

ENGINEERING INSTRUCTION

EI 09-0001

HIGH VOLTAGE INSULATION TESTING POLICY

Network(s): EPN, LPN, SPN

Summary: This engineering instruction details the policy for the on-site insulation testing of new and existing high voltage cables, switchgear and transformers.

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Document History

(The document history notes below are intended as a guide only and may not cover all of the changes. If you wish to make use of this document it should be read in full.)

Version	Date	Details	Originator
5.0	10/03/2009	Revision to test voltage for 66 and 132kV cables	Paul Williams

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1 Introduction

This engineering instruction details the policy for the on-site insulation testing of high voltage cables, switchgear and transformers. The purpose of on-site insulation testing is to demonstrate that apparatus can be safely connected to the system.

The testing regime detailed in this policy is designed to avoid unnecessary overstressing and to prolong the life of the apparatus. It should identify any gross defect, damage or earths left connected at a remote end. The testing regime is based on current practice from the relevant British and International standards together with current practice used on the three EDF Energy networks. Consideration has been given to safety of field staff, the availability of test equipment and the relative merits of ac, dc and very low frequency (VLF) ac testing.

This policy supersedes the following documents:

- EPN: EDM V12/S1/8 - Site Insulation Tests for High Voltage Equipment.
- LPN: E5-6-1 - Dielectric Testing.
- LPN: E5-6-1-1 - HV Dielectric Testing.
- SPN: EI 9-001-12 - Site Insulation Testing of Cables, Switchgear and Transformers.
- SPN: Site Testing & Commissioning Manual – 2.N3 - On-site Insulation Testing of Cables, Switchgear & Transformers.

2 Scope

This policy applies to the insulation testing of cables, switchgear and transformers from 1000V to 132kV on the EPN, LPN, SPN and private networks and includes:

- New apparatus before it is connected to the system for the first time.
- Existing apparatus after it has been modified, repaired or moved.
- Existing solid cable after it has been de-energised for an extended period.
- Cable fault locating.
- The testing of insulated cable sheaths.
- Overhead lines where insulation testing is not considered practicable.

This policy does not seek to provide condition monitoring information or partial discharge information.

3 References

EDF Energy Distribution Safety Rules

EI 05-1001 Commissioning Policy

4 Testing

4.1 General

Testing shall be carried out:

- After apparatus is installed (or re-installed) but before energisation for the first time.
- After work on the insulation of apparatus, but not normally after routine maintenance.
- After cable with solid insulation has been intentionally left de-energised for more than one month

For new and re-commissioned equipment the interval between testing and energisation from the system should be the minimum practicable:

- Cables up to and including 11kV no more than 24 hours.
- Cable systems from 22kV and up to and including 132kV this should normally be no longer than 72 hours.
- However for cables at all voltages an extension to this period is available to the SAP providing the integrity of the system can be assured by for example visual inspection of the route or the completion of another successful sheath test.
- Swinger transformers and other standby equipment that is left intentionally de-energised will need to be energised monthly to avoid the need for isolation and testing.

Dispensation to vary from the test methods and voltage levels set out in this policy for test voltages above nominal phase to earth voltages can be granted by the EDF Energy Asset Optimisation and Technology Manager. Where the test voltage is lower than the nominal phase to earth voltage, permission to test should be sought from the Head of Asset Management.

4.2 New Apparatus

All new apparatus should, following installation, be successfully tested once at the voltage specified in this policy. Where the manufacturer recommends tests that differ from this policy guidance shall be obtained from Asset Management.

4.3 Existing Apparatus

All apparatus which has been de-energised and has knowingly had the insulation affected (except changing oil and topping up SF6) shall be subjected to an insulation test as specified in this policy.

4.4 Test Application

Where two or more items of apparatus are connected, the apparatus requiring the least onerous test determines the test voltage.

Site engineers shall take account of the risks involved in disconnecting equipment compared with the risks of a reduced voltage test.

Equipment installed to run initially at a lower voltage than its rating shall be tested according to its rating before connection to the lower voltage system. If, after this test, the insulation is

in any way disturbed, e.g. a 33kV cable is jointed to an 11kV cable, an insulation test voltage appropriate to the working voltage shall be applied before commissioning.

4.5 Test Methods

This policy includes both dc and ac test methods. A dc test is usually carried out using an insulation tester with the appropriate voltage output, such as a Megger or dc pressure test set. An ac test is usually carried out using an ac test set or test van to give the required voltage. Where both dc and ac tests are specified for equipment or cables either test may be used.

For cables it is necessary to apply the test voltage and allow the cable to fully charge up. Generally with test sets the timing begins when the set has reached the required voltage and for insulation resistance (IR) testers the time begins when the IR value has stabilised.

Also, with some newer IR test sets, the test is considered a pass if the cable remains at the specified voltage for the duration of one minute - the voltage will drop if the insulation breaks down during that time span.

Partial discharge testing methods are being developed and operational advice will need to be followed.

5 Cable Testing

5.1 New and Existing Cables up to and including 33kV

It is essential before energisation to ensure the cable is continuous from end to end. This will check that the cable is laid as planned and that any route joints have been completed.

These voltages can also be used for testing transformer tails between the winding and earth but see also section 7.1.

Table 1 shows the minimum voltages to be used. Voltages up to those mentioned in Table 2 are acceptable if site conditions require.

Table 1: Minimum test voltages for new and existing cables up to and including 33kV

Rated Line Voltage (kV)	Cable Type	DC Test ¹		Test Application
		Voltage (kV)	Duration (min)	
6.6 (2 & 3.3)	All Types	5	1	Test voltage applied to one phase with the other two phase connected to earth/metallic screen
11	All Types Note 1			
20 & 22	All Types			
33	All Types			

Notes:

1. Partial discharge mapping carried out in London, mainly at 11kV, is used as a commissioning test. These tests do require the test voltage to be of the order of $1.5U_0$ ac at 0.1Hz for a period of up to 15 minutes.

5.2 Acceptable IR Values

It is not possible to specify a lowest acceptable insulation resistance value for dc testing (as it depends on a number of factors including cable type/length, weather conditions, etc.) all three cores should be similar and a different value on one core would indicate a problem. The determining factor here will be whether any of the phases has an unacceptably low reading ($1M\Omega$) or a drastically different reading. Engineering judgement needs to be applied to the value obtained. If traditional fault location fails to indicate a fault then connecting the circuit to the network for a 24 hour soak test is acceptable. If customers will be affected by the fault occurring during this test the number of customers must be as low as reasonably practical.

5.3 Cable Fault Location up to 33kV

It is permissible to apply higher dc voltages for fault location up to the maximum shown in Table 2.

Table 2: Maximum voltage levels for fault location for cable up to and including 33kV

Rated Line Voltage (kV)	dc Test Voltage (kV) to Earth
6.6	7
11	12
20 & 22	24
33	36

5.4 Cable Over-sheath Tests – 11kV to 33kV Cables

The test voltages for over-sheath tests are given in Table 3. Tests are required for new cables (having an insulated sheath) prior to energisation. Also, when returning an insulated sheath cable to service following diversion or repair then a sheath test as shown in Table 3 is required.

Table 3: Cable over-sheath test voltages for cables up to 33kV

System Nominal Voltage (kV)	Minimum dc Test Voltage (kV) New cables	Minimum dc Test Voltage (kV) On return to service	Test Duration (min)	Maximum Leakage Current (mA)	Test Application
11	5	Not Applicable	1	10	Between metallic sheath and earth
20 & 22		5			
33		5			

Note - specially bonded cable circuits complying with the requirements of ENA ER C55/4 may require further tests in addition to the over-sheath tests above.

5.5 New and Existing Cables – 66kV and 132kV Oil and Gas Pressure Assisted Cables

It is essential before energisation to ensure the cable is continuous from end to end. This will check that the cable is laid as planned and that any route joints have been completed.

The cable shall withstand a dc test voltage of negative polarity applied between the conductor(s) and sheath with the sheath earthed.

Table 4 shows the minimum voltages to be used. No breakdown of the insulation shall occur.

Table 4: Minimum test voltages for new and existing fluid and gas filled 66kV and 132kV cables

Rated Line Voltage (kV)	dc Test Voltage for New Cable Systems (kV)	Minimum dc Test Voltage for Systems with old Cable (kV)	Duration (min)	Test Application
66	170	71	15	Test voltage applied to one phase with the other two phases connected to earth/metallic screen
132	305	130		

5.6 New and Existing Cables - 66kV and 132kV cables containing XLPE insulated Cable

It is essential before energisation to ensure the cable is continuous from end to end. This will check that the cable is laid as planned and that any route joints have been completed.

The cable shall withstand an ac test voltage applied between the conductor(s) and sheath with the sheath earthed. Where possible a Partial Discharge (PD) test shall be carried out during the ac test.

The test will normally be provided by a series resonant test set operating close to power frequency.

Table 5 shows the minimum voltages to be used. No breakdown of the insulation shall occur.

Table 5: Minimum test voltages for new 66kV and 132kV XLPE cables

Rated Line Voltage (kV)	Ac Test Voltage for New Cable Systems (kV)	Frequency (Hz)	Duration (min)
66	72	20 - 300	60
132	132		

If the cable system contains sections of existing fluid filled, gas filled or XLPE cable the test voltage should be reduced in line with table 6.

Table 6: Minimum test voltages for 66kV and 132kV Cable System containing existing sections of cable

Rated Line Voltage (kV)	Existing cable < 5 years old		Existing cable < 20 years old		Existing cable > 20 years old	
	ac Test Voltage (kV)	Duration (min)	ac Test Voltage (kV)	Duration (min)	ac Test Voltage (kV)	Duration (min)
66	72	60	61	60	54	60
132	132		114		95	

5.7 Cable Fault Location – 66kV and 132kV

It is permissible to apply higher dc voltages for fault location up to the maximum shown in Table 7.

Table 7: Maximum voltage levels for fault location for 66kV and 132kV Cable Systems

Rated Line Voltage (kV)	dc Test Voltage (kV) to Earth
66	50
132	50

5.8 Cable Over-sheath Tests – 66kV and 132kV Cables

The test voltages for over-sheath tests are given in Table 8. Tests are required for new cables (having an insulated sheath) prior to energisation. Also, when returning an insulated sheath cable to service following diversion or repair then a sheath test as shown in Table 8 is required.

Table 8: Cable over-sheath test voltages for cables - 66kV and 132kV

System Nominal Voltage (kV)	Minimum dc Test Voltage (kV) New cables	Minimum dc Test Voltage (kV) On return to service	Test Duration (min)	Maximum Leakage Current (mA)	Test Application
66	10	Not Applicable	1	10	Between metallic sheath and earth
132		5			

Note - specially bonded cable circuits complying with the requirements of ENA ER C55/4 may require further tests in addition to the over-sheath tests above.

5.9 Switchgear Associated with Cable Testing

It shall be established whether the switchgear is capable of withstanding the cable test voltage, otherwise, the least onerous test voltage shall be used.

Note: the specification for new switchgear ensures that all cable test access points will withstand the highest cable test voltages mentioned in this document.

6 Switchgear Testing

6.1 Test Voltages

6.1.1 New switchgear

The test voltages to be used for new switchgear are given in Table 9. These test voltages shall apply to:

- all extensible switchgear which incorporates site made high-voltage connections.
- any non-extensible switchgear where work has been done affecting the insulation.

For non-extensible switchgear at all voltages (including, for example, dead and live tank 132kV circuit-breakers) which has been factory tested, and on which no work has been done on the insulation a test voltage of 5kV dc shall be applied for one minute.

6.1.2 Existing switchgear

The test voltages to be used for existing switchgear are given in Table 10. These test voltages shall apply to:

- all switchgear where work has been done affecting the insulation.
- all switchgear which has been re-installed.

6.1.3 Application of test voltage

The test voltages shall be applied:

1. Between phases and phase to earth with the contacts closed:

Test voltage applied to	Earth applied to
L1 and L2	L3
L2 and L3	L1

2. Across the open contacts:

Test voltage applied to	Earth applied to
L1, L2 and L3	L1, L2 and L3 opposite contacts

If surge diverters, neutral voltage displacement (NVD), capacitor bushings, etc. cannot be disconnected then the manufacturer's advice should be obtained before proceeding.

Table 9: Test voltages for new extensible switchgear

Rated Line Voltage (kV)	Switchgear Rated Voltage	ac Test Voltage (kV)	Test Duration (min)
Up to 11kV	12kV	22 ¹	1
20/22	24kV	40 ¹	
33	36kV	56 ¹	
66	72.5kV	112 ¹	
132	145kV	220 ¹	

Table 10: Test voltages for existing switchgear

Rated Line Voltage (kV)	Switchgear Rated Voltage ³	ac Test Voltage (kV)	Test Duration (min)
Up to 6.6	7.2kV	10 ²	1
11	12kV other than above	16.5 ²	
20/22	24kV other than above	33 ²	
33	36kV	50 ²	
66 ³	72.5kV	99 ²	
132 ³	145kV	198 ²	

Notes:

1. The ac test voltage for new extensible switchgear is 80% of factory test and should also include a 5kV IR result both before and after the ac test.
2. The switchgear will withstand the full test voltage applied to new equipment but to reduce the stress for this and subsequent tests the test voltage for existing switchgear has been reduced to 1.5 times the line voltage.
3. See alternative soak test for 66kV and 132kV GIS switchgear.

6.2 Alternative Soak Test for 66kV and 132kV GIS Switchgear

An alternative regime for retesting, following an earlier full test, 66kV and 132kV GIS switchgear is to connect the switchgear to the network for a 24 hour period to soak test it rather than apply a voltage test.

This test has been approved because:

- The difficulty, expense and risk of providing full test voltage immediately prior to energisation.
- GIS equipment, connecting and disconnecting the test set involves work on the equipment; consequently the reconnection and re-gassing after removing the test set is not then tested.

This option is available to the SAP who will supervise the re-commissioning if:

- The switchgear is GIS, requiring opening of gas compartments for connecting and disconnecting the test connections.
- No external insulation has been disturbed in the parts being tested.
- The protection is arranged such that in the event of a fault on the equipment being tested no loss of supplies to customers shall occur.
- The system fault level is reduced to the lowest possible level and access to the plant under test is restricted.

6.3 Air Insulated Bus Bars and Disconnectors

Testing of air insulated bus bars, air break isolators or post insulators, etc. is not required by this policy providing a visual inspection is made prior to energisation.

7 Transformer Testing

The assembly of transformers, transport arrangements, quality controls during installation and sealing is such that high voltage insulation testing is generally unnecessary. Unless otherwise agreed with the manufacturer the only testing required for transformers (including pole-mounted) is insulation resistance testing using the test voltages given in Table 11. The insulation resistance shall be comparable with the original test documentation (if available). If, in order to test other equipment, it is necessary to apply a higher test voltage to the windings, then the voltages given in Table 12 should not be exceeded.

Table 11: Test voltages for transformers

Test	System Nominal Voltage (kV)	dc Test Voltage (kV)	Test Duration (min)	Test Application
Winding Insulation	Up to 6.6	1	1	Apply to each winding in turn with the other winding(s) earthed
	11			
	22			
	33	1 – 2.5 ¹		
	66	2.5		
	132			
Core Insulation	All	1	1	Core insulation should be clear of earth with core earth link removed and connected to earth after core earth link replaced

Notes: The test voltage specified in the manufacturers test documentation should be used.

Table 12: Maximum test voltages for transformers (for example where other equipment is connected)

System Nominal Voltage (kV)	DC Test Voltage (kV)	Test Duration (min)
6.6	6.6	1
11	11	
22	22	
33	33	
66	66	
66 (graded insulation)	30	
132 (graded insulation)	50	

If a higher test voltage is to be considered, the manufacturer should be consulted prior to testing.

7.1 Transformer Tails and Test Access

Where test access is available transformer tails must always be tested. Where test access requires the dismantlement of apparatus and the SAP considers the risk to personnel of gaining the test access is higher than the risk of failure then the test may be omitted. This will usually apply at 11kV primary substations where the cable tails are within the EDF Energy site and there is no reason to believe there has been any damage.

8 Overhead Line Testing

Insulation testing of overhead lines is not considered reasonably practicable. However, before commissioning, a visual inspection shall be made of new overhead lines and the modified parts of previously energised lines.

Also, before re-commissioning overhead lines that have been de-energised for an extended period of time, a risk assessment shall be made to decide if a visual inspection is required. This assessment shall take into account factors, such as the activity of third parties in the vicinity of the circuit and severe weather conditions.

9 Test Results

The results of the tests shall be recorded in the substation log book where available. Additionally the EDF Energy Commissioning Policy (EI 05-1001) provides guidance.