

<b>Unipetrol RPA, s.r.o.</b>	<b>Functional tests of medium (high) voltage cable lines up to 35kV</b>	N 11 018
LDS section		

The standard is binding on all departments of the company and on the external companies performing any activities on cabling, operator of which is Unipetrol RPA, within the Chempark Záluží premises. The standard does not apply to subsidiaries of UNIPETROL RPA s.r.o. including the Kralupy refinery branch. The departments are obliged to introduce this standard to all external companies which perform any works related to maintenance and repairs of cables and which are also bound by this standard.

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## 1 Purpose

To determine conditions for functional tests of medium (high) voltage power lines with cables with XLPE extruded insulation or PVC and impregnated paper insulation in three-phase medium (high) voltage cable network up to 35 kV in UNIPETROL RPA, s. r. o.

## 2 Scope of validity

This document applies to activities in the cable network of UNIPETROL RPA, s.r.o.

### 2.1 LDS UNIPETROL RPA, s. r. o.

- Employees of the LDS operator

### 2.2 Contractors providing activities on VETZ electro (designated el. equipment) based on respective Contract for Work

- Kabeex, s.r.o.
- Bilfinger Euromont, a.s.
- Inelsev, s.r.o.
- Contractor selected for investment activities.

## 3 Terms, definitions, abbreviations

SLDS	Section of Local distribution system (LDS operator)
LDS	Local distribution system of UNIPETROL RPA, s.r.o. Litvínov
LDS operator	In UNIPETROL RPA, s.r.o. pursuant to the Act No. 458/2000 Coll. assigned employee (PLDS) responsible for the LDS operation – employee of LDS section assigned for ensuring operation and attendance and other activities stipulated through this Act
vn	medium (high) voltage

## 4 Types of cable line tests

### 4.1 Functional test

Functional test of cable line after assembly, after repair, after decommissioning of cables, after operational ageing of insulation (preventive diagnostics), when commissioning new cable lines in order to check its operating abilities.

### 4.2 Diagnostics

The non-destructive method for assessment of cable insulation condition, where the value of insulation physical parameters measured are the information carriers regarding the insulation condition.

<b>Title</b>	<b>Description</b>	<b>Evaluation</b>	<b>Conditions</b>
<b>Sheathing test</b>	This is a check of quality of cable line (PVC insulated cables) laying – check of outer sheathing intactness. It is carried out using the DC voltage between the metal shielding of the cable (disconnected from earthing on both ends) and earthing of the substation or the earthing tape. It is carried out before connection to other construction types of cable lines. This is a destructive method that enables temporary operation of the tested cable, even in case of negative result. In case of cable laid in air (laying in collectors, on cable trays, as suspended cable) the sheathing test is not applied.	Basic criterion for evaluation is the ability of the cable to withstand voltage stress without dielectric breakdown for the whole period of the test. Additional criterion is the leakage current value and change in the current value in the course of the test.	Insulation condition of sheathing may be test only what concerns buried cable and covered at least in the sand bed. The test is conditioned with the possibility to disconnect the cable shielding from the ground connection.
<b>AC (50 Hz) voltage test of insulation</b>	This is a check of cable insulation strength and cable fitting strength. It is carried out using the AC voltage 50 Hz between the phase and the metal shielding or the sheathing (or connected to the substation earthing). This is a destructive method that does not enable further operation of the cable, in case of negative result, without repair.	Basic criterion for evaluation is the ability of the cable to withstand voltage stress without dielectric breakdown for the whole period of the test.	
<b>AC (VLF) voltage test of insulation</b>	This is a check of cable insulation strength and cable fitting strength. It is carried out using the AC voltage of very low frequency (VLF) 0,1 Hz between the phase and the metal shielding or the sheathing (or connected to the substation earthing). This is a destructive method that does not enable further operation of the cable, in case of negative result, without repair.	Basic criterion for evaluation is the ability of the cable to withstand voltage stress without dielectric breakdown for the whole period of the test. Additional criterion is the leakage current value and change in the current value in the course of the test.	
<b>DC voltage test of insulation</b>	This is a check of cable insulation strength and cable fitting strength. It is carried out using the DC voltage between the phase and the metal shielding or the sheathing (or connected to the substation earthing). This is a destructive method that does not enable further operation of the cable, in case of negative result, without repair.	Basic criterion for evaluation is the ability of the cable to withstand voltage stress without dielectric breakdown for the	

		whole period of the test. Additional criterion is the leakage current value and change in the current value in the course of the test.	
<b>Local diagnostics</b>	Quality of insulation and assembly of cable sets is verified by a diagnostics test of partial discharges. This is determination of local points of the cable line where partial discharges may occur – local criterion.	Based upon results from the measurement and diagnostics systems	Ability to calibrate the measurement systems based on composition of the cable route
<b>Integral diagnostics</b>	This is a complex assessment of overall condition of the cable line – leakage factor value $\text{tg } \delta$ , residual breakdown strength, water content, etc. – integral criterion.	Based upon results from the measurement and diagnostics systems	Ability to calibrate the measurement systems based on composition of the cable route

### 4.3 Example of basic voltage levels used for cable network diagnostics:

Table 2 defines requirements for functional tests of medium (high) voltage cable lines for rated AC voltage levels: 1,73/3(3,6) kV, 3,46/6(7,2) kV, 6/10(12) kV; 12,7/22(25) kV; 20/35(40,5) kV in the distribution network.

Values of AC and DC test voltage of insulation are defined as multiple of the rated phase voltage  $U_0$ . Values of AC, pulse and DC voltage were taken from DIN VDE 0276-1001.

The value of DC voltage for repeated tests of cables with impregnated paper insulation was set on the basis of the operating experience of the distribution system operators in the Czech republic.

For AC tests with voltage of 0,1 Hz, voltage shape is not taken into consideration (sinusoidal or cosine)

Rated voltage of the cable and conductor is the operating voltage the cable was designed for, the cable is labelled with and that serves for definition of the el. testing. Rated voltage is shown as a fraction of two values  $U_0 / U$  ( $U_m$ ) expressed in kV.

For example:  $U_0 / U$  ( $U_m$ ) - 3,46/6 (7,2)

$U_0$  is effective value of voltage between any insulated core and „earth“,  $U_0 = 3,46$  kV

$U$  is effective value of voltage between any two phase cores of multi-core cable or conductor,  $U = 6,0$  kV

$U_m$  is effective value of the highest voltage of the grid, in which the device may be used,  $U_m = 7,2$  kV

When using the cable or conductor in the AC grid, the rated voltage of the cable must be higher than or equal to rated voltage of the grid.

The manufacturer shall take these values to its TP or company standard and demonstrates these abilities in scope of the tests mentioned herein.

### 4.4 Rated voltage of insulated conductors and cables of medium (high) voltage:

The cables are intended for rated AC voltage levels: 6/10 kV; 12,7/22 kV; 20/35 kV. It must comply with the requirements of ČSN EN 60071-1 and ČSN EN IEC 60071-2 ed. 2.

The cables must be capable of permanent work under the highest voltage as per ČSN EN 60038 Rated voltage CENELEC.

**Tab. 1 Table of voltage levels up to 35 kV**

Voltage level	$U_0$	$U$	$U_m$
3 kV	1,73 kV	3 kV	3,6 kV
6 kV	3,46 kV	6 kV	7,2 kV
10 kV	6k V	10 kV	12 kV
22 kV	12,7 kV	22 kV	25 kV
35 kV	20 kV	35 kV	38,5 kV

**Tab. 2 Table of values of functional tests for medium (high) voltage cable lines up to 35 kV**

The table determines minimum values of voltage and duration of the test. Application of individual methods depends on the type of cable line as per the chapter „ Scope of functional tests as per the cable line type“

	Type of test	Voltage	Duration	Requirement
1	PE sheathing test	5 kV DC	5 minutes	Without breakdown, Leakage current < 2 mA/1km
2	PVC sheathing test	3 kV DC	5 minutes	Without breakdown, Leakage current < 2 mA/1km
3	AC voltage test of insulation	$2U_0$ 50 Hz	60 minutes	Without breakdown,
4	AC VLF voltage test of insulation	$3U_0$ 0,1 Hz	60 minutes	Without breakdown,
5	DC voltage test of insulation	$4U_0$	10 minutes	Without breakdown,
6	Local diagnostics – diagnostics of partial discharges	$1,7U_0$	-	Without concentration of partial discharge <sup>1)</sup>
7	Integral diagnostics	As per the type of testing method <sup>2)</sup>	-	As per the type of applied diagnostics

<sup>1)</sup> without exceeding the limit values determined by the measurement device manufacturer or as per limits defined by the DS operator.

<sup>2)</sup> Values from several volts in case of relaxation methods up to  $2U_0$  in case of tangent delta measurement.

In case the cable finishes in a metal-clad switchgear and may not be disconnected, it is necessary to respect the test voltage prescribed by the equipment manufacturer, in case its value is lower than the values in table 2.

**Tab. 3 Voltage levels used for localization of cable failures**

	<b>Type of voltage used</b>	<b>Voltage value</b>
1	DC voltage	$\leq 8 U_0$ *)
2	AC voltage 50 Hz	$\leq 2 U_0$
3	Impulse voltage (e.g. impulse generator)	$\leq 8 U_0$

\*) In case the DC voltage is used for localization of the cable line failures with already operated XLPE cables, it is necessary to select the lowest possible value.

#### 4.5 Scope of functional tests as per the cable line type

Type of cable line	Types of applicable tests
<b>PVC insulated cables</b>	<p>Condition of insulation and quality of cable and cable set assembly is verified by local diagnostics – measurement of partial discharges and sheathing test.</p> <p>What concerns this cable type, the local diagnostics – measurement of partial discharges may be replaced with the AC voltage test of insulation 50 Hz or VLF 0,1 Hz.</p> <p>It is advised to start testing of the cable line with the sheathing test. In case the sheathing test fails, it is necessary to remove the sheathing failure first and then repeat the test again. Only after the cable passes the sheathing test, the insulation testing may proceed.</p> <p>What concerns reconstructions of sections of existing cable lines, the sheathing test is always carried out before connection to the old section of the cable.</p> <p>What concerns sheathing test for combined PE+PVC sheathing, the values for PVC sheathing shall be used.</p> <p>What concerns PVC insulated cables, it is advised to use the combination of the sheathing test + diagnostics of partial discharges as a non-destructive method with higher informative value and exact localization of assembly defects.</p> <p>It is appropriate to detect overall condition and ageing of insulation by one of the integral methods – Tangent delta, recovery voltage and currents, frequency spectroscopy. etc.</p> <p>DC voltage test of insulation may be used in exceptional cases only, when none of the above mentioned tests may be applied.</p> <p><b>Not recommended for PVC insulated cables!</b></p>
<b>Cables with impregnated paper insulation</b>	<p>Condition of insulation and quality of cable and cable set assembly is verified by AC voltage test of insulation 50 Hz, AC voltage test of insulation VLF 0,1 Hz or in exceptional cases by DC voltage test of insulation.</p> <p>Condition of insulation may also be verified by local diagnostics – measurement of partial discharges in combination with one of the integral methods.</p> <p>In order to ascertain operating ageing of insulation, it is recommended to carry out local diagnostics - measurement of partial discharges in combination with one of the integral methods (preventive diagnostics).</p>
<b>Mixed cable lines</b>	<p>Condition of insulation and quality of cable and cable set assembly is verified by AC voltage test of insulation 50 Hz, AC voltage test of insulation VLF 0,1 Hz or in exceptional cases by DC voltage test of insulation.</p> <p>Condition of insulation may also be verified by local diagnostics – measurement of partial discharges in combination with one of the integral methods. It should be noted that the values of partial discharges in the parts with impregnated paper insulation may be of higher order than in the part with PVC insulation and therefore the defects in the PVC part may be undetectable</p> <p>What concerns newly established mixed cable lines, it is recommended to initiate the tests with a sheathing test of the new part of the PVC insulated cable always before connection to the old section of the cable. If the sheathing test fails, it is necessary to remove the sheathing failure first and then repeat the test again.</p> <p>What concerns sheathing test for combined PE+PVC sheathing, the values for PVC sheathing shall be used.</p> <p>In order to ascertain operating ageing of insulation, it is recommended to carry out local diagnostics - measurement of partial discharges in combination with one of the integral methods (preventive diagnostics).</p>

Applicability of individual methods depends on possibilities of the measurement device and possibility to calibrate the device for the specific cable route (cable routes combined from many types of cable, limit operating parameters).

#### 4.6 Cable tests as per type of tested cable line

<p><b>1. PVC insulated cable lines before first commissioning</b></p>	<p>1.1. Condition of insulation and quality of cable and cable set assembly is tested by a method of partial discharges, sheathing test of insulation condition using DC voltage 5 kV for the period of 5 minutes, for new lines the insulation resistance must be higher than 2,5 MΩ /km i.e. leakage current lower than 2 mA/km.</p> <p>1.2. Carry out voltage test by increased test voltage AC, VLF or DC as per table 2 or by the method for partial discharge measurement</p> <p>1.3. The DC sheathing test of insulation condition using must always be carried out as per point 1.1, this test replaces even test of insulation condition listed in the previous paragraphs, in case it is not possible to carry out the test from the time, capacity or technical reasons.</p> <p>1.4. Measurement of electrical length is also a part of the test. The electrical length is recorded in the Protocol on Medium (high) voltage test.</p>
<p><b>2. PVC insulated cable lines established as a modification of existing grid</b></p>	<p>2.1. These cable lines are created by looping or extension of already operated cables with PVC insulation with new PVC insulated cables.</p> <p>2.2. This type of cables is tested as per point 1.1 , see above.</p>
<p><b>3. Combined PVC insulated cable lines established as a modification of existing grid</b></p>	<p>3.1. Combined cable lines are such lines where the cables with impregnated paper insulation are extended with PVC insulated cables.</p> <p>3.2. This type of cables is tested by AC VLF test voltage as per table 2 for the period of min. 60 minutes.</p> <p>3.3. In case the AC VLF voltage test cannot be carried out, these cables may be also tested with adequate DC test voltage as per table 2. For the period of min. 10 minutes.</p> <p>3.4. The DC sheathing test of insulation condition using must always be carried out as per point 1.1, this test replaces even test of insulation condition listed in the previous paragraphs, in case it is not possible to carry out the test from the time, capacity or technical reasons.</p> <p>3.5. Measurement of electrical length is also a part of the test. The electrical length is recorded in the Protocol on Medium (high) voltage test.</p>
<p><b>4. PVC insulated cable lines after executed repair</b></p>	<p>4.1. Condition of insulation and quality of cable and cable set assembly is tested by a method of partial discharges, sheathing test of insulation condition using DC voltage 5 kV for the period of 5 minutes, for new lines the insulation resistance must be higher than 2,5 MΩ /km i.e. leakage current lower than 2 mA/km.</p> <p>4.2. This type of cables is tested by AC VLF test voltage as per table 2 for the period of min. 60 minutes.</p> <p>4.3. In case the AC VLF voltage test cannot be carried out, these cables may be also tested with adequate DC test voltage as per table 2. For the period of min. 10 minutes.</p>
<p><b>5. Combined cable lines and with paper insulation after executed repair</b></p>	<p>5.1. Condition of insulation and quality of cable and cable set assembly is tested by a method of partial discharges, sheathing test of insulation condition using DC voltage 5 kV for the period of 5 minutes, for new lines the insulation resistance must be higher than 2,5 MΩ /km i.e. leakage current lower than 2 mA/km.</p> <p>5.2. This type of cables is tested by AC VLF test voltage as per table 2 for the period of min. 60 minutes.</p> <p>5.3. In case the AC VLF voltage test cannot be carried out, these cables may be also tested with adequate DC test voltage as per table 2. for</p>



	<p>the period of min. 10 minutes,</p> <p>5.4. What concerns cable lines, where neither ageing nor type of cable may be defined, it is proceeded as for cables with paper insulation, i.e. DC voltage insulation test is carried out as per table 2. For the period of 10 minutes or by AC voltage as per table 2. for the period of 60 minutes.</p>
<b>6. Informative test</b>	<p>6.1. Informative test of cable line is a test of cable which was out of order, but did not display any failure condition, e.g. cables disconnected due to safety reasons or due to transformer station failure, distribution system. Before the cable is connected to the grid, this test verifies whether the cable was not damaged during its disconnection, e.g. by unauthorized intervention.</p> <p>6.2. Informative test of cable line is carried out by a DC voltage as per table 2. for the period of 1 minute after leakage current stabilization or by AC VLF voltage as per 2. for the period of 10 minutes.</p> <p>6.3. In case the AC voltage test cannot be carried out, these cables may be also tested with adequate DC test voltage as per table 2. For the period of min. 10 minutes</p>

## 5 List of related documents

- ČSN 34 7405 ed.2 Distribution cables with extruded insulation for rated voltages from 3,6/6 (7,2) kV up to and including 20,8/36 (42) kV (HD 620.S2)
- PNE 34 7626 ed.2 Functional tests of medium (high) voltage cable lines up to 35 kV
- ČSN EN 60060-1 High-voltage test techniques. Part 1, General definitions and test requirements
- ČSN EN 60071-1 ed.2 Insulation co-ordination. Part 1, Definitions, principles and rules
- ČSN EN 60270 +A1 High-voltage test techniques - Partial discharge measurements

### Related foreign standards

- DIN VDE 0276-1001 Starkstromkabel. Teil 1001: Prüfungen an verlegten Kabeln
- DIN VDE 0276 part 620
- DIN VDE 0276 part 621