MEĐUNARODNO REGIONALNO SAVETOVANJE O ELEKTRODISTRIBUTIVNIM MREŽAMA

REGIONAL CONFERENCE AND EXHIBITION ON ELECTRICITY DISTRIBUTION

Crna Gora, Herceg Novi, 5 - 8. oktobar 2004. / ***Montenegro, Herceg Novi, October 5 - 8, 2004***

*** ***

TESTING OF HIGH-VOLTAGE CABLE ACCESSORIES

M. Sredojevic, Electrical Engineering Institute “Nikola Tesla“, Serbia and Montenegro
P. Vukelja, Electrical Engineering Institute “Nikola Tesla”, Serbia and Montenegro
J. Mrvic, Electrical Engineering Institute “Nikola Tesla”, Serbia and Montenegro
D. Hrvic, Electrical Engineering Institute “Nikola Tesla”, Serbia and Montenegro

ABSTRACT

In the paper are described type tests of high-voltage cable accessories in the high-voltage laboratory. The equipment for these tests and the circuit-diagram according to which long-term thermal cyclic tests at elevated temperature are carried out is presented. A brief description of the course and results of tests on cable accessories foreseen for 10 kV network is given. The tests were performed in the high-voltage laboratory of Electrical Engineering Institute “Nikola Tesla”.

1. INTRODUCTION

The 10 kV, 20 kV and 35 kV cable networks are spread more and more, and therefore the need for cable accessories is increased (cable terminations and joints). Besides, the number of failures is increased in those cable networks which are already for a long time in exploitation, and for that reason also the need for cable joints in the first place is increased. In the last few years new manufacturers of cable terminations and joints have appeared. Like any other equipment, cable terminations and joints shall pass type tests required by regulations. In this paper the equipment as well as test procedure for testing cable accessories is described. Furthermore a part of the type tests on cable terminations and joints foreseen for 10 kV networks, which were performed in the high-voltage laboratory of Electrical Engineering Institute “Nikola Tesla” is presented.

M.Sredojevic, Electrical Engineering Institute “Nikola Tesla”, Koste Glavinica 8a, 11000 Belgrade, Serbia&Montenegro, email: dehrvic@ieent.org, fax +381-11-3690823, phone: +381-11-3691447

2. TYPE TESTS

According to CENELEC standard (1), for cable terminations for indoor installation of cable lines with oil-impregnated paper insulation the following type tests are foreseen and according to required sequence:

a) DC withstand voltage tests, at 6 U_o for 15 minutes,

b) power-frequency withstand voltage tests, at 4.5 U_o for 5 minutes,

c) impulse withstand voltage tests, with 10 impulses of each polarity,

d) cyclic tests at elevated temperature in air, with 126 cycles (5 hours of heating with current and 3 hours of cooling) at 1.5 U_o power-frequency voltage,

e) power-frequency withstand voltage tests at 3 U_o for 4 hours,

f) dynamic short-circuit tests,

g) thermal short-circuit tests,

h) impulse withstand voltage tests with 10 impulses of each polarity,

i) power-frequency, withstand voltage test at 2,5 U_o, for 15 minutes.

The U_o voltage is 6 kV for 10 kV network, 12 kV for 20 kV network and 21 kV for 35 kV network.

Similar tests in compliance with (1) are foreseen also for cable joints, but thermal cyclic tests are performed in air and also in water. From 126 thermal cycles, 63 cycles are performed with joints under water. Also, the tests with power-frequency voltage at 3 U_o (for 4 hours point “e” in tests sequence) are performed with joints under water.

When testing cable terminations for outdoor application according to (1) in the previously presented test sequence for cable terminations for indoor application, the following tests are inserted:

- between “b” and “c” – tests with power-frequency voltage, 1 min. at 4 U_o in rain,
- between “d” and “e” – testing with 10 cycles under water.

According to the IEC standard for cable terminations and joints, similar tests are to be carried out and in the same sequence as in the standard (1). Significant difference exists in the number of thermal cycles. For cable terminations, instead of 126 thermal cycles, 63 thermal cycles have to be performed. For cable joints instead of 63 thermal cycles in the air, only 3 cycles have to be performed. For cable terminations as well as for cable joints, after thermal cycles according to standard (3) power-frequency voltage tests at 3 U_o, for 4 hours are not performed, as it is foreseen in the test sequence of the standard (1).

Comparison of standards (1) and (3) shows that more severe tests of cable terminations and joints are defined in the standard (1).

3. TEST EQUIPMENT

Type tests of cable terminations and joints, as presented in part 2, consist from: voltage tests, tests related to heating and short-circuit tests. For all these tests it is necessary to have different testing and measuring equipment in disposition. For voltage test are required: alternating voltage source, direct voltage source, and impulse voltage generator, as well as voltage dividers and oscilloscopes. For tests with 126 thermal cycles (tests “d” in part 2) it is necessary to form the test circuit containing the prescribed number of cable terminations and joints. In the circuit shall flow the corresponding current, and in the same time the conductors shall be subjected to adequate test voltage. Short-circuit tests require a strong power source.

In the high-voltage laboratory of Institute “Nikola Tesla” already existed adequate testing and measuring equipment for all voltage tests of cable terminations and joints for the networks up to 35 kV. However, long-term tests with cyclic heating required specific equipment – special measuring current transformers and appropriate measuring voltage transformers.

This equipment has been supplied. One-pole diagram of the test circuit for testing cable terminations and joints with thermal cycles is presented in fig. 1. On the primary winding (PN) of the special current transformer (SST), wounded on its magnetic circuit (MK), voltage is applied. Current (I_p) is established in it, and in the inductive manner current (I_s) is established in the short-circuited secondary winding. Secondary winding is mono-phase cable conductor passing through the aperture of the magnetic circuit SST and short-circuited through cable terminations and joints. In fact, it is test circuit on whose conductor, during long-term tests with thermal cycles the voltage of 1.5 U_o is applied permanently.

4. TESTING OF CABLE TERMINATION AND JOINTS

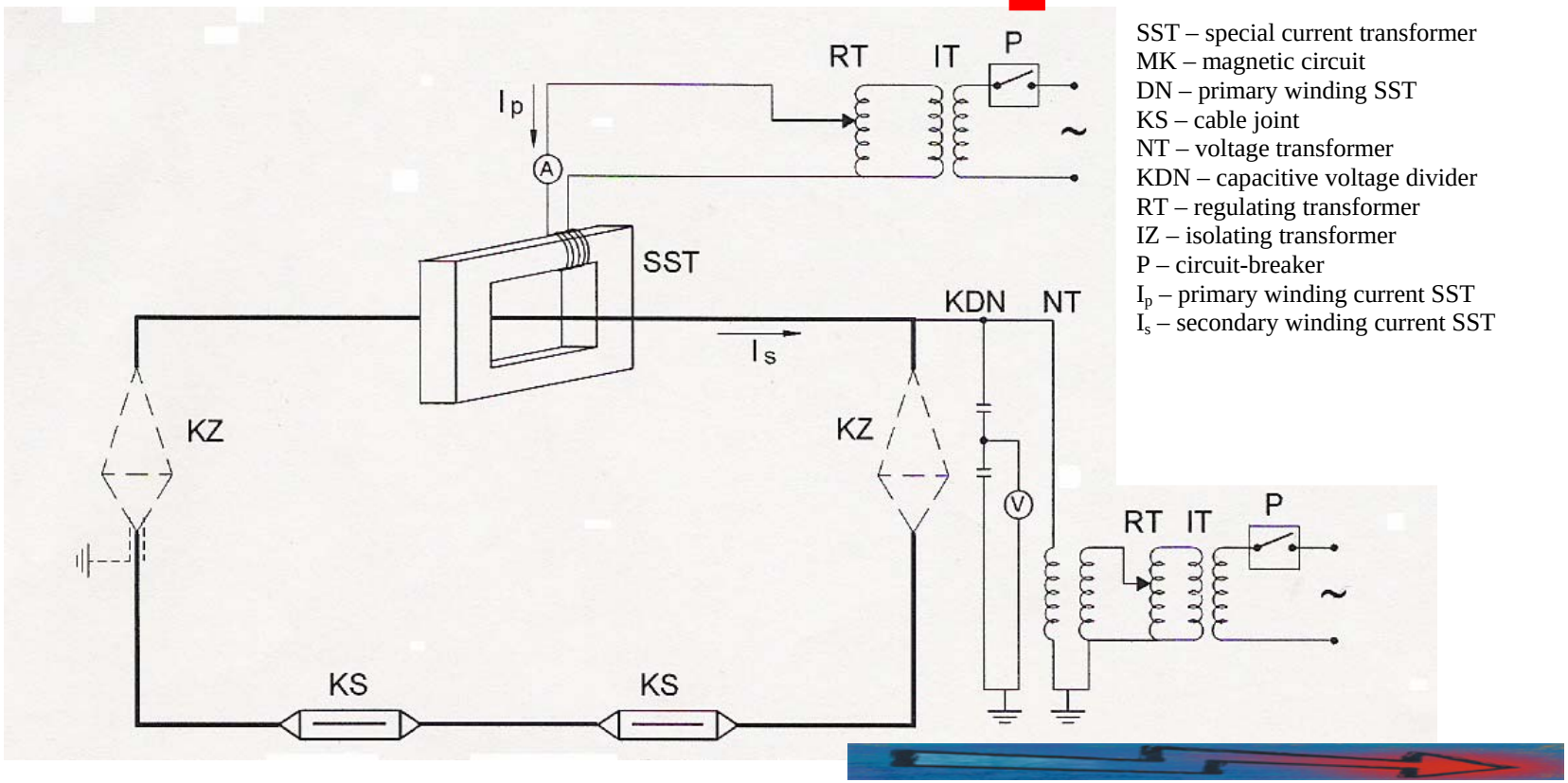
In the high-voltage laboratory of Institute “Nikola Tesla”, type tests of cable terminations and joints for 10 kV networks of two domestic manufacturers were carried out. Three-phase test circuit was created according to standard (1). Upon request of the first manufacturer in the circuit were present two oil joints and two oil terminations for outdoor installation foreseen for three-core cables with oil-impregnated paper insulation 3 x 150 mm^2, 6/10kV. For another manufacturer in the tests circuit were present: two oil-joints, one heat shrinkable cable termination for indoor installation and one heat shrinkable cable termination for outdoor installation, also foreseen for three-core cables with oil-impregnated paper 3 x 150 mm^2, 6/10kV. Connections cable termination-joint-joint-cable termination is performed with parts of three-core cable with oil-impregnated paper insulation 3 x 150 mm^2. Test circuit was performed by connecting cable joints with three single-core cables 1 x 150 mm^2 6/10kV (fig. 2). Test samples were installed by the manufacturer according to preliminary supplied instructions.

Type tests were carried out according to the program given in the part 2, but inclusively with point “e”. The rest of the tests was not performed, since for short-circuit tests, strong-power source is required which is not available in the laboratory. The tests were performed according to defined sequence, presented in part 2. Insulation tests with DC voltage were carried out between every phase conductor and the remaining two connected to the metallic sheath and earthed. The duration of every one of these tests is 15 minutes with test voltage 6 U_o = 36 kV.

Afterwards, insulation was tested with power frequency AC voltage of 4.5 U_o = 27 kV during 5 minutes between each phase conductor and the remaining two joined with metallic sheath and earthed.

Than followed the testing of insulation with impulse voltage having the peak value of 75 kV and 1.2/50 waveform. Ten positive polarities and ten negative polarities impulses were applied between each conductor and the remaining two joined together and with metallic sheath and earthed. After these voltage tests, the test circuit is subjected to cyclic heating in air. 63 cycles was performed. The duration of one cycle was 8 hours. The heating of three-phase test circuit was carried out with induced current I_s = 300 A in each of the phase conductors. After three hours, the temperature of aluminium phase conductors was brought to the value between 70ºC and 75ºC (before this test cable loop had been heated up and it was established that at current value of about 300 A, the conductor temperature is between 70ºC and 75ºC, and that cable sheath temperature is between 55ºC and 58ºC). This temperature was maintained during 2 hours and than the current was switched out. In the following time period of 3 hours, the temperature of three-core cable loop was brought to the ambient temperature. In total, 65 thermal cycles was carried out in continuous duration of 504 hours (21 days). During the whole of the test period, on the conductors of three-core cable circuit, three-phase, power frequency voltage 1.5 x 6kV=9 kV was applied. During testing, the temperature of cable sheath of cable circuit was measured by means of thermocouples. After these tests, the insulation of the test circuit was subjected to the power-frequency test voltage having RMS value 3 x 6kV=18 kV during 3 hours.

During these tests neither breakdown or flashover on test circuit insulation occurred, nor any changes on tested cable terminations and joints were observed.



SST – special current transformer
MK – magnetic circuit
DN – primary winding SST
KS – cable joint
NT – voltage transformer
KDN – capacitive voltage divider
RT – regulating transformer
IZ – isolating transformer
P – circuit-breaker
I_p – primary winding current SST
I_s – secondary winding current SST

Fig. 1 Circuit diagram for thermal cyclic testing of cable terminations and joints

5. CONCLUSION

Type tests of cable terminations and joints are indispensable, as well as for another equipment, before they are accepted for installation in high-voltage networks. They are long-term and require different testing and measuring equipment. It is indispensable to carry them out as well, when the applied material or dimensions of already type tested product is changed. When forming cable terminations and joints, manufacturer's instructions shall be strictly applied. This condition is fulfilled at type tests in the laboratory, because the manufacturer's team does it. Cable terminations and joints on cable lines in exploitation require well-trained teams and permanent supervision during their installation.

REFERENCES

1. SENELEC ND 629.2 S1 Standard: 1997-8 (equal to VDE 0278 Teil 629-2: 1998-06.)
2. CENELEC HD 628. S1 Standard: 1996-1 (equal to VDE 0278 Teil 628: 1997-11)
3. Standard IEC 60055-1: 1997-5. Part 1: insulated metal-sheathed cables for rated voltages up to 18/30 kV (with copper or aluminium conductors and excluding gas – pressure and oil – filled cables)
4. Sredojevic M. and the others, 2002., "Type tests of cable joint type KS-64 and termination for outdoor installation type KGTs – 10 for power cables with paper insulation type IPO (NPO) 13-AS 3 x 150 mm^2 6/10 kV". Test report No. 350201, Electrical Engineering Institute "Nikola Tesla", Belgrade.
5. Sredojevic M. and the others, 2004 " Type tests of heat shrinkable cable termination for outdoor installation type KZSE-s 10/3–150, 10 kV for three-core power cables with paper insulation type IPO (NPO) 13-As 3 x 150 mm^2, 6/10kV". Test report No. 350402, Electrical Engineering Institute "Nikola Tesla" Belgrade.
6. Sredojevic M. and the others, 2004 "Type tests of heat – shrinkable cable termination for outdoor installation type KZSE-u 10/3-150 10 kV for three-core power cables with paper insulation type IPO (NPO) 13-As 3 x 150mm^2 6/10 kV". Test report No. 350403, Electrical Engineering Institute "Nikola Tesla", Belgrade.
7. Sredojevic M. and others, 2004 "Type tests of cable straight joint type KS-64 10 kV for three – core power cables with paper insulation type IPO (NPO) 13-As 3x150 mm^2 6/10kV". Test report No. 350404, Electrical Engineering Institute "Nikola Tesla" Belgrade.