SHREE GANESH ENTERPRISES
NEW DELHI · AMC MEP 24x7 · sge.org.in

DOC: SGE-EB-2026-11

E-BOOK 11 ADVANCED EDITION

HT Cable Hi-Pot Testing & Fault Location

Safe Procedures for 11 kV Underground Cables

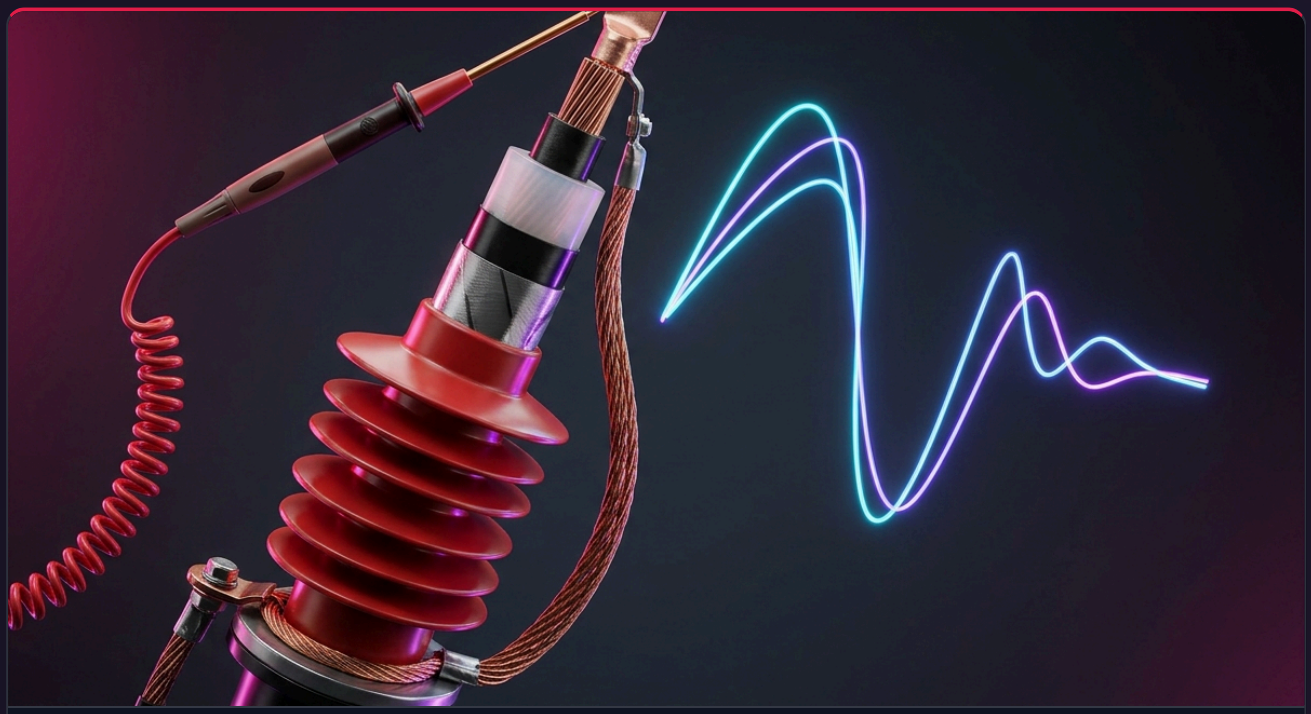


FIG 11.1 — 11 KV XLPE TERMINATION, HIPOT PROBE & TDR FAULT TRACE

SYLLABUS	CALCULATIONS	SITE READY
10 Structured Chapters	Worked SI Examples & Tables	Forms & Hinglish Glossary

Shree Ganesh Enterprises (SGE) — AMC MEP 24x7
Fire Fighting · Fire Alarm · Electrical · Plumbing · HVAC · IBMS · AMC

1st Edition, 2026
sge.org.in/ebooks/ht-cable-hipot-testing-fault-location

HT Cable Hi-Pot Testing & Fault Location

Safe Procedures for 11 kV Underground Cables

A strict, safety-first procedure manual for 11 kV underground XLPE cable testing and fault location: cable anatomy, Permit-to-Work & LOTO isolation, IR/Megger diagnostics, VLF 0.1 Hz AC vs DC Hi-Pot testing principles, step-by-step discharge safety, TDR pre-location, acoustic thumper pinpointing without blind excavation, and sheath fault tracing.

Intended Audience: High-voltage testing & commissioning engineers, substation operators, electrical maintenance heads, and fault-location field crews.

Engineering Notice & Standards Policy

This publication is an educational and field-reference guide prepared by **Shree Ganesh Enterprises (SGE)**. It is **not** a substitute for a stamped project design, statutory approval, or the governing text of the National Building Code of India (NBC), Bureau of Indian Standards (BIS) codes, Indian Electricity Rules / CEA Regulations, or your State/Municipal Fire Service Bye-Laws. Standards are cited at document level; always verify the **current applicable edition**, manufacturer datasheets, and local amendments before design, procurement, testing, or certification.

Worked numerical examples across this book are illustrative engineering demonstrations. All design inputs, pipe friction factors, battery deratings, and protective clearances must be re-checked for project conditions by a competent licensed professional. High-voltage electrical testing, pump-room servicing, and gaseous fire suppression operations can be fatal if undertaken without qualified personnel, written Permits-to-Work, and Lockout-Tagout (LOTO) controls.

Roman-script Hindi/Hinglish site terms are included cleanly to assist execution teams; formal English engineering terminology governs contractual and code interpretations.

Copyright & Licensing

© 2026 Shree Ganesh Enterprises (SGE). All rights reserved. No part of this manual may be reproduced, redistributed, or resold publicly without written authorization. Licensed strictly for purchaser and internal engineering team reference.

Publisher: Shree Ganesh Enterprises (SGE) — AMC MEP 24x7 | **Web:** sge.org.in | **Support:** support@amcmep.in

Contents

01 Chapter 1: 11 kV XLPE Underground Cable Anatomy and Failure Mechanisms

02 Chapter 2: Mandatory Pre-Test HV Safety, Permits, LOTO and Earthing

03 Chapter 3: Diagnostic Tests — IR (Megger), VLF 0.1 Hz AC vs DC Hi-Pot and Sheath Test

04 Chapter 4: Step-by-Step Hi-Pot / Withstand Test Execution and Post-Test Discharge

05 Chapter 5: Cable Fault Classification

06 Chapter 6: Pre-Location Without Digging — TDR, Arc Reflection and Murray Loop

07 Chapter 7: Acoustic Pinpointing (Thumper), Surge Generator and Route Tracing

08 Chapter 8: Step-Voltage Sheath Fault Location and Post-Joint Re-Testing

09 Chapter 9: HT Test Record Templates, Instrument Calibration and Permit Forms

10 Chapter 10: Safety Cheat Sheet, FAQ and Bilingual HV Glossary

What You Will Learn

- Inspect 11 kV XLPE layered construction (semicon screens, insulation, copper tape screen, armour) and common failure triggers
- Enforce strict dual-end HV Isolation, Permit-to-Work, LOTO, Barricading, and Stored-Charge Earthing
- Understand why modern utilities favour VLF 0.1 Hz AC over DC Hi-Pot on aged XLPE cables—and how to verify test kV safely
- Execute high-voltage withstand tests with safe ramp-up, leakage monitoring, and earthing-stick discharge
- Pre-locate underground cable faults precisely with TDR pulse arithmetic (V/2 velocity calibration)
- Pinpoint exact fault coordinates acoustically with surge thumper + step-voltage before opening a single pit

Chapter 1: 11 kV XLPE Underground Cable Anatomy and Failure Mechanisms

Why 11 kV Cables Cannot Be Treated Like Ordinary 415 V Wires

Inside a 3-core 11 kV XLPE underground feeder, electrical stress gradients concentrate intensely around every sharp point, air void, or trapped moisture drop. Manufacturers build a precise multi-layer coaxial shield assembly where every microscopic layer prevents corona breakdown:

Cable Layer (Inside -> Outside)	Engineering Function	What Happens When Damaged on Site
Stranded Al/Cu Conductor	Carries 11 kV phase load amperes	Water wicks down strand gaps causing black oxidation
Conductor Semicon Screen	Smooths sharp wire-strand bumps into uniform circular electric field	Leaving scratches/knife nicks during stripping triggers partial discharge!
XLPE Main Insulation	High-dielectric polymer holding e.g. 6.35 kV phase-to-ground smoothly	Water treeing, voids, or bending crushes cut dielectric strength
Insulation Semicon Screen	Confines electric field purely inside XLPE; peeled carefully at terminations	Failure to paint/terminate stress-control cone causes surface flashover tracking
Copper Tape Metallic Screen	Carries capacitive charging current & phase-to-earth fault return	Un-earthed or corroded screen burns jackets rapidly
Galvanized Steel Armour & PVC Sheath	Protects against JCB digs & blocks underground groundwater	Sheath cuts admit subsoil moisture into metallic screen

WARNING (LETHAL HAZARD)

High-voltage (11 kV / 33 kV) cables act as massive electrical capacitors storing lethal DC/AC trapped energy **long after switchboards are turned OFF!** All testing, earthing, and termination work MUST be executed strictly by authorized, qualified HV personnel holding valid Electrical Supervisory Permits, PPE, insulated rescue hooks, and written Permits-to-Work.

HINGLISH

Semicon layer = taar ke upar ki kaali conducting parat jise joint banate samay bade dhyan se chheela jata hai.
Stress cone = 11 kV termination par electric dabav kam karne wala joint hissa.

Chapter 2: Mandatory Pre-Test HV Safety, Permits, LOTO and Earthing

Never Touch a Core Because an Incomer Light Is Off

1. **Both-End Isolation & Visible Break:** Open RMU / VCB / HT isolator switches at **BOTH sending end and receiving end**! Never rely solely on closed breaker indicator LEDs—rack out breakers physically to visible

disconnected test position.

2. **Apply Personal Padlocks & Warning Tags (LOTO):** Each crew working on the feeder places an individual padlock and signed **"DANGER — MEN WORKING ON CABLE / HV TEST IN PROGRESS"** tag at *both* ends!
3. **Discharge & Solidly Earth Before Touching:** Verify dead state with a rated HV Contact/Proximity Voltage Detector (tested on live known source first -> test cable -> re-verify tester!). Apply dedicated heavy copper portable **Discharge & Earthing Leads** to all three phases (`R–Y–B`) cleanly before touching terminations with bare hands or insulated tools!
4. **Disconnect Sensitive Equipment Completely:** Isolate Potential Transformers (PTs), Surge Arresters (LAs), transformer bushings, and RMU SF6 bus links cleanly BEFORE applying high-voltage withstand pressure—testing with a Surge Arrester attached blows the arrester directly at ~8–10 kV!
5. **Perimeter Barricade & Guards:** Rope off both cable ends cleanly with bright caution tape and station a dedicated guard **at the far open end** with two-way radio contact so nobody walks into bare energized 20+ kV test tips!

> **HINGLISH**
> Earthing rod / Discharge stick = cable test karne ke baad andar bachi hui jaanleva bijli ko zameen mein utarne wali lambi insulated chhad. Both-end isolation = taar ke dono siron (sending aur receiving) se breaker khol kar lock karna.

Chapter 3: Diagnostic Tests — IR (Megger), VLF 0.1 Hz AC vs DC Hi-Pot and Sheath Test

Why Utilities Shifted Away from High-Voltage DC on XLPE

Years ago, field crews plugged heavy **DC Hi-Pot** sets blindly onto underground cables because DC sets were small and light. Experience proved **high-voltage DC damages aged extruded XLPE polymers** by trapping permanent space-charge pockets inside water trees—causing cables that *passed* a DC test on Monday to explode catastrophically on 50 Hz AC energisation on Wednesday! Therefore modern utilities and global standards (such as IEC 60502 / IS 7098 / IEEE 400.2) strongly favour **VLF (Very Low Frequency 0.1 Hz) Sinusoidal/Cosine-Rectangular AC** for field withstand tests on XLPE—keeping legacy DC tests restricted carefully (e.g., primarily PILC paper-oil cables or outer PVC sheath checks!).

Test Method	What It Finds Best	Modern Field Status for 11 kV XLPE	Key Field Precaution
1. DC Insulation Resistance (Megger e.g. 5 kV DC)	Gross dampness, direct earth/phase breakdown, dead shorts	Mandatory **BEFORE & AFTER** any Hi-Pot test!	Always verify discharge after test (`5x` test time minimum earth!)
2. VLF 0.1 Hz AC Withstand Test	Pinholes, bad joints, installation cuts inside XLPE cleanly	**Preferred modern standard** per utilities / IEEE 400.2	Confirm exact test kV & hold duration per cable standard/utility rules
3. DC Hi-Pot Test	Legacy paper-oil (PILC) insulation & low-kV sheath checks	Discouraged on *aged* XLPE cores by utilities	NEVER exceed vendor/utility approved sheath or core kV limits!
4. Outer PVC Jacket Sheath Test	Trench stone cuts/pinholes admitting soil water into armour	Routine acceptance & preventive check after backfilling	Disconnect armour earth pit bond temporarily at both ends cleanly!

NOTE (HOW TO DETERMINE CORRECT TEST VOLTAGE)

Do NOT guess or invent test kV numbers on site! Exact Hi-Pot / VLF test voltages vary depending on cable rated voltage (`Uo/U` , e.g., `6.35/11 kV` un-earthed vs `11/11 kV`), **New Acceptance Test vs Aged Maintenance Test**, waveform type (Peak vs RMS), and local **State DISCOM / BIS IS 7098 / IEC 60502** rules. Always extract the signed test voltage and minute duration directly from your approved OEM/Utility commissioning sheet before setting dials!

WORKED EXAMPLE 1

Why VLF 0.1 Hz Works Portable vs 50 Hz AC (Illustrative). A **0.8 km** (`800 m`) feeder of `11 kV 3C x 300 mm2 XLPE` has assumed core-to-screen capacitance `0.25 uF/km` -> Total capacitance `C = 0.8 x 0.25 = 0.20 uF` (`0.20 x 10^-6 F`). Assume an illustrative RMS test voltage of `19 kV` (check your utility spec!). Compare reactive capacitive charging current `I_c = 2 x pi x f x C x V` :

- On a normal **50 Hz** supply: `I_50Hz = 2 x 3.1416 x 50 x 0.20e-6 x 19,000 = 1.194 Amps` (~22.7 kVA heavy truck-mounted generator!).
- Using **0.1 Hz VLF AC**: `I_0.1Hz = 2 x 3.1416 x 0.1 x 0.20e-6 x 19,000 = 0.00239 Amps = 2.39 mA` ! (Powers off a **45 VA portable briefcase** on a single 230 V socket!).

HINGLISH

VLF 0.1 Hz test = XLPE cable ko bina nuksan pahunchaye uski asli ac-jaisi taaqat check karne wala modern machine. Sheath test = bahari kaale PVC cover mein gadda ya kankad se kata hua chhed check karna.