Designing and Implementation a Lab Testing Method for Power Cables Insulation Resistance According with STAS 10411-89, SR EN ISO/CEI/17025/2005

R Dobra1*, D Pasculescu2, G. Marc1, M Risteiu1 and A Antonov3
1Department of Computer Science, "1 Decembrie 1918" University Alba-Iulia, Gabriel Bethlen Str., No.5, 510009 Alba Iulia, Romania
2Department of Computers and Power Engineering, University of Petrosani, 20 Universitatii str, Petrosani, România
3Electrical and Mechanical Risks Laboratory, National Research and Development Institute for Labor Protection “Alexandru Darabont”, Bucharest, Blvd. Ghencea no. 35A, district 6, Romania
E-mail: remusdobra@upet.ro

Abstract. Insulation resistance measurement is one of the most important tests required by standards and regulations in terms of electrical safety. Why these tests are is to prevent possible accidents caused by electric shock, damage to equipment or outbreak of fire in normal operating conditions of electrical cables. The insulation resistance experiment refers to the testing of electrical cable insulation, which has a measured resistance that must be below the imposed regulations. Using a microcontroller system data regarding the insulation resistance of the power cables is acquired and with SCADA software the test results are displayed.

1. Introduction
Measurement of insulation resistance is one of the most important tests required by standards and norms in terms of electrical safety. The reason these tests are done is to prevent accidents caused by electric shock, damage to equipment or fire in normal operation of electrical cables. In time resistance testing, test voltage remains constant, and resistance values increase over time if insulation is good. The Fluke 1550 C has an internal timer that allows a constant test voltage (500 V, 1 kV, 2.5 kV or 5 kV) to be applied for up to 99 minutes, although 10 minutes or less is the typical value [1, 3].

Standard time resistance tests include polarization and dielectric absorption index tests. Despite the "pretentious" terms, the tests themselves are quite simple. The dielectric absorption test compares the values of two resistance readings, such as a reading of 60 seconds and one to 30 seconds. The higher the rate the better the insulation. In general, a ratio greater than 1.4 to 1.6 indicates good insulation. The polarization index test is the same as the 1 minute and 10 minute test. The resistance at 10 minutes is divided by the resistance of 1 minute. Indicators from 2 to 4 or more indicate good insulation. The polarization index test can be performed on new equipment to establish a base value and then periodically to predict when the equipment starts to fail. If the index decreases over time, it means that isolation deteriorates.
2. Technical safety requirements for mine electric cables and their accessories

Taking into consideration the mechanical stresses in the mining industry (dynamic and static crushing, simultaneous torsion and flexion, alternate torsion and flexion), the flexible mine electric cables with natural or synthetic rubber insulation, as well as the mine armored cables with polyethylene or PVC insulation and PVC sheath, intended for use in electric installations and equipment for powering, signaling, telecommunications and telemechanic, in the underground and quarries mine workings have to assure a strength appropriate to these stresses. If for the electric and non-electric equipment or components and protective components used in areas with explosion hazards specific types of protection had been designed according to the dangerous zone the equipment is intended to be used and to the chosen category of equipment, in the case of electric cables especially in large electric networks where particularly dangerous short-circuits may occur, since short-circuits develop heat, electric arcs, and metallic droplets that may represent an imminent danger of occurrence of unwanted events: fires or explosions and environment pollution [3,5].

There are two different approaches related to mechanical influences of insulation characteristics of the electrical power cables:

- Structural integrity analysis
- Dielectric strengths of the insulation materials

E. David, in its paper [2] proves and describes the elastic motion of the power cable insulation materials when it is “activated” by the mechanical stress. It is generally accepted that electrical performances of the insulation materials that composes the power cables are influenced by the mechanical stress.

On the other hand, the literature [1] offers values for dielectric strength of insulating materials, relative to nitrogen, unless units of kV/mm are indicated.

Both aspects are subject of our paper research: to prove the variation of the material insulation capabilities when different mechanical efforts are applied to the power cables.

3. The standardization testing method for cables insulation resistance

When tested for the resistance to flame propagation, in accordance with SR EN 60332-1-1:2005 and SR EN 60332-1-2:2005, the insulated conductor or the cable successfully passes the resistance to flame propagation or increased resistance to flame propagation if the distance between the lower edge of the upper support and the limit of the carbonized zone is higher than 50 mm, and in the case when the carbonized area spreads down on a length higher than 540 mm starting from the lower limit of the upper support, then the test is considered to be failed and as consequence the cables are not allowed to be used in the underground of firedamp mines, non-firedamp mines or quarries. In order to perform these tests, in the ENExEMEIP laboratory had been conceived and carried out test stands with software interface for control of the test cycles of static and dynamic stresses [5,6,7].

According with invoked standards [3,4] three mechanical tested are proceeded:
Squash test
There is a squashing force two (F) that acts over an impressive area (I) (see next figure): is carried out by means of a rig provided with a ram weighing 20 ± 1kg, falling upon the test sample, which is placed on a 80 mm diameter CopperZinc cylinder

![Figure 2](image.png)

Figure 2. The static crushing test

Torsion test
There are two contrary torsion (T, -T) torques that act over an impressive area (I) (see next figure):

![Figure 3](image.png)

Figure 3. The simultaneous torsion and flexion test.

Shear test
There are two contrary forces (F, -F) that act over an impressive area (I) (see next figure)

![Figure 4](image.png)

Figure 4. The dynamic crushing test.

4. Test of mine electric cables and their accessories
The simultaneous torsion and flexion test is performed with the apparatus and according to the main assembly diagram shown in figure 5. For the needs of ensuring the rotary and translation motions for the cable samples submitted to this test the rig in figure 4 had been designed. The rig ensures through its translation device, a number of 7...8 coming and going cycles with the speed of 20...30 m/min, and through its torsion device at each cycle 3 rotations (6π radians) on one side and 3 rotations (6π radians) on the other side are generated.

The distance between sample the locking devices, in their wide spaced position shall be 2.5 m, and the stroke length of the translation motion shall be 1.5 m. The test samples locked in these locking devices is connected to the control apparatus. The system monitors and acquisition the following parameters:
- the insulation resistance in order to detect the insulation flaws
- the currents on the three phases in order to detect short-circuits or splitting of conductors inside the cable
- the number of strikes in case of dynamic crushing or the number of twists in case of torsion test
- the pressure applied in case of static crushing test.
The current on its three phases R, S, T is measured by means of current transformers. This current in case of normal operation without faults is identical for each of the three phases. The current increases when a short-circuit occurs and decreases when a phase is split.

**Figure 5.** Laboratory testing method for power cables.

A IRDH 375 isometric model was used at the test bench. It is designed to monitor the insulation resistance of the main circuits (AC, AC / DC 0 ÷ 793V and DC 0 ÷ 650). Standard time resistance tests include polarization and dielectric absorption index tests. Despite the "pretentious" terms, the tests themselves are quite simple [8].

**Figure 6.** The control system for the testing cycles in the dynamic and static crushing tests.

The dielectric absorption test compares the values of two resistance readings, such as a reading of 60 seconds and one to 30 seconds. The higher the rate the better the insulation. In general, a ratio greater than 1.4 to 1.6 indicates good insulation. The polarization index test is the same as the 1 minute and 10 minute test. The resistance at 10 minutes is divided by the resistance of 1 minute. Indicators from 2 to 4 or more indicate good insulation.

The polarization index test can be performed on new equipment to establish a base value and then periodically to predict when the equipment starts to fail. If the index decreases over time, it means that isolation deteriorates. Note that the polarization index is a ratio, not an absolute value. Taking the reports from two tests done under the same conditions, cancel the temperature and humidity variables.
5. Software testing method for power cables insulation resistance

The insulation resistance is permanently monitored and in case an insulation fault occurs, a signal is transmitted to the data acquisition unit, in order to stop the test. The electric cable network in underground are carried out with mine electric cables that, together with the assembly of electric equipment and device in the electromechanical installations, have the role of ensuring protection against electrocution, fire and/or explosion hazards.

![Data acquisition software for testing electrical power cables.](image)

Figure 7. Data acquisition software for testing electrical power cables.

On this interface are monitored currents on the three phases of the test conductor, the insulation resistance and the pressure applied by the crushing piston on the conductor, at the bottom there is a graph showing all parameters monitored along with the time at which the cable testing was performed.

An electric signal is taken over from a digital numerator and then recorded together with the other data for setting out the number of rotations or twists up to occurrence of fault. The pressure applied to the dynamic crushing test stand is displayed and monitored by a digital manometer that transmits the data to the data acquisition unit, through the multiplexor.

The program is made in the WinTR software, it can be configured as a web server facilitating the access from the Ethernet network of another operator that can track the execution of the test in real time, the server is redundant, can send messages to the address Email, GSM or Skype network, the customer, operator or service staff can receive messages about the test result, problems with the operation of the equipment.

In laboratory was test some different power cables. One example is presented below:

**Cable type:** 3x35+3x16/3E

*The cable consists of:* 3 phase active conductors with 36.04 mm² section isolated in rubber; the earthing conductor (special grounding) with 37.08 mm² section is distributed concentrically around each active phase; the red rubber outer jacket is embossed: CMCCGCEF - 3x35 + 3x16 / 3E - 6kV ICME ECAB S.A. 2003

Dimensional measurements:
- Average outside diameter of the cable sample: 52.26 mm;
- Average thickness of outer shell 7.02 mm;
- Protective conductor (special earthing) is formed 63 tiles of copper tin with φ 0.5 mm and the total section 37.08 mm²;
- Phase active conductors are made up of 7 bundles of 39 tinned copper wires with φ 0.41 mm with 36.04 mm² section insulated into rubber of the same color each: brown;
- Average insulation thickness 4.63 mm
From the last point of application of the force, a cable end was made to more than 200 mm and the first series (j = 1) of consecutive kicks was applied to the occurrence of insulation faults, phases or short circuits. In 4 different places spaced at approx. 200 mm was applied a series of strokes. The results for the 5 requests are as follows:
- strain in the first hitting place (j =1): number of hits until an insulation fault occurs: n11 = 144; number of hits until a phase is interrupted: n21 = 204;
- strain in the second hitting place (j =2): number of hits until an insulation fault occurs n12 = 150; number of hits until a phase is interrupted n22 = 180;
- strain in the third hitting place (j =3): number of hits until an insulation fault occurs n13 = 120; number of hits until a phase is interrupted n23 = 162;
- strain in the fourth hitting place (j =4): number of hits until an insulation fault occurs n14 = 147; number of hits until a phase is interrupted n24 = 202;
- strain in the fifth hitting place (j =5): number of hits until an insulation fault occurs n15 = 149; number of hits until a phase is interrupted n25 = 198;

Disconnection preventive factor: 
\[ k = \frac{\sum_{j=1}^{5} n_{1j}}{\sum_{j=1}^{5} n_{2j}} = \frac{710}{946} = 0.751 \]  

6. Conclusions

The electric cable network in underground are carried out with mine electric cables that, together with the assembly of electric equipment and device in the electromechanical installations, have the role of ensuring protection against electrocution, fire and/or explosion hazards.

The safety specific technical requirements for mine cable are not regulated at international level, such as each country applies its own national regulations / standards. In Romania the requirements in STAS 10 411 apply. In order to successfully pass the above mentioned tests, the electric power cables as well as the signaling and control cables used in underground mine workings, along with being manufactured with materials adequate from a point of view of their mechanical, thermal, electric characteristics and flame, the cables shall have a proper constructional form with a special protective conductor, designed for connection to earth in the general network.

References

[1] HG nr. 1049 / 2006 Regarding the minimum requirements for ensuring the safety and health of workers in surface or underground mining
[2] David E, Parpal J L and Crine J P 1994 - Influence of mechanical strain and stress on the electrical performance of XLPE cable insulation Proceedings of IEEE International Symposium on Electrical Insulation Proceeding
[3] STAS 10411-89: Electrical cables for mining purposes. Test methods
[4] SR 11388, 2000: Common test methods for electric cables an conductors
[5] SR HD 629.1 S2, 2006: Test requirements on accessories for use on power cables of rated voltage from 3,6/6(7,2) kV up to 20,8/36(42) kV. Part 1: Cables with extruded insulation
[6] SR EN 60332 - 1-2: 2005, Tests on electric and optical fiber cables under fire conditions. Part 1-2: Test for vertical flame propagation for a single insulated wire or cable. Procedure for 1kW pre-mixed flame
[7] SR EN 60332 - 1-1: 2005 - Tests on electric and optical fiber cables under fire conditions. Part 1-1: Test for vertical flame propagation for a single insulated wire or cable. Apparatus
[8] SR EN 60332 - 2-1: 2005: Tests on electric and optical fiber cables under fire conditions. Part 2-1: Test for vertical flame propagation for a single small insulated wire or cable