DC Hi Pot Testing
Excerpt
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PRYSMIAN'S
WIRE AND CABLE
ENGINEERING GUIDE

(FOR INFORMATIONAL PURPOSES ONLY)

700 Industrial Drive
Lexington, South Carolina 29072
Phone: 1.800.845.8507
Fax: 1.803.951.1142
www.na.prysmian.com/energy

DC HIGH POTENTIAL TESTING

DC Hi-Pot testing can be applied as a withstand test (a Type I – Destructive Test) or a leakage current measurement technique (a Type II – Non-Destructive test). The Hi-Pot withstand test is a Pass/Fail test that *has been* applied to many types of cable and accessories. The Hi-Pot leakage current technique is a diagnostic test which involves the measurement of leakage current when a high potential (above nominal) is applied to the conductor while the metallic shield of the cable is grounded. The behavioral characteristics of the leakage current are evaluated to determine the condition of the cable, specifically the insulation.

As part of any cable testing program, many factors must be considered to properly characterize the test results obtained. Many of those factors are controllable as part of material testing, qualification testing, and production testing. Unfortunately, field testing does not allow control over various factors, two of which are temperature and humidity. Keeping track of the factors that influence cable testing results and accounting for them can be the difference between passing or failing results.

It is important to recognize that published documentation provides details showing DC hi-pot testing mostly finds conductive type gross workmanship errors in extruded dielectric cable systems[†]. Consequently, the practical use of the DC hi-pot testing is recommended only for paper insulated cable systems and for performing a safety check before switching an extruded cable system into service (to prove that the system is not grounded).

Additional details on DC high potential testing can be found by referencing IEEE 400.1 *IEEE Guide for Field-Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5kV and Above with High Direct Current Voltage*.

GENERAL INFORMATION:

- DC Hi-Pot Testing is commonly applied at much higher voltage levels than megger testing. The elevated voltage levels place more electrical stress on the dielectric[†] (megger testing is typically used at voltages up to 5kV).
- DC Hi-Pot Testing is typically reserved for shielded, medium-voltage cables[†].
- Several types of currents are flowing at the beginning of this test.
  - o *Capacitive current* – Current required to charge the capacitance of the insulation; after all, cable is a long capacitor. This current quickly declines to zero[†].
  - o *Absorption or Polarization current* – Current absorbed by the insulation during molecular changes in the insulation. This current may go to zero quickly or possibly linger for an extended period of time[†].
  - o *Leakage current* – This current is the primary current to be concerned with. This current quickly reaches and maintains a constant value[†].
  - o *Total Current* – is comprised of the Capacitive Current, the Absorption Current and the Leakage Current[†].
- In order to obtain leakage current readings that are most representative of the cable system, and to insure against flashovers to other structures, all bus ties and/or aerial jumpers from the terminals should be removed before performing such tests[†].
- It is sometimes necessary to "smooth" any sharp edges or points of the hardware on the terminal top fittings using a soft, putty-like insulating compound. This helps reduce stress concentration and corona discharge off such sharp projections. Alternatively, or in addition, a clean, dry plastic bucket or trashcan (containing NO metallic fittings) is placed over the top of the terminals to effectively lengthen the leakage path to a surrounding grounded structure. Note that the far-end terminals must be treated in the same manner.

- Because surface contamination or moisture can significantly increase leakage current flow over the surface of the terminals, all surfaces of the terminal insulators should be carefully wiped to remove any contamination and moisture and remain completely clean and dry during the test.
  - For the same reason, such testing is normally not performed in inclement weather (rain, snow, sleet, fog) when there are outdoor terminations involved. The most representative test results will be obtained when the tests are performed under cool, dry weather conditions.
- After each cable has been tested, its conductor should be grounded, using a properly terminated resistor, to drain off the electrical charge that has accumulated in the cable. To ensure that this charge has been completely drained, the conductor should be grounded for a period of time equal to or not less than 5 times the test period.
  - If there is any doubt that this has been done, ground the cable with a grounding stick before starting any work after such testing has been performed.

STEP-BY-STEP PROCEDURE FOR DC FIELD TESTING

- Ground all conductors, except the one to be tested.
- Connect cable shield to ground; ground any adjacent equipment.
- Ensure adequate clearance of the conductor/terminals to be tested from ground to prevent flash over.
- Carefully wipe terminals to remove any contamination (i.e. dust, moisture, etc.)
- Corona-proof conductor/terminal ends of cable by sufficiently taping them. If cable is terminated, cover termination with a polyethylene bucket or bag.
- Fence test cable ends to ensure personnel safety.
- Preliminary step: 'Megger' cable to be tested. Any cable that exhibits low 'Megger' readings is questionable and should be cleared before the high voltage DC test is performed.
- Connect output of test set to conductor/terminal to be tested and connect ground terminal of test set to ground.
- Bring DC voltage up to prescribed test level in five equal steps. Raise the voltage at an even rate, so as to reach the required level in not less than 10 seconds. Hold the voltage at each step for 60 seconds. Read and record the leakage current at the end of each hold period.
- Hold the full test voltage for not less than 10 minutes or more than 15 minutes. Read and record the leakage current at 15-second intervals for the first 2 minutes and then every minute for the duration of the test.
- Bring the test voltage control quickly and smoothly to zero. Read and record the voltage remaining on the cable after 30 and 60 seconds. Discharge the cable to ground using a properly terminated resistor stick. When the test set voltmeter indicates zero voltage on the cable, attach a solid ground to the cable and then disconnect the test set and resistor stick.
- Test each conductor/cable in the circuit in the same manner.
- Record all data concerning the circuit and test results.

LEAKAGE CURRENT BEHAVIOR: ANALYZING THE RESULTS

The following Leakage Current characteristics are of significance in evaluating the condition of the cable:

- Linearity of the leakage current at a number of incremental voltages between zero and the prescribed test voltage.
- The behavior of the leakage current when the prescribed test voltage is reached and maintained for the duration of the test.
- With a sound system, the current will drop rapidly from the value indicated when the test voltage is first reached, with the decrease gradually diminishing until the current becomes stable at a value well below the peak.

- Instability of the leakage current (provided that is not caused by test set supply voltage fluctuations or corona discharge at terminals) may be an indication of incipient breakdown. In such cases, an extension of the test period may be appropriate to precipitate breakdown, thereby pinpointing the problem and making location possible.
- If the leakage current does not decrease, or begins increasing after an initial drop, it is a strong sign of trouble in the cable system. As noted above, one course of action in such cases is to extend the test so as to precipitate breakdown and make location of the defective section possible.
- In general, it is not considered meaningful to compare values of leakage current measured on the same cable at different times, or on different but like cables at the same time. The reason being, there are many factors (cable temperature, number and type of splices, type of terminals or terminations, cleanliness of terminal or termination surfaces, length of cable circuit, air temperature, humidity, etc.) which can affect these measurements and can make such direct comparisons less than meaningful.

ON-REEL TESTING

On-Reel (field) testing is a rather uncommon practice that allows the end user or installer to test the integrity of the cable on the reel at the time of delivery and prior to installation. On-Reel (field) testing is uncommon due to the fact that prior to shipping, the cable undergoes a thorough testing program at the factory. On-Reel testing by the end-user insures that the cable has arrived without sustaining any damage while in transit. During shipment the cable may be loaded and unloaded several times after it leaves the manufacturer and before it arrives at its final destination. This extraneous, but sometimes necessary, handling of the cable provides added opportunity for the cable to experience mechanical damage. If the cable is damaged during transit and is not On-Reel tested, the cable may then be installed, prepared, and tested only to determine the cable is failing installation test due to damage incurred during shipping.

DC Hi-Pot testing can be used as a testing method for On-Reel testing of shielded, medium voltage cables. The procedures above should be followed while utilizing the voltage limits as specifically listed in Table 1.

It is important to note that any intention to On-Reel test cables should be pointed out to the manufacturer. In order to facilitate On-Reel testing by the end-user, the manufacturer will have to ensure test 'tails' are present on the reel. Test tails will consist of allowing access to appropriate lengths of cable at the drum end of the cable. This will enable the connection of both cable ends to the necessary test equipment. Test tails typically consist of a length of cable at the drum end that is approximately 24 inches long.

INSTALLATION TESTING

Installation testing is conducted after cable installation but before jointing (splicing) or terminating. The test is intended to detect shipping, storage, or installation damage. *Installation testing of cable offers the best possible assurance that the cable has not been damaged and will perform satisfactorily when energized.*

There are many ways cables can be damaged during installation: pulling through ducts that are in poor condition, improper use of pulling equipment, exceeding minimum bending radii or training radii, or exceeding maximum pulling tensions or maximum sidewall bearing pressures. If damage has occurred during installation, it is important to determine this prior to energizing. Installation testing can prevent a safety hazard or a potential cable or accessory failure during inopportune times. To test the integrity of only the cable, the installation test should be performed. Once the cable tests satisfactorily, the accessories can then be applied and the system can be 'Acceptance Tested' to ensure the accessories were applied successfully and are of good quality.

DC Hi-Pot testing can be used as a testing method for installation testing of shielded,

medium voltage cables. The procedures above should be followed while utilizing the voltage limits as specifically listed in Table 1.

ACCEPTANCE TESTING

Acceptance testing is conducted after the cable system installation, including all terminations and joints (splices), but before the cable system is placed into normal service. The test is intended to detect installation damage and to show any gross defects or errors in installation of other system components/accessories.

DC Hi-Pot testing can be used as a testing method for acceptance testing of shielded, medium voltage cables. The procedures above should be followed while utilizing the voltage limits as specifically listed in Table 1 for the cable in conjunction with the voltage limits for accessories.

As part of an Acceptance Test, the accessory manufacturer should be contacted for appropriate testing practices. *In no case should the testing of the cable system exceed the limits of the accessories or the cable.*

MAINTENANCE TESTING

Maintenance testing is conducted during the operating life of a cable system. It is intended to detect deterioration of the system (in cable or accessories) so that suitable maintenance procedures can be initiated.

While there are multiple maintenance test methods available, DC Hi-Pot Testing is not recommended as a maintenance test for any solid dielectric insulated cable, especially for Cross-Linked Polyethylene (XLPE/TRXLPE) cables and definitely not after five years of in-service life. Several sources indicate that DC testing of power cables that have been in service can result in premature failures as a direct result of DC Hi-Pot testing. More information concerning this issue can be found in the Electric Power Research Institute (EPRI) project report TR-101245 “Effect of DC Testing on Extruded Cross-Linked Polyethylene Insulated Cables” as well as EPRI project RP2436.

Maintenance testing of cables typically includes all the cable accessories as part of the test results. Consequently, any test result must be interpreted to properly determine if there may be a problem with the cable or an accessory. Maintenance testing of cables can be accomplished through multiple test techniques: AC Hi-Pot testing, Tan Delta testing, PD testing, and/or VLF testing. Each test offers unique advantages as well as disadvantages.

CABLE TESTING

The interpretation of cable testing results is the key to properly assess the characteristics of a cable!

[†]Documentation references are available upon request.

TABLE 1
DC Test Voltages

Rated Voltage Phase To Phase (kV)	Conductor Size (AWG or kcm)	Nominal Insulation Thickness (mils)		On-Reel Testing Maximum DC Hi-Pot Voltage (kV)		Installation Testing Maximum DC Hi-Pot Voltage (kV)		Maintenance Testing Maximum DC Hi-Pot Voltage (kV)*	
		100%	133%	100%	133%	100%	133%	100%	133%
5	8 - 1000 1001 - 3000	90 140	115 140	26 26	34 34	28 28	36 36	9 9	11 11
8	6 - 1000 1001 - 3000	115 175	140 175	34 34	41 41	36 36	44 44	11 11	14 14
15	2 - 1000 1001 - 3000	175 220	220 220	53 53	60 60	56 56	64 64	18 18	20 20
25	1 - 3000	260	320	75	90	80	96	25	30
28	1 - 3000	280	345	79	94	84	100	26	31
35	1/0 - 3000	345	420	94	116	100	124	31	39
46	4/0 - 3000	445	580	124	161	132	172	41	54

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