

DC High Potential Testing - DC Hi-Pot Testing

Purpose

DC Hi-Pot Testing is used for proof testing shielded cables (5kV to 46kV) in the field. The test can be done at various times such as acceptance of new cable installation, maintenance testing to track insulation degradation and as a pre and post test for splicing existing cables to new ones. The test will expose gross imperfections that are caused by improper handling, installation techniques or termination workmanship. A DC Hi-Pot test is not capable of locating the point of failure, rather it gives you an assessment of the whole system.

General Testing Information

DC Hi-Pot Testing monitors the ability of the cable's insulation to withstand a specific voltage for a specific length of time. The test can be performed as a simple "Go, No-Go" withstand test, or it can be performed as a monitoring test where the leakage current is measured giving the user additional information about the status of the cables insulation.

Equipment

- DC High Potential Test Set
- Stress Control Devices (optional)

Safety

Before conducting tests on cables, verify circuits are de-energized. Follow all safety practices according to NFPA 70E and NESC C2.

Follow the test equipment instructions and guidelines.

Only qualified persons should perform this testing.

Barricade the test area.

After a test the cable will have a charge. It is VERY IMPORTANT that the capacitive charge the cable continues to hold after testing is properly discharged. Do this by attaching the cable's conductor to the grounded cable shield draining off the charge. Discharge the cable for at least 4 times the duration of the test.



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Preparation

Ensure that test equipment is in good working order and has been calibrated within the last year.

Clean up the area. Good housekeeping and environmental conditions are important since Hi-Pot leakage current readings are affected by dirt, moisture, heat and humidity.

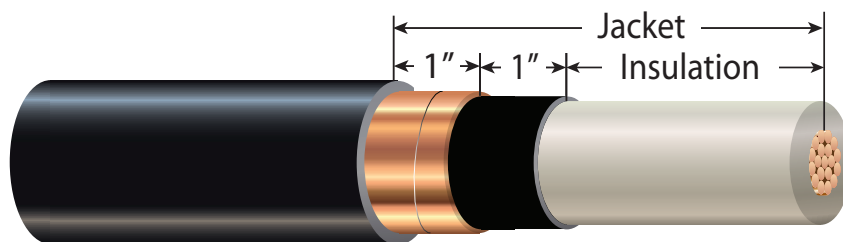
Disconnect cables from equipment on both ends.

Clean cable ends/terminations with appropriate cleaning solution.

If terminations or accessories are not being used, cutback the cable as described in the table below. For cables above 35kV, terminations are required.

Table 1

Cable Voltage Rating	Cutback Measurement			
	Jacket	Tape Shield	Semicon	Insulation
5kV	8 inches	1 inch	1 inch	6 inches
8kV	10 inches	1 inch	1 inch	8 inches
15kV	12 inches	1 inch	1 inch	10 inches
25kV	14 inches	1 inch	1 inch	12 inches
35kV	17 inches	1 inch	1 inch	15 inches



Determine the correct cutback measurement and test voltage using Tables 1 and Table 2.

Test Procedure

If the cable has been energized, allow the cable to cool to ambient temperature before testing.

While it is possible to test more than one cable at a time, optimal results are obtained by testing each phase individually. This allows precise monitoring of each conductor's leakage current.

Connect the test leads to the cable's phase conductor and shield.

Tie all the other cable conductors, shields and ground wires to ground.

Make sure both cable ends under test are suspended in free air at least 15" away from any surface.



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Having the cable end near a conductive path may increase leakage current readings.

Minimize corona discharge on cable ends with the use of plastic wrap, bottles, or corona balls. This is much more important at higher voltages (15kV to 46kV rated cables).

While NETA ATS (Standard for Acceptance Testing Specification) recommends insulation resistance (megger) testing before performing a Hi-Pot Test, Southwire considers this to be optional.

Withstand Test

Turn the test set on and ramp up the voltage to the prescribed test voltage in 5 to 7 equal steps, (the initial applied voltage should not be greater than 3 times the cables rated AC voltage), hold the voltage at each step for 60 seconds before proceeding to the next level. Voltage steps may be rounded to the nearest kilovolt. Once the prescribed test voltage has been reached, hold at that voltage for 15 minutes and then bring the voltage quickly back down to zero. If the test set does not indicate a fault occurred during the test, the conductor has passed the withstand test.

Monitor Test

Turn the test set on and ramp up the voltage to the prescribed test voltage in 5 to 7 equal steps, (the initial applied voltage should not be greater than 3 times the cables rated AC voltage), hold the voltage at each step until the leakage current level has stabilized (about 1 minute) taking a current reading before proceeding to the next level. Once the prescribed test voltage has been reached, hold at that voltage for 15 minutes. A leakage current measurement should be taken at 2 minutes and again at the end of the test (15 minutes). Bring the voltage quickly back down to zero.

What is important in evaluating Monitor Test results is not the actual leakage current values, but the shape of the current/time curve.

The current measured in this test is commonly called the leakage current, but it is actually the combination of three currents: The absorption current (the current actually absorbed by the insulation); the charging current (the current that charges the phase-shield capacitor that the cable is); and the actual leakage current (the current that actually leaks through the insulation from the conductor to the grounded shield). At a steady-state voltage the absorption current and the charging current will decay quickly but the actual leakage current component will remain constant. The actual leakage current is the most important component and the current we are most interested in monitoring.

The actual leakage current component is simply "I" in a " $V = IR$ " equation where V is the test voltage and R is the cables insulation resistance. Because this is a linear relationship, we want to see a linear change in leakage current (once stabilized) with voltage. Because of this, you should expect to see a positive slope straight-line graph of the stabilized current when plotted vs. time as you ramp up. Once you have ramped up and are holding at the prescribed test voltage you should see the current quickly decrease to a steady state (horizontal line) for remainder of the test.



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This is the ideal and your actual results will vary to some degree. Also, because your results will vary based on elevation, temperature, humidity and wind, it is important to log that information along with your test results. Whenever re-testing cable, it is best to test in similar conditions.

If you see a steady linear increase in the leakage current values as the test voltage ramps up and a steady state value of leakage current at the prescribed test voltage and all three phase conductors display similar plots after being tested, the cable has passed the test.

When to Test

A DC Hi-Pot test will fall into one of four categories: On-Reel (while the cable is still on the reel, before the cable is pulled); Installation (after the cable is pulled but before terminations and splices are installed); Acceptance (after the cable is pulled and terminations and splices are installed); and Maintenance (performed on installed, terminated cable at regular intervals).

Maximum DC test voltages vary based on the cable's voltage rating, insulation level, and test type. Maintenance tests are performed at a lower voltage than non-Maintenance tests.

If the Cable Does Not Pass

If the test results for one of the three conductor varies significantly, further investigation should be performed. The difference could be caused by dirty terminations, poor workmanship of cable preparation, improper test procedures, defective terminations, or bad cable.

Before taking further action, consult Southwire to determine the possible cause of the failed test.

Consideration for XLP Insulated Cables

Table 2

Cable Rating	On-Reel/Installation/Acceptance DC Test Voltages (kV)		Maintenance DC Test Voltage (kV)		Maintenance DC Test Voltage (kV)	
	EPR and XLP		EPR		XLP	
	100% Level	133% Level	100% Level	133% Level	100% Level	133% Level
5kV	28	36	22	29	9	11
8kV	36	44	29	35	11	14
15kV	56	64	45	51	18	20
25kV	80	96	64	77	25	30
28 kV	84	100	67	80	26	31
35 kV	100	124	80	99	31	39
46 kV	132	172	106	138	41	54



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There has been a study by EPRI, project report TR-101245, that DC testing of aged XLP insulations could lead to early cable failures. Therefore, Maintenance Test Voltages have been lowered considerably for XLP insulations. ICEA does not recommend DC testing after 5 years of a cable's service life. Southwire recommends before Maintenance Testing, careful evaluation of the cable should be completed, considerations such as age, type of insulation and if the cable is in a dry or wet environment. If there is a concern of compromising aged cable, we recommend the AC VLF Test with Tan Delta be performed.

Considerations for EPR Insulated Cables

EPR is not susceptible to electro-chemical treeing like XLP insulated cables are. Unlike XLP insulated cables, there has been no evidence of premature failure of EPR insulated cables due to DC Hi-Pot testing. Because of this, Southwire does not suggest limiting maintenance testing of these cables to 5 years. Also, there seems to be no correlation between the number of tests performed and cable failure.

References

- **NFPA 70E** National Electrical Code
- **NESC C2** National Electrical Safety Code
- **AEIC CS8** Specification for Extruded Dielectric, Shielded Power Cables Rated 5 Through 46 kV
- **ICEA S-93-639** 5-46KV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy
- **ICEA S-94-649** Concentric Neutral Cables Rated 5 through 46kV
- **IEEE Std 576** Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications

