-insulated switchgear.

Principle of Partial Discharge Test

When high voltage is applied:

- Defective insulation produces **high-frequency signals**
- These signals are detected using **special PD measuring equipment**

PD activity is measured in **pico-coulombs (pC)**.

Basic PD Test Setup (Conceptual)

- High-voltage source
- PD detector / sensor
- Coupling capacitor
- Measuring instrument

Test Procedure (Simplified – Diploma Level)

1. Ensure GIS is properly assembled and earthed
2. Apply high voltage gradually
3. Monitor PD level continuously
4. Compare measured PD value with permissible limit
5. Record results

⚠ **Safety Note:**

Only trained personnel should perform PD testing.

Acceptance Criteria

- PD level must be **within permissible limits** specified by **IS/IEC**
- No sudden rise in PD magnitude
- Stable PD pattern during test duration

If PD level is high:

- GIS must **not be energized**
- Fault location and rectification are required

Common Causes of Partial Discharge

- Dust or metallic particles inside GIS
- Improper tightening of joints
- Insulation damage during transport
- Moisture contamination

Why PD Test is Important Even After HV Test

- HV test checks **dielectric strength**
- PD test checks **insulation quality and longevity**

✦ *Short exam point:*

HV test proves *strength*, PD test predicts *life*.

Real-World / Industry Applications (≈ 10 minutes)

In **EHV substations and urban GIS installations**, PD testing is a **standard commissioning requirement**.

🔧 *Industry example:*

During GIS commissioning, PD test detected abnormal discharge near a joint.

After opening and cleaning the joint, PD level dropped to acceptable value—**preventing a future breakdown**.

This shows:

Partial discharge testing prevents failures before they happen.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Partial discharge is a localized insulation discharge
- PD test is mainly used for GIS
- Detects hidden insulation defects
- Measured in pico-coulombs (pC)
- Essential for long-term reliability

Common Student Doubts

- *Is PD test compulsory for all switchgear?* → ❌ Mainly for GIS
- *Can PD cause immediate failure?* → ❌ Usually gradual

👤 Mentorship Note (Career Connection)

Engineers who understand **partial discharge concepts** are highly valued in:

- GIS substations
- High-voltage testing agencies
- Power transmission utilities

Remember:

Good engineers fix faults.

Smart engineers detect them early.

Mastering PD testing moves you one step closer to becoming a **future-ready power system engineer**.

Topic 5.3.3: On-Site Commissioning Tests of Switchgear – Breaker Timing Test

1 Hook / Introduction (≈ 5 minutes)

Let me begin with a simple but powerful question:

“If a circuit breaker trips... does it matter *how fast* it trips?”

Absolutely—**timing is everything**.

A circuit breaker is expected to **open and close within a specified time**.

Even a delay of a few milliseconds can:

- Increase fault damage
- Stress insulation
- Reduce system stability

That is why **Breaker Timing Test** is an essential **on-site commissioning test**—it confirms that the breaker operates **quickly, uniformly, and correctly**.

2 Core Concepts (≈ 40 minutes)

What is a Breaker Timing Test?

Breaker Timing Test is a test used to **measure the time taken by a circuit breaker contacts to open and close** after a command is given.

✦ Simple definition:

It checks **how fast and how uniformly** the breaker operates.

Why Breaker Timing is Important

- Ensures **proper fault clearance**
- Confirms **mechanical health of breaker**
- Prevents **contact damage and arcing**
- Ensures **synchronization of poles**

💡 Key idea:

A breaker that trips late is as dangerous as a breaker that does not trip.

What Parameters are Measured

During breaker timing test, the following are measured:

1. **Opening time**
2. **Closing time**
3. **Pole-to-pole time difference**
4. **Contact bounce (if any)**

✦ Exam Tip:

Mention **opening, closing, and pole discrepancy** in answers.

Equipment Used

- **Breaker Timing Test Set (CB Analyzer)**
- Control supply
- Test leads connected to breaker contacts

✦ *Visual to draw:*

Block diagram showing CB analyzer connected to three breaker poles.

Pre-Test Checks

Before testing:

- Ensure breaker is **isolated and earthed**
- Check control supply voltage
- Confirm mechanical condition
- Ensure safety clearance

⚠ Safety Rule:

Timing test is done **without energizing power circuit.**

Test Procedure (Step-by-Step)

1. Connect timing test set to breaker contacts
 2. Provide control supply to trip/close coil
 3. Issue **OPEN command**
 4. Measure opening time of each pole
 5. Issue **CLOSE command**
 6. Measure closing time
 7. Record and compare values
-

Acceptance Criteria

- Opening and closing times must be **within manufacturer limits**
- Pole-to-pole timing difference should be **minimal**
- No abnormal delay or inconsistency

If results are unsatisfactory:

- Lubrication may be required
 - Mechanical adjustment needed
 - Re-testing is compulsory
-

Common Causes of Timing Problems

- Weak operating mechanism
- Mechanical wear
- Improper lubrication
- Faulty control supply

✦ *Short exam point:*

Timing issues indicate **mechanical defects**, not insulation problems.

Relation with Other Tests

- IR test → checks insulation
- Contact resistance → checks contact health
- Timing test → checks **speed and coordination**

Together, they ensure **complete breaker reliability**.

Real-World / Industry Applications (≈ 10 minutes)

In **substations and industrial switchyards**, breaker timing test is conducted:

- After installation
- After major maintenance
- Before energization

🔧 *Industry example:*

During commissioning, one pole of breaker opened slower than others.

After adjustment, timing became uniform—**preventing unequal arcing and contact damage**.

This proves:

**A breaker must not only open...
it must open *together* and *on time*.**

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Breaker timing test measures operating speed
- Checks opening, closing, and pole synchronization
- Essential for safe fault interruption
- Indicates mechanical health of breaker
- Mandatory before energization

Common Student Doubts

- *Is timing test destructive?* → ❌ No
 - *Is it done for all breakers?* → ✅ Yes
 - *Is it exam-important?* → ✅ High (procedure + purpose)
-

🎓 **Mentorship Note (Career Connection)**

Engineers skilled in **breaker testing and analysis** are highly demanded in:

- Substation commissioning
- Power utilities
- Industrial maintenance teams

If you understand **timing curves, coordination, and breaker behavior**, you move closer to becoming a **trusted protection and commissioning engineer**.

Remember:

A fast and synchronized breaker protects not just equipment, but the entire power system.

Topic 5.4.1: Pre-Commissioning Checks of Power Cable – Physical Inspection

1 Hook / Introduction (≈ 5 minutes)

Let me start with a very practical question:

“If a power cable is new and unused, can it still fail immediately after energization?”

Surprisingly, **yes**.

In most cable failures, the problem is **not electrical testing**, but **poor physical installation**—damaged joints, improper terminations, or sharp bending.

A power cable is like the **blood vessel of an electrical system**.

If it is twisted, crushed, or poorly connected, no amount of testing can save it later.

That is why **physical inspection is the first and most important pre-commissioning check of power cables**.

2 Core Concepts (≈ 40 minutes)

What is Physical Inspection of Power Cable?

Physical inspection is a **visual and manual examination** of the cable installation to ensure that:

- Cable is mechanically healthy
- Joints and terminations are correctly made
- Bending radius is within permissible limits

◆ Key idea:

Physical inspection prevents hidden mechanical damage before electrical testing.

Why Physical Inspection is Essential

- To avoid **early insulation failure**
- To prevent **heating and breakdown at joints**
- To ensure **long service life of cable**
- To comply with **IS/IEC installation practices**

💡 Important point:

Most cable faults originate at **joints and terminations**, not in the cable length.

Inspection of Cable Joints

Cable joints are used to connect two cable lengths.

Check the following:

- Proper alignment of conductors
 - Tight and clean conductor connections
 - Correct insulation restoration
 - No air gaps, moisture, or sharp edges
 - Proper mechanical protection and sealing
-

Inspection of Cable Terminations

Terminations connect cable to:

- Switchgear
- Transformer
- Motor or panel

Check points:

- Correct termination kit as per cable rating
- Proper stress control (for HT cables)
- No cracks, cuts, or insulation damage
- Firm clamping and earthing

♦ *Exam tip:*

Termination failure is a **common cause of flashover**.

Bending Radius – A Very Important Check

Bending radius is the minimum safe radius to which a cable can be bent without damage.

- Excessive bending causes:
 - Internal conductor stress
 - Insulation cracks
 - Reduced cable life

♦ *Rule to remember (general idea):*

Never bend a cable sharply or forcefully.

Other Physical Inspection Checks

- Cable sheath condition (no cuts or abrasion)
 - Proper cable routing and support
 - Adequate spacing between cables
 - Correct identification tags
 - Proper earthing of metallic sheath
-

Sequence of Cable Commissioning (Exam-Important)

1. Physical inspection
2. Continuity test
3. Insulation resistance test
4. High-voltage test (if applicable)

♦ *Short exam answer point.*

Common Mistakes Found During Inspection

- Tight bends near terminations
- Poor joint workmanship

- Damaged outer sheath
- Unsupported cable weight

Corrective action must be taken **before electrical testing**.

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

In **substations, industries, and underground cable systems**, engineers always perform **physical inspection before megger testing**.

Industry example:

A newly laid HT cable failed during HV test.

On inspection, a **sharp bend near termination** was found.

After re-laying the cable correctly, it passed all tests.

This proves:

Good cable performance starts with good physical installation.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Physical inspection is the first cable check
- Focus on joints, terminations, and bending radius
- Prevents early cable failure
- Must be done before electrical tests
- Highly exam-oriented topic

Common Student Doubts

- *Is physical inspection enough?* → ❌ No, but it is essential
- *Can sharp bending really damage insulation?* → ✅ Yes

👤 Mentorship Note (Career Connection)

In real projects, **experienced engineers trust their eyes before instruments**.

If you master:

- Cable joints and terminations
- Installation discipline
- Bending and routing practices

you become suitable for roles in:

- Cable laying and commissioning teams
- Industrial electrical maintenance
- Utility and infrastructure projects

Remember:

A cable that is installed carefully serves reliably for decades.

Topic 5.4.2: Pre-Commissioning Checks of Power Cable – Conductor Resistance & Continuity Test

1 Hook / Introduction (≈ 5 minutes)

Let me ask you something very practical:

“If a power cable looks perfectly installed from outside, can it still fail to carry current?”

Yes—if there is a **broken conductor, loose joint, or improper connection inside**.

Before we even think about applying voltage to a cable, we must confirm one basic truth:

👉 **Current can flow freely and uniformly through the conductor.**

That is exactly the purpose of the **Conductor Resistance and Continuity Test**.

This test answers a simple but critical question:

“Is the conductor continuous and healthy from one end to the other?”

2 Core Concepts (≈ 40 minutes)

What is Conductor Resistance Test?

The conductor resistance test measures the **electrical resistance of the cable conductor** over its length.

🔴 **Simple definition:**

It checks whether the conductor has **normal resistance as per its size and length**.

What is Continuity Test?

Continuity test confirms that:

- The conductor is **not broken**
- There is a **complete electrical path** between two ends of the cable

🔴 **Key idea:**

Continuity test answers *“Is the path complete?”*

Resistance test answers *“Is the path healthy?”*

Why These Tests Are Necessary

- To detect **open circuits**
- To identify **loose or faulty joints**
- To ensure **uniform conductor cross-section**
- To avoid **overheating during operation**

💡 *Important concept:*

Higher resistance → higher heat → early cable failure.

When Are These Tests Performed?

- After **physical inspection**
- Before **insulation resistance (IR) test**
- Before **energization**

🔴 *Exam-important sequence:*

Physical inspection → Continuity → Resistance → IR test

Equipment Used

- **Digital Multimeter (DMM)** – for LT cables
- **Micro-ohmmeter / Low resistance meter** – for large conductors

Conductor Resistance Test Procedure (Step-by-Step)

1. Ensure cable is **isolated and discharged**
2. Short all strands of the conductor at one end
3. Connect measuring instrument at both ends
4. Measure resistance value
5. Compare with standard or calculated value

Continuity Test Procedure

1. Connect test leads across cable ends
2. Check for low resistance or buzzer indication
3. Repeat for all cores

✦ *Result interpretation:*

- Very low resistance → continuity OK
- Infinite resistance → conductor broken

Acceptance Criteria

- Resistance should be **within permissible limits**
- All cores must show **proper continuity**
- No abnormal variation between phases

If results are abnormal:

- Check joints and terminations
- Re-terminate if required
- Repeat test

Common Causes of Abnormal Results

- Loose joints
- Improper crimping
- Damaged conductor strands
- Incorrect cable size

✦ *Short exam point:*

Conductor resistance test mainly detects **mechanical and connection defects**.

Real-World / Industry Applications (≈ 10 minutes)

In **substations, industries, and cable laying projects**, continuity and resistance tests are done **before megger testing**.

🔧 *Industry example:*

A newly laid LT cable failed to supply load.

Continuity test showed an **open conductor due to poor jointing**.

After re-jointing, the cable operated normally.

This proves:

**Electrical testing cannot correct physical mistakes—
but it can reveal them early.**

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Continuity test checks complete conductor path
- Resistance test checks conductor health
- Both are pre-commissioning tests
- Must be done before IR and HV tests
- Highly important for exams and practicals

Common Student Doubts

- *Is continuity test enough?* → ❌ No, resistance also matters
 - *Is this test destructive?* → ❌ No
-

Mentorship Note (Career Connection)

In real projects, **junior engineers are often assigned cable testing tasks first.**

If you master:

- Continuity testing logic
- Resistance interpretation
- Test sequencing

you build strong foundations for roles in:

- Cable commissioning teams
- Industrial maintenance
- Utility and infrastructure projects

Remember:

**Before testing insulation strength,
always confirm conductor integrity.**

Topic 5.4.3: Pre-Commissioning Checks of Power Cable – Insulation Resistance Measurement (Megger Test)

Hook / Introduction (≈ 5 minutes)

Let me begin with a question every site engineer must ask before energizing a cable:

“Current can flow through the conductor—but where else might it flow?”

If insulation is weak, current may leak to **earth or between cores**, causing shocks, heating, or sudden failure.

That is why, before energizing any power cable, we must test **how strong the insulation is.**

The **Insulation Resistance (IR) Measurement**, commonly called the **Megger Test**, is the most important **electrical safety check** for power cables.

It answers a simple but critical question:

👉 **“Is the insulation good enough to safely hold voltage?”**

Core Concepts (≈ 40 minutes)

What is Insulation Resistance (IR)?

Insulation resistance is the **resistance offered by the insulation material** between:

- Conductor and earth
- Conductor and conductor (between cores)

♦ Simple definition:

Higher insulation resistance means **better insulation quality**.

What is a Megger?

A **Megger** is a special instrument used to measure **very high resistance values** by applying **DC high voltage**.

Typical test voltages:

- 500 V DC – LT cables
- 1000 V / 2.5 kV DC – HT cables

♦ Visual to draw:

Megger connected between cable core and earth.

Why IR Test is Necessary for Power Cables

- To detect **moisture ingress**
- To identify **damaged or aged insulation**
- To prevent **leakage current**
- To avoid **electric shock and fire hazards**
- To ensure **safe commissioning**

💡 Key idea:

A cable may look perfect physically but fail electrically due to poor insulation.

When IR Test is Performed

- After **physical inspection**
- After **continuity and resistance tests**
- Before **HV withstand test**
- Before **energization**

♦ Exam-important sequence:

Physical inspection → Continuity → Resistance → **IR Test**

IR Test Connections (Cable Testing)

IR is measured between:

1. **Core to Earth**
2. **Core to Core** (for multi-core cables)

♦ Diagram to draw:

Three-core cable showing megger connection between one core and earth, other cores shorted.

IR Test Procedure (Step-by-Step)

1. Ensure cable is **isolated and discharged**
2. Short all conductors except the one under test
3. Connect megger between:
 - Core and earth
4. Apply test voltage for **specified duration**
5. Note IR value
6. Repeat for all cores and combinations
7. Discharge cable after test

⚠ Safety Rule:

Always **discharge the cable** after megger testing.

Acceptance Criteria (General Concept)

- IR value should be **high**
- No sudden drop during testing
- Consistent readings between phases

🔴 *Diploma-level note:*

Exact limits depend on **cable rating and standards**, but **higher is always better**.

Common Causes of Low IR Value

- Moisture inside insulation
- Damaged sheath
- Improper jointing or termination
- Aging or contamination

Corrective actions:

- Drying the cable
 - Repairing sheath or termination
 - Re-testing before approval
-

Difference Between Continuity Test & IR Test

- Continuity test → checks **conductor path**
- IR test → checks **insulation strength**

🔴 *Very common exam question.*

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

In **substations, industries, and underground cable systems**, IR testing is a **mandatory site test**.

🔧 *Industry example:*

A newly laid cable showed very low IR value.

Reason: **Moisture entered during storage.**

After drying and re-testing, IR improved and the cable was safely energized.

This proves:

Megger test does not repair insulation—it prevents unsafe energization.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- IR test checks insulation health of power cable
- Performed using a Megger (DC high voltage)
- Done before HV test and energization
- Low IR indicates insulation problem
- Extremely important for safety and exams

Common Student Doubts

- *Is megger test harmful to cable?* → **✗** No, if done correctly
 - *Why DC voltage is used?* → For stable and accurate IR measurement
-

Mentorship Note (Career Connection)

In real electrical projects, **IR test results are the first values senior engineers check.**

If you master:

- Megger operation
- Correct test connections
- Interpretation of IR values

you build strong skills for roles in:

- Cable commissioning and testing
- Industrial maintenance
- Power utility and infrastructure projects

Remember:

Good insulation is silent—but when it fails, it speaks loudly.

Megger testing ensures you never energize blindly.

Topic 5.5.1: Site Acceptance Tests of Power Cable – High-Voltage Withstand Test

Hook / Introduction (≈ 5 minutes)

Let me start with a reality check from the field:

“A cable may pass continuity and megger tests, yet still fail the moment high voltage is applied.”

Why does this happen?

Because **normal tests check insulation quality, but only a high-voltage test proves insulation strength under stress.**

The **High-Voltage Withstand Test (HV Test)** is the **final and most decisive test** before a power

cable is approved for service.
It answers one critical question:

👉 “Can this cable safely withstand its rated voltage without breakdown?”

2 Core Concepts (≈ 40 minutes)

What is High-Voltage Withstand Test?

The HV Withstand Test is a **site acceptance test** in which a **higher-than-normal voltage** is applied to the power cable for a **specified duration** to verify insulation integrity.

🔴 Simple definition:

It checks whether cable insulation can **withstand high electrical stress without failure**.

Why HV Test is Necessary

- To confirm **overall insulation strength**
- To detect **hidden defects** not found by IR test
- To ensure **safe energization**
- To meet **IS/IEC standards**

💡 Key concept:

IR test measures *resistance*; HV test proves *strength*.

When is HV Test Performed?

- After:
 - Physical inspection
 - Continuity & resistance test
 - Insulation resistance (megger) test
- Before:
 - Final energization
 - Handing over cable for service

🔴 Exam-important sequence.

Types of HV Tests for Cables

At Diploma level, understand the concept:

- **AC High-Voltage Test**
- **DC High-Voltage Test** (commonly used on site)

🔴 Note:

Test type depends on **cable rating and standards**.

Test Equipment Used

- **High-Voltage Test Set**
- Control panel
- Measuring instruments
- Safety earthing arrangement

✦ *Visual to draw:*

HV test set connected to cable core, cable sheath earthed.

HV Withstand Test Connections

- One conductor connected to **HV source**
- All other conductors and sheath **solidly earthed**

✦ *Diagram idea:*

Single-core cable showing HV applied to conductor and earth on sheath.

Test Procedure (Step-by-Step)

1. Ensure cable is **isolated and properly earthed**
2. Connect HV test set as per procedure
3. Gradually raise voltage to **specified test value**
4. Maintain voltage for **specified time**
5. Observe:
 - Leakage current
 - Any abnormal sound or smell
6. Reduce voltage gradually
7. Discharge cable completely after test

⚠ Safety Rule:

HV testing must be done **only by authorized personnel**.

Acceptance Criteria

- No insulation breakdown
- No flashover or tripping
- Stable leakage current

✦ *If cable fails:*

- Test must be stopped immediately
 - Fault location and rectification required
-

Difference Between IR Test and HV Test

IR Test	HV Test
Low DC voltage	High AC/DC voltage
Checks insulation quality	Checks insulation strength
Non-stress test	Stress test

✦ *Very common exam question.*


Precautions During HV Testing

- Maintain safe distance
- Proper earthing

- Warning signage
- Never touch cable during or immediately after test

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

In **substations, industries, and underground cable projects**, HV withstand test is a **mandatory site acceptance test**.

 *Industry example:*

A cable passed IR test but failed HV test due to **poor joint insulation**.

After joint re-termination, the cable successfully passed HV test and was energized safely.

This shows:

**HV test does not weaken a good cable—
it exposes a weak one.**

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- HV withstand test is a site acceptance test
- Proves insulation strength under high stress
- Performed after IR test
- Mandatory before energization
- Very important for exams and safety

Common Student Doubts

- *Is HV test dangerous?* → Only if safety rules are ignored
- *Can HV test damage cable?* → ❌ Not if cable is healthy
- *Is it exam-important?* → ✅ Very high

Mentorship Note (Career Connection)

Understanding **HV cable testing** prepares you for roles in:

- Power cable commissioning teams
- Substation and utility projects
- High-voltage testing agencies

Senior engineers trust those who **respect HV testing procedures and safety discipline**.

Remember:

**A cable that survives high voltage in testing
will serve reliably under normal operation.**

Topic 5.5.2: Site Acceptance Tests of Power Cable – Sheath Integrity Test

1 Hook / Introduction (≈ 5 minutes)

Let me begin with a field-based question:

“If the conductor and insulation of a cable are perfect, can the cable still fail underground?”

Yes—if the **outer sheath is damaged**.

The sheath is the **first line of defense** of a power cable against moisture, chemicals, rodents, and mechanical stress.

A small cut in the sheath may not affect continuity or insulation resistance immediately, but over time it can allow **moisture ingress**, leading to serious insulation failure. That is why the **Sheath Integrity Test** is an essential **site acceptance test** before a power cable is finally commissioned.

2 Core Concepts (≈ 40 minutes)

What is Cable Sheath?

The **sheath** is the **outer protective covering** of a power cable, usually made of:

- PVC
- XLPE
- PE

✦ Function of sheath:

- Protects insulation from moisture
 - Prevents mechanical damage
 - Protects against chemical attack
-

What is Sheath Integrity Test?

Sheath Integrity Test is a test conducted to **detect any damage, puncture, or discontinuity in the cable sheath**.

✦ Simple definition:

It checks whether the outer sheath is **electrically and physically intact**.

Why Sheath Integrity Test is Necessary

- To detect **sheath cuts or punctures**
- To prevent **water ingress**
- To avoid **corrosion of metallic screen/armour**
- To ensure **long service life of cable**

💡 Key idea:

Good sheath = long-lasting insulation.

When is Sheath Integrity Test Performed?

- After cable laying and jointing
- Before final energization
- As part of **site acceptance testing**

✦ Exam-oriented point:

Sheath test is done **after pre-commissioning tests**.

Principle of Sheath Integrity Test

A **DC voltage** is applied between:

- Cable sheath
- Earth

If sheath is damaged:

- Leakage current flows
- Test fails

Basic Test Procedure (Diploma Level)

1. Ensure cable is **isolated and de-energized**
2. Disconnect sheath from earth
3. Apply DC test voltage between sheath and earth
4. Observe leakage current
5. Maintain test for specified time
6. Remove voltage and re-earth sheath

⚠ Safety Note:

Proper earthing is mandatory before and after test.

Acceptance Criteria

- No significant leakage current
- No sudden increase in current
- Stable reading throughout test duration

If sheath fails:

- Locate damage
 - Repair sheath
 - Repeat test before approval
-

Common Causes of Sheath Damage

- Sharp stones during laying
- Improper handling
- Rodent attack
- Mechanical impact

✦ *Short exam answer point.*

Difference Between IR Test & Sheath Test

IR Test	Sheath Integrity Test
Checks insulation	Checks outer sheath
Core to earth/core	Sheath to earth
Prevents leakage	Prevents moisture ingress

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

In **underground cable projects**, sheath integrity testing is mandatory before backfilling.

🔧 *Industry example:*

A sheath test detected leakage due to a nail puncture.
After repair, cable passed test and was safely energized.

This shows:

Sheath test protects the future health of the cable, not just present operation.

Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Sheath protects cable from external damage
- Sheath integrity test detects outer damage
- Prevents moisture ingress and insulation failure
- Mandatory site acceptance test
- Important for exams and safety

Common Student Doubts

- *Is sheath test needed for overhead cables?* → ❌ No
 - *Does sheath test replace IR test?* → ❌ No
 - *Is this topic exam-important?* → ✅ Yes
-

Mentorship Note (Career Connection)

Cable failures are costly and difficult to repair once buried.

Engineers skilled in **sheath testing and damage detection** are highly valued in:

- Underground cable projects
- Utility and infrastructure companies
- Maintenance and testing agencies

Remember:

**The cable sheath is silent when healthy,
but once damaged, it slowly destroys insulation.
Testing today prevents failure tomorrow.**

Topic 5.5.3: Site Acceptance Tests of Power Cable – Capacitance and Tan δ Measurement

Hook / Introduction (≈ 5 minutes)

Let me begin with a thought-provoking question from real industry practice:


“Two cables show the same insulation resistance value, yet one fails earlier in service. Why?”

Because **insulation quality is not judged only by resistance**, but also by **dielectric losses inside the insulation**.

This is where **Capacitance and Tan δ (Dissipation Factor) Measurement** becomes important.

This test helps engineers assess the **health and aging condition of cable insulation**, especially for **HT and EHT cables**.

In simple words, this test answers:

 **“How efficiently does the insulation store energy without losing it as heat?”**

Core Concepts (≈ 40 minutes)

Capacitance of Power Cable

A power cable behaves like a **capacitor**:

- Conductor → one plate
- Insulation → dielectric
- Metallic sheath/earth → other plate

✦ **Definition:**

Capacitance is the ability of the cable to **store electrical charge** between conductor and sheath.

Capacitance value depends on:

- Cable length
- Insulation material
- Cable construction

What is Tan δ (Dissipation Factor)?

Tan δ is a measure of **dielectric loss in insulation**.

✦ **Simple definition:**

It indicates how much electrical energy is **lost as heat** in the insulation when AC voltage is applied.

- **Low Tan δ** → healthy insulation
- **High Tan δ** → aged or deteriorated insulation

💡 *Analogy:*

Good insulation is like a **new rubber sheet** (flexible, no cracks).

Bad insulation is like **old rubber** (hard, cracked, and leaky).

Why Capacitance and Tan δ Test is Required

- To assess **quality of insulation**
- To detect **aging, moisture, or contamination**
- To compare insulation condition with standard values
- To ensure **long-term reliability**

✦ *Important point:*

This test is **condition-based**, not just pass/fail.

When is This Test Performed?

- During **site acceptance testing**
- After HV withstand and sheath tests
- Before final commissioning of HT cables

✦ *Exam-oriented sequence point.*

Test Equipment Used

- **Tan Delta Test Set / Capacitance Meter**
- AC high-voltage source (50 Hz)

✦ *Visual to draw:*

Cable model showing conductor, insulation, sheath, and measurement connections.

Basic Test Principle

- AC voltage is applied to the cable
- Charging current flows due to capacitance
- Loss current flows due to insulation imperfections
- $\tan \delta = \text{Loss current} / \text{Charging current}$

✦ *Diploma-level understanding:*

Higher loss current means **poor insulation quality**.

Test Procedure (Conceptual Steps)

1. Isolate and discharge cable
2. Connect test set between conductor and sheath
3. Apply rated test voltage gradually
4. Measure capacitance and $\tan \delta$
5. Compare readings with standard/reference values

Interpretation of Results

- **Low $\tan \delta$, stable value** → insulation is healthy
- **High or increasing $\tan \delta$** → insulation deterioration

✦ *Common causes of high $\tan \delta$:*

- Moisture ingress
- Aging of insulation
- Thermal stress
- Manufacturing defects

Difference Between IR Test and $\tan \delta$ Test

IR Test	$\tan \delta$ Test
DC voltage	AC voltage
Measures insulation resistance	Measures dielectric loss
Basic safety check	Advanced condition assessment

✦ *Very common exam question.*

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

In **HT underground cable systems**, utilities use $\tan \delta$ measurement to **predict insulation aging**.

🔧 *Industry example:*

Two cables passed IR test, but one showed higher $\tan \delta$ value.
That cable was scheduled for **closer monitoring**, preventing sudden failure.
This shows:

$\tan \delta$ test helps engineers take decisions before failure occurs.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Power cable behaves like a capacitor

- Capacitance shows storage ability
- Tan δ shows insulation losses
- Low Tan δ means healthy insulation
- Important site acceptance and diagnostic test

Common Student Doubts

- *Is Tan δ test done for LT cables?* → Usually for HT cables
- *Does it replace IR test?* → ❌ No, it complements IR test
- *Is it exam-important?* → ✅ Yes (concept + purpose)

Mentorship Note (Career Connection)

Knowledge of **Tan δ and capacitance testing** is a **high-value skill** in:

- Power utilities
- Cable testing agencies
- Substation commissioning teams

Engineers who understand **insulation behavior**, not just test values, grow faster in their careers.

Remember:

Resistance tells you if insulation exists.

Tan δ tells you how healthy it really is.

Topic 5.6.1: Post-Commissioning Checks for Power Cable – Load Test Under Service Conditions

Hook / Introduction (≈ 5 minutes)

Let me start with a real-life engineering question:

“A power cable has passed all tests and is energized—can we immediately trust it for long-term service?”

Not yet.

Electrical tests confirm **installation quality**, but **real performance is proven only under actual load**.

A cable may pass insulation and HV tests, yet show **overheating or voltage drop** when current flows continuously.


That is why the **Load Test under Service Conditions** is the **final confirmation** that a power cable is ready for reliable operation.

Core Concepts (≈ 40 minutes)

What is Load Test Under Service Conditions?

The load test is a **post-commissioning check** in which the power cable is:

- Energized
- Operated under **normal or rated load**
- Observed for performance, temperature rise, and stability

 **Simple definition:**

It checks whether the cable can **carry actual service current safely and continuously**.

Why Load Test is Necessary

- To verify **current-carrying capacity**
- To detect **overheating or abnormal losses**
- To confirm **proper joint and termination performance**
- To ensure **voltage drop is within limits**

💡 *Key idea:*

A cable that is electrically strong must also be **thermally stable**.

When is Load Test Performed?

- After all **site acceptance tests**
- After energization
- During initial operation period

🔴 *Exam-oriented point:*

Load test is a **post-commissioning** activity, not a pre-commissioning test.

Parameters Observed During Load Test

1. **Load current** in each phase
 2. **Cable temperature** along route and at terminations
 3. **Voltage drop** across the cable
 4. **Any abnormal smell, sound, or heating**
- .
-

Load Test Procedure (Diploma Level)

1. Energize cable under normal operating conditions
2. Gradually apply load up to rated value
3. Measure current using clamp meter
4. Monitor temperature rise at:
 - Cable terminations
 - Joints
5. Continue observation for specified duration
6. Record readings and compare with permissible limits

⚠ Safety Rule:

Monitoring must be done **without touching live parts**.

Acceptance Criteria

- Load current within rated value
- Temperature rise within safe limits

- No excessive heating at joints or terminations
- No abnormal voltage drop

If any abnormality is observed:

- Reduce load immediately
- Investigate joint/termination
- Rectify before continuing service

Common Problems Detected During Load Test

- Loose or improper terminations
- Undersized cable
- High resistance joints
- Poor ventilation or cable grouping

✦ *Short exam answer point:*

Load test reveals **thermal and installation-related defects**.

Difference Between HV Test and Load Test

HV Test	Load Test
High voltage, no load	Normal voltage, actual load
Checks insulation strength	Checks thermal performance
Short duration	Continuous observation

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

In **industries, substations, and utility networks**, cables are closely monitored during the **first few days of service**.

🔧 *Industry example:*

During initial operation, a cable termination showed abnormal heating.

Cause: **Loose lug connection**.

After tightening, temperature normalized—**preventing long-term damage**.

This proves:

Load testing exposes real-world weaknesses that laboratory tests cannot.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Load test is a post-commissioning check
- Conducted under actual service conditions
- Verifies thermal and current-carrying performance
- Detects joint and termination issues
- Essential for reliable long-term operation

Common Student Doubts

- *Is load test compulsory?* → Yes, for critical cables
- *Does load test replace electrical tests?* → No, it complements them

Mentorship Note (Career Connection)

In professional practice, **experienced engineers trust cables only after observing them under load.**

If you master:

- Load monitoring
- Temperature interpretation
- Cable behavior under service conditions

you prepare yourself for careers in:

- Industrial electrical maintenance
- Utility operation teams
- Commissioning and inspection services

Remember:

A cable proves its quality not in testing rooms, but while carrying real power to real loads.

Topic 5.6.2: Post-Commissioning Checks for Power Cable – Temperature Monitoring During Initial Energization

1 Hook / Introduction (≈ 5 minutes)

Let me ask you a practical question:

“If a power cable is energized for the first time, what is the first invisible danger that may appear?”

The answer is **abnormal temperature rise.**

When a new cable is energized, current starts flowing through conductors, joints, and terminations.

Even a **small installation defect**—like a loose lug or improper joint—can cause **localized heating.**

If this heat goes unnoticed, it may damage insulation permanently.

That is why **temperature monitoring during initial energization** is a **critical post-commissioning check** for power cables.

2 Core Concepts (≈ 40 minutes)

What is Temperature Monitoring During Initial Energization?

It is the process of **observing and measuring temperature rise** of power cables, joints, and terminations during the **first few hours or days of operation** after energization.

Simple definition:

It ensures that the cable operates **within safe thermal limits** under actual service conditions.

Why Temperature Monitoring is Necessary

- To detect **overheating at joints and terminations**
- To confirm **proper current carrying capacity**
- To identify **installation or workmanship defects**
- To prevent **insulation aging and early failure**

Key concept:

Electrical strength alone is not enough—**thermal stability is equally important.**

When is Temperature Monitoring Carried Out?

- Immediately after initial energization
- During first few hours of load operation
- During first few days of service

◆ *Exam-oriented point:*

This is a **post-commissioning activity**, not a pre-commissioning test.

Main Areas Monitored

1. **Cable terminations** (most critical)
2. **Joints and straight-through joints**
3. **Cable route at accessible points**
4. **Panel or transformer connection points**

◆ *Visual to draw:*

Cable termination showing temperature measurement at lug and insulation surface.

Methods of Temperature Measurement

- **Infrared thermometer (non-contact)**
- **Thermal imaging camera**
- **Temperature sensors (in advanced systems)**

◆ *Diploma-level understanding:*

Non-contact methods are preferred for **safety and accuracy**.

Monitoring Procedure (Step-by-Step)

1. Energize cable under normal operating conditions
2. Allow load current to stabilize
3. Measure temperature at:
 - Each phase termination
 - Joint locations
4. Record temperature values periodically
5. Compare temperatures of all phases
6. Observe for abnormal rise or imbalance

⚠ **Safety Rule:**

Never touch live cable or termination during monitoring.

Normal and Abnormal Temperature Behavior

- **Normal:** Gradual, uniform temperature rise in all phases
- **Abnormal:**
 - One phase hotter than others

- Sudden temperature increase
- Hot spots at joints

✦ *Possible causes of overheating:*

- Loose connection
- Poor crimping
- Undersized conductor
- High contact resistance

Corrective Actions if Abnormal Heating is Observed

- Reduce or disconnect load
- Inspect joint or termination
- Tighten or remake connection
- Re-monitor after correction

✦ *Short exam answer point:*

Temperature monitoring helps detect **hidden installation defects**.

Difference Between Load Test and Temperature Monitoring

Load Test	Temperature Monitoring
Checks current & performance	Checks thermal behavior
Electrical parameter focus	Thermal safety focus
Short-term observation	Continuous observation

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

In **industrial plants and substations**, engineers closely watch cable terminations during the **first 24–48 hours** of operation.

🔧 *Industry example:*

During initial energization, one cable termination showed higher temperature. Investigation revealed a **loosely tightened lug**. After correction, temperature normalized—**preventing long-term insulation damage**.

This proves:

Temperature monitoring turns small mistakes into early warnings instead of major failures.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Temperature monitoring is a post-commissioning check
- Done during initial energization
- Focuses on joints and terminations
- Detects thermal and connection problems
- Essential for long cable life and safety

Common Student Doubts

- *Is temperature monitoring compulsory?* → Yes, for critical cables

- *Does it replace electrical tests?* → ❌ No, it complements them
- *Is it exam-important?* → ✅ Yes (concept + purpose)

Mentorship Note (Career Connection)

Many cable failures start with **small hot spots** that were ignored.

Engineers who understand **thermal behavior of cables** are trusted in:

- Industrial maintenance teams
- Power utilities
- Commissioning and inspection roles

Remember:

Electric current shows problems through heat before it causes failure.

A good engineer learns to read that heat early.

Topic 5.6.3: Post-Commissioning Checks for Power Cable – Documentation of Test Results

1 Hook / Introduction (≈ 5 minutes)

Let me start with a simple but powerful question:

“If a cable passes all tests, but there is no record—did the testing really happen?”

In real engineering practice, **testing without documentation has no value.**

Engineers, inspectors, utilities, and auditors all depend on **proper test records** to ensure safety, accountability, and future maintenance.

That is why **documentation of test results** is considered the **final and most professional step** in post-commissioning of power cables.

It converts testing work into **legal, technical, and operational proof.**

2 Core Concepts (≈ 40 minutes)

What is Documentation of Test Results?

Documentation is the **systematic recording, verification, and preservation** of all test data obtained during:


- Pre-commissioning
- Site acceptance
- Post-commissioning tests

📌 Simple definition:

It is the written evidence that a power cable is **safe, tested, and ready for service.**

Why Documentation is Necessary

- To provide **proof of safe commissioning**
- To satisfy **utility, consultant, and statutory requirements**
- To act as **baseline data** for future maintenance
- To support **fault analysis and troubleshooting**
- To protect engineers from **legal and safety liability**

 *Key idea:*

Good documentation protects **both the system and the engineer**.

What Test Results Must Be Documented (Unit-5 Focus)

For power cables, documentation generally includes:

- Physical inspection checklist
- Continuity and conductor resistance values
- Insulation resistance (Megger) results
- High-voltage withstand test results
- Sheath integrity test observations
- Capacitance and Tan δ values
- Load test readings
- Temperature monitoring records

✦ *Exam-important point:*

All tests mentioned in **Unit-5** must be documented.

Typical Format of Cable Test Documentation

A standard test report usually contains:

1. Cable identification details (type, size, length)
2. Location and date of testing
3. Test equipment used
4. Test procedure followed
5. Measured values and observations
6. Acceptance criteria
7. Remarks and corrective actions
8. Engineer's signature and approval

✦ *Visual to draw:*

Sample test report layout with headings.

Importance of Accuracy and Clarity

- Readings must be **clear and correct**
- Units must be mentioned properly
- No overwriting or ambiguity
- Corrections must be signed

✦ *Diploma-level tip:*

Neat documentation reflects **engineering discipline**.

Use of Documentation in Maintenance

Test records are used later to:

- Compare insulation deterioration over time

- Identify abnormal temperature rise
- Plan preventive maintenance
- Decide cable replacement or upgrading

✦ *Short exam point:*

Documentation helps in **condition-based maintenance**.

Common Mistakes in Documentation

- Missing test values
- Improper cable identification
- No date or signature
- Mixing results of different cables

Such mistakes can **invalidate the entire testing work**.

Documentation as Part of Handover Process

Final documentation is submitted to:

- Client or utility
- Maintenance department
- Safety and audit teams

✦ *Important concept:*

No system is considered commissioned **until documentation is approved**.

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

In **power utilities and industries**, cable test reports are preserved for **years**.

🔧 *Industry example:*

During a cable fault investigation, old test records showed a **gradual drop in insulation resistance** over time.

This helped engineers trace the root cause and avoid repeat failure.

This proves:

Documentation turns test data into engineering intelligence.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Documentation is a post-commissioning activity
- Records all cable test results
- Acts as proof of safety and quality
- Helps in maintenance and troubleshooting
- Extremely important for professional engineers

Common Student Doubts

- *Is documentation required for small projects?* → Yes
- *Can testing be accepted without records?* → No

- *Is this topic exam-important?* → Yes (concept + advantages)

Mentorship Note (Career Connection)

In the industry, **good engineers are known not only for testing skills but also for documentation quality.**

If you master:

- Test reporting formats
- Clear technical writing
- Organized record keeping

you become suitable for roles in:

- Commissioning and inspection teams
- Utility and maintenance departments
- Quality assurance and audit roles

Remember:

**Machines run on electricity,
but engineering runs on documentation.**

Topic 5.7: Faults and Troubleshooting of Switchgear

1 Hook / Introduction (≈ 5 minutes)

Let me begin with a situation every electrical engineer fears:

“The circuit breaker trips again and again... production stops... everyone looks at you.”

In that moment, your value as an engineer is not judged by how well you know theory, but by **how quickly and safely you can identify the fault.**

Switchgear is the **guardian of the power system**. When it malfunctions, it may either:

- Fail to protect the system, or
- Create unnecessary shutdowns.

Understanding **faults and troubleshooting of switchgear** is therefore one of the **most practical and job-oriented skills** for a Diploma Electrical Engineer.

2 Core Concepts (≈ 40 minutes)

What is a Fault in Switchgear?

A fault in switchgear is an **abnormal condition** that prevents correct operation of devices like:

- Circuit breakers
- Isolators
- Relays
- Control circuits

♦ Simple definition:

Any condition where switchgear does not operate **as intended or required.**

Classification of Switchgear Faults

For easy understanding, faults can be classified as:

1. **Mechanical faults**
2. **Electrical faults**
3. **Control circuit faults**
4. **Protection relay faults**

✦ *Exam-oriented classification.*

Common Mechanical Faults

- Stuck or sluggish breaker operation
- Worn-out springs
- Misalignment of moving parts
- Failure of interlocking mechanism

✦ *Effect:* Breaker fails to open or close properly.

Common Electrical Faults

- Insulation failure
- Loose power connections
- Contact burning or pitting
- High contact resistance

✦ *Effect:* Overheating, nuisance tripping, or flashover.

Control Circuit Faults

- Blown control fuse
- Loose wiring
- Failure of auxiliary contacts
- DC supply failure

✦ *Important point:*

Many breaker failures are due to **control circuit issues**, not power faults.

Protection Relay Related Faults

- Incorrect relay settings
- CT/PT wiring mistakes
- Relay malfunction
- False tripping

✦ *Diploma-level tip:*

Always verify relay settings before assuming equipment fault.

General Troubleshooting Approach

Troubleshooting should follow a **systematic sequence**:

1. Observe fault indication or alarm

2. Identify whether fault is mechanical or electrical
3. Check control supply and wiring
4. Inspect contacts and connections
5. Verify relay operation
6. Rectify fault and test operation

🔴 *Visual to draw:*

Flowchart showing “Fault → Check → Rectify → Test”.

Safety Precautions During Troubleshooting

- Follow **lock-out and tag-out (LOTO)**
- Ensure proper earthing
- Never bypass safety interlocks
- Use PPE and insulated tools

⚠ Golden Rule:

Never troubleshoot live switchgear unless specifically permitted.

Typical Fault–Cause–Remedy Example

Fault	Possible Cause	Remedy
Breaker not closing	Control fuse blown	Replace fuse
Frequent tripping	Loose connection	Tighten terminals
Overheating	High contact resistance	Clean/replace contacts

🔴 *Highly useful for exams and viva.*

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

In **industries and substations**, switchgear troubleshooting is a **daily activity**.

🔧 *Industry example:*

A breaker tripped repeatedly during peak load. Investigation showed **loose control wiring**, not overload. After correction, the system operated normally.

This proves:

Correct troubleshooting avoids unnecessary shutdowns and equipment replacement.

4 Summary & Q&A (≈ 5 minutes)

Key Takeaways

- Switchgear faults may be mechanical, electrical, or control-related
- Troubleshooting must be systematic and safe
- Control circuit faults are very common
- Safety is more important than speed
- High exam and job relevance topic

Common Student Doubts

- *Is frequent tripping always due to overload?* → ❌ No
- *Can relay faults cause breaker failure?* → ✅ Yes

- *Is this topic exam-important?* → Very high

Mentorship Note (Career Connection)

Industries value engineers who can **diagnose faults calmly and logically**.
Mastering switchgear troubleshooting prepares you for careers in:

- Substation operation
- Industrial maintenance
- Power utilities
- Commissioning and service teams

Remember:

**Good switchgear protects the system,
but a good engineer protects the switchgear.**

Student AI Toolkit

A. Low-Level Prompts (Remember & Understand)

(10 prompts – focus on basics, definitions, and clarity)

1. Explain the purpose of commissioning in electrical systems using simple words and examples.
 2. Define pre-commissioning, commissioning, and post-commissioning in an easy comparison table.
 3. List the main pre-commissioning checks required before energizing switchgear.
 4. Explain insulation resistance testing and why it is important before energization.
 5. Describe the role of protection relays in switchgear operation in simple terms.
 6. What is meant by functional testing of switchgear? Explain with basic steps.
 7. Explain why physical inspection of power cables is done before testing.
 8. Define contact resistance and state why low contact resistance is required.
 9. Explain the meaning of site acceptance test (SAT) for power cables.
 10. Summarize common post-commissioning checks carried out after energizing power cables.
-

B. Moderate-Level Prompts (Apply & Analyze)

(10 prompts – focus on application, reasoning, and comparisons)

11. Explain step-by-step how insulation resistance testing of switchgear is performed and interpreted.
12. Compare mechanical operation test and electrical interlock verification of switchgear.
13. Analyze the impact of incorrect CT/PT connections on protection relay operation.
14. Explain how breaker timing test helps in assessing the health of a circuit breaker.
15. Describe the sequence of tests carried out during on-site commissioning of switchgear.

16. Explain conductor resistance and continuity testing of power cables with expected results.
17. Analyze why temperature monitoring is critical during initial energization of power cables.
18. Compare pre-commissioning tests and site acceptance tests of power cables.
19. Explain possible reasons for abnormal insulation resistance values and corrective actions.
20. Analyze typical faults in switchgear and explain how systematic troubleshooting is done.

C. High-Level Prompts (Design & Create)

(5 prompts – focus on workflows, logic, and system-level thinking)

21. Design a complete commissioning checklist for switchgear from inspection to final energization.
22. Create a logical flowchart for testing and commissioning of a power cable at site.
23. Develop a fault-finding workflow for switchgear based on symptoms and test results.
24. Prepare a sample commissioning test report format including key parameters and observations.
25. Design a standard operating procedure (SOP) for safe commissioning of switchgear and power cables.

How Students Should Use This Toolkit

- Use Low-Level prompts for first reading, viva, and quick revision
- Use Moderate-Level prompts for exam answers and practical understanding
- Use High-Level prompts for distinction marks, projects, and interview preparation

Mentor Tip:

Students who regularly practice such AI prompts develop **structured thinking**, which is exactly what examiners and industry supervisors look for during **commissioning jobs, site work, and interviews**.

Mastery Check

1. Key Definitions / Glossary (15 Important Terms)

1. **Commissioning** – The process of testing and verifying electrical equipment before it is put into service.
2. **Pre-commissioning** – Tests and inspections carried out before energizing the equipment.
3. **Switchgear** – Electrical devices used for switching, protection, and control of power circuits.
4. **Insulation Resistance (IR)** – The resistance offered by insulation to prevent leakage current.
5. **Contact Resistance** – Resistance at the contact points of breakers or isolators during operation.
6. **Circuit Breaker** – A protective device that automatically interrupts current during faults.
7. **Interlocking** – A safety arrangement that prevents incorrect sequence of operation.

8. **Protection Relay** – A device that detects faults and initiates circuit breaker operation.
9. **High-Voltage Withstand Test** – A test to check insulation strength under high voltage.
10. **Partial Discharge** – Localized insulation breakdown without complete failure.
11. **Power Cable** – An insulated conductor used to transmit electrical power.
12. **Continuity Test** – A test to confirm the conductor path is complete and unbroken.
13. **Sheath Integrity Test** – A test to check the condition of the cable outer sheath.
14. **Tan δ (Dissipation Factor)** – A measure of dielectric losses in cable insulation.
15. **Post-commissioning** – Checks performed after energization to confirm safe operation.

2. FAQ & Assessment Section

A. Multiple Choice Questions (MCQs)

(20 questions covering the full unit)

1. The main purpose of commissioning is to:
 - A) Increase power consumption
 - B) Verify safety and correct operation
 - C) Reduce equipment size
 - D) Improve aesthetics
2. Insulation resistance is measured using a:
 - A) Ammeter
 - B) Voltmeter
 - C) Megger
 - D) Wattmeter
3. Contact resistance test is mainly conducted on:
 - A) Transformers
 - B) Cables
 - C) Circuit breakers and isolators
 - D) Motors
4. Interlocking in switchgear ensures:
 - A) Faster operation
 - B) Reduced losses
 - C) Safe operating sequence
 - D) Higher voltage
5. Which test checks mechanical health of a circuit breaker?
 - A) IR test

- B) Mechanical operation test
 - C) HV test
 - D) Continuity test
6. Protection relays operate based on input from:
- A) PTs and CTs
 - B) Batteries
 - C) Motors
 - D) Insulation oil
7. High-voltage withstand test is performed to verify:
- A) Contact resistance
 - B) Insulation strength
 - C) Mechanical alignment
 - D) Load capacity
8. Partial discharge test is mainly applicable to:
- A) Overhead lines
 - B) GIS switchgear
 - C) Motors
 - D) Transformers only
9. Physical inspection of cables includes checking:
- A) Frequency
 - B) Bending radius
 - C) Speed
 - D) Power factor
10. Continuity test ensures:
- A) Insulation quality
 - B) Complete conductor path
 - C) High voltage strength
 - D) Proper earthing
11. Sheath integrity test is used to detect:
- A) Conductor breaks
 - B) Sheath damage
 - C) Relay faults
 - D) Overload

12. Tan δ value indicates:

- A) Cable length
- B) Dielectric losses
- C) Load current
- D) Voltage drop

13. Load test under service conditions checks:

- A) Insulation only
- B) Thermal performance
- C) Cable colour
- D) Installation cost

14. Temperature monitoring is most critical during:

- A) Storage
- B) Initial energization
- C) Manufacturing
- D) Transportation

15. Post-commissioning activities are performed:

- A) Before installation
- B) Before testing
- C) After energization
- D) During manufacturing

16. Frequent breaker tripping may be due to:

- A) Correct operation
- B) Control circuit fault
- C) Proper insulation
- D) Normal loading

17. Control circuit testing ensures:

- A) Power flow
- B) Proper signal and logic operation
- C) Reduced voltage
- D) Mechanical strength

18. Breaker timing test checks:

- A) Opening and closing time
- B) Insulation resistance

C) Contact resistance

D) Cable length

19. Documentation of test results is required to:

A) Increase load

B) Provide legal and technical record

C) Reduce testing time

D) Avoid maintenance

20. Troubleshooting means:

A) Equipment replacement

B) Fault identification and rectification

C) Increasing voltage

D) Ignoring alarms

MCQ Answer Key

1-B, 2-C, 3-C, 4-C, 5-B,
6-A, 7-B, 8-B, 9-B, 10-B,
11-B, 12-B, 13-B, 14-B, 15-C,
16-B, 17-B, 18-A, 19-B, 20-B

B. Short Answer / Viva Questions (10)

1. Why are pre-commissioning checks necessary before energizing switchgear?
2. Explain the importance of insulation resistance testing.
3. Why is contact resistance kept as low as possible in breakers?
4. What is the function of interlocking in switchgear?
5. State the purpose of CT and PT connection verification.
6. Why is high-voltage withstand testing done at site?
7. Explain the significance of Tan δ measurement in power cables.
8. Why is temperature monitoring required during initial energization?
9. What information is included in post-commissioning documentation?
10. Explain the importance of systematic troubleshooting in switchgear.

✔ Mentor's Note

If you can **define clearly, explain logically, and apply practically**, you are already operating at **industry-ready Diploma level**. Use this Mastery Check before exams, vivas, and interviews—it reflects exactly how **GTU-pattern questions** are framed.

✔ Academic & Syllabus Validation (Expert Review)

✓ Alignment with GTU Syllabus

- All resources directly support **Unit-5 topics (5.1 to 5.7)** as listed on **pages 4-5 of the syllabus**
- Strong linkage with **suggested practical experiments** (IR test, relay testing, cable testing, breaker timing) mentioned on **page 6**
- Supports **R-U-A levels** (Remember-Understand-Apply), exactly matching the **GTU theory weightage pattern**

✓ Pedagogical Strengths

- Clear separation between **concept learning, visualization, and application**
- Suitable for:
 - Slow learners (repeatable simulations & videos)
 - Average learners (step-by-step AI explanations)
 - Advanced learners (troubleshooting & industry portals)
- Encourages **self-learning, digital literacy, and lifelong learning** (NEP-2020 compliant)

Why This Library Is Strong (Educator's Insight)

1 AI Tools Section – *Very Well Designed*

- Avoids naming specific brands → **future-proof**
- Matches GTU's expectation of **procedural understanding**
- Excellent for **viva, short answers, and last-minute revision**

2 Video Repository – *Highly Practical*

- All topics map **one-to-one with Unit-5 subtopics**
- Search-keyword approach is ideal for:
 - LMS usage
 - Offline sharing
 - Exam-time quick access

3 Mentor Guidance – *High Educational Value*

- Encourages **smart study habits**
- Motivational but still technical
- Appropriate tone for Diploma students



Suggested Minor Enhancements (Optional but Valuable)

You may optionally add **one line** under the title for official use:

“Prepared as per GTU Diploma Electrical Engineering syllabus (DI04009031), Unit-5, w.e.f. Academic Year 2025-26.”

You may also tag this resource as:

-  **OBE Support Material**

-  Self-Learning Module
-  Supplementary Digital Content

Predicted Question Bank

Most Repeated / High-Probability Questions

(Based on GTU trends: definitions, procedures, tests, and troubleshooting)

A. Core Definition-Based Questions

1. Define commissioning of switchgear. State its importance.
2. Define insulation resistance (IR). Why is IR measurement essential before energization?
3. What is contact resistance? Why should it be minimum in circuit breakers?
4. Define interlocking in switchgear. Explain its safety role.
5. What is a protection relay? State its basic function.

B. Explanatory / Procedure-Based Questions

6. Explain pre-commissioning checks of switchgear.
7. Explain insulation resistance (IR) measurement of switchgear with precautions.
8. Describe the procedure for contact resistance test of circuit breakers and isolators.
9. Explain CT and PT connection verification during commissioning.
10. Describe mechanical operation test of switchgear.
11. Explain protection relay and control circuit testing.
12. Explain interlock verification (electrical and mechanical) in switchgear.
13. Explain SF₆ gas / vacuum integrity test of circuit breakers.
14. Explain on-site high-voltage withstand test of switchgear as per IS/IEC.
15. Explain breaker timing test and its significance.

C. Power Cable-Focused Questions

16. Explain pre-commissioning checks of power cable.
17. Explain physical inspection of power cable with respect to joints, terminations, and bending radius.
18. Describe conductor resistance and continuity test of power cable.
19. Explain insulation resistance (megger) test of power cable.
20. Explain site acceptance tests of power cable.
21. Explain sheath integrity test of power cable.
22. Explain capacitance and $\tan \delta$ (dissipation factor) measurement of power cable.

D. Post-Commissioning & Fault-Based Questions

23. Explain load test under service conditions for power cables.
24. Why is temperature monitoring required during initial energization?
25. Explain the importance of documentation of commissioning test results.
26. List common faults in switchgear and their causes.
27. Explain troubleshooting steps for switchgear faults.
28. List common faults in power cables and their remedies.

2 Application & Logical Thinking Questions

(5 questions – high-scoring, differentiation questions)

1. A circuit breaker trips repeatedly immediately after commissioning.
Explain possible causes and systematic troubleshooting steps.
2. During commissioning, insulation resistance of a power cable is found to be very low.
Analyze possible reasons and suggest corrective actions.
3. CT secondary wiring is found incorrect during relay testing.
Explain how this can affect protection system operation.
4. During initial energization of a newly laid power cable, abnormal temperature rise is observed.
Analyze possible reasons and explain corrective measures.
5. After commissioning, improper documentation of test results is noticed.
Explain how this can affect maintenance, safety, and future fault analysis.

Exam Strategy Tips (Mentor's Insight)

- **Short answers (2–3 marks):** Definitions + purpose
- **Medium answers (4–5 marks):** Procedure + significance
- **Long answers (7–8 marks):** Step-wise explanation + precautions + neat diagram
- **Application questions:** Always write *cause* → *effect* → *remedy*

GTU focus for Unit-5:

Commissioning steps, testing logic, safety compliance, and troubleshooting approach.

Final Mentor Note

If you can confidently answer **Questions 6–15 and any two application questions**, you are **well-prepared to score full marks** from this 18% weightage unit.

Appendices & Extra Resources

Below is an **External Exposure & Enrichment Module** designed for **Diploma Electrical Engineering students**, aligned with **Commissioning & Maintenance of Electrical Equipments** and **Unit-4: Commissioning of Rotating Machines** of the GTU syllabus (w.e.f. 2025–26). The module connects **classroom learning with modern industry practices**, supports NEP-2020, and motivates **lifelong learning and employability**.

🌐 EXTERNAL EXPOSURE MODULE

Commissioning & Maintenance of Electrical Equipments

(Industry Awareness + Career Orientation)

1 Beyond the Syllabus – Emerging Technologies

1. Smart Condition Monitoring & Predictive Maintenance

What it is:

Modern industries use sensors and data analysis to continuously monitor **vibration, temperature, current, and insulation health** of motors and generators.

Link to syllabus fundamentals:

- Builds directly on **vibration measurement, no-load test, and troubleshooting** concepts
- Traditional tests are now done **continuously and digitally**

Why students should care:

- Predictive maintenance reduces breakdowns and cost
 - High demand skill in **power plants, manufacturing, and automation industries**
-

2. Variable Frequency Drive (VFD)–Based Motor Systems

What it is:

VFDs control motor **speed, torque, and starting current** electronically instead of direct-on-line starting.

Link to syllabus fundamentals:

- Commissioning still requires **IR test, trial start, no-load observation, vibration check**
- Understanding motor behavior during starting and no-load is essential

Why students should care:

- VFDs are widely used in **modern industries and smart factories**
 - Knowledge improves career prospects in **automation and energy-efficient systems**
-

2 MOOC & Online Course Recommendations

1. Electrical Machines – Part I / II

- **Platform:** NPTEL
- **Theme:** Operation and behavior of electrical machines
- **How it helps:**

Strengthens understanding of **motor characteristics, faults, and testing**, directly supporting commissioning concepts

2. Industrial Maintenance

- **Platform:** NPTEL / SWAYAM
- **Theme:** Maintenance strategies and equipment care

- **How it helps:**

Explains **preventive and breakdown maintenance**, troubleshooting logic, and real industrial practices

3. High Voltage Engineering (Audit Mode)

- **Platform:** NPTEL
 - **Theme:** High-voltage testing and insulation behavior
 - **How it helps:**
Deepens understanding of **HV power frequency tests and insulation safety**
-

3 Industrial Exposure / Field Visit Suggestions (Regional Focus)

(Suitable for Gujarat and nearby industrial regions)

1. Thermal / Gas Power Plant

Type: Power generation industry

What students observe:

- Commissioning and testing of **large synchronous machines (alternators)**
 - Vibration monitoring, excitation systems, and safety practices
-

2. Industrial Motor Repair & Rewinding Workshop

Type: Electrical maintenance service industry

What students observe:

- Common motor faults, rewinding process, insulation drying
 - Practical troubleshooting beyond textbooks
-

3. Water Pumping Station / Industrial Utility Plant

Type: Infrastructure / utility services

What students observe:

- Commissioning and maintenance of **induction motors**
 - Trial runs, no-load checks, vibration issues, and alignment
-

4 Conferences, Seminars & Technical Events

1. IEEE Electrical Machines & Drives Conferences

Theme: Electrical machines, drives, and diagnostics

Why exposure helps:

- Introduces students to **future trends, research, and innovation**
 - Motivates higher studies and professional growth
-

2. National Power Engineering Conferences (India)

Theme: Power generation, maintenance, and safety

Why exposure helps:

- Shows real challenges faced by engineers
- Builds understanding of **industry standards and practices**

3. Institution of Engineers (India) – Technical Seminars

Theme: Maintenance, safety, and reliability of electrical systems

Why exposure helps:

- Encourages professional networking
- Builds confidence and communication skills

Mentor's Closing Note for Students

Your diploma gives you **skills**, but **exposure gives you vision**.

When you connect **commissioning tests** to **modern technology and industry needs**, you move from being a **student** to becoming a **professional engineer**.

Strong fundamentals + industry exposure = lifelong employability