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RESEARCH ARTICLE

INCREASING THE EFFICIENCY OF NON-DESTRUCTIVE METHODS OF THE DIAGNOSIS POWER CABLE LINES UP TO 35 KV

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ABSTRACT

Efficient non-destructive methods of the diagnostics power cable lines are considered in the article. Also are presented applicable overseas methods of the diagnostics power cable line by voltage up to 35 kV: measurements and localizations of partial category cable lines; the measurements and analysis of the revocable voltage in insulating the cable; the measurements of the current to relaxations in insulating the stitched polyethylene of the cables; the measurements of dielectric features insulating cables; pulse of reflect meter for fault localizations (low-impedance) in power cable lines; checking the wholeness of the power cables shell and determination of faulty places in sheath. It Is offered for power cables of the different design and insulation by voltage 6-35 kV as the most economical sparing method of the test by variable voltage over low frequencies 0,1 Hz and equipment's in composition of mobile laboratories.

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INTRODUCTION

In the developed countries of the world, a non-destructive method of diagnostics of power cable lines (CL) is widely used, which provides for improving the reliability of power supply by reducing emergency outages and eliminating the costs of conducting unreasonable repairs of CL. Non-destructive diagnostic methods allow to obtain data on the insulation condition of CL, rationally and reasonably plan the timing of repairs of CL, as well as the replacement of cables with expired insulation resource. Thus, at present, extensive studies of non-destructive diagnostic methods are being carried out under operating conditions in Germany, France, USA, Japan, and other countries of the world. Based on the use of modern technologies, progressive systems, arrangements and devices for non-destructive diagnostics of power CLs embedded in mobile electrical laboratories have been created (Zita Pápay and Ákos Török, 2007).

The following non-destructive diagnostic methods for power CLs up to 35 kV are also widely used abroad:

1. Measurement and localization of partial discharges (Partial Discharge) CL;
2. Measurement and analysis of the return voltage in the cable insulation;
3. Measurement of relaxation current in the insulation of stitched polyethylene (SPE) cables;Measurements of dielectric characteristics of cable insulation;
4. Pulsed reflect meters for the localization of damage (low impedance) in power CL;
5. Monitoring the integrity of the sheath of power cables and identifying fault locations in the sheaths.

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Main Body

Theoretical analysis: At present, the service life of cable lines that have worked in distribution networks is 40 years or more. The reason for their replacement is unacceptably high rates of specific damage (the number of failures per 100 km of lines per year), especially cables in aluminium shells due to their low corrosion resistance. In this regard, the transition to new types of high-voltage power cables is part of the program of technical re-equipment of many cable enterprises, taking into account the existing investment opportunities of Uzbek enterprises. It should also be noted that in the next 5–10 years, cables with Impregnated Paper Insulation (IPI) will be almost completely replaced with cables with SPE insulation (Fig. 1). Cable enterprises producing high-voltage power cables are focused on the following areas: the use of new technological equipment, taking into account the latest achievements of global manufacturers in this field; manufacture of sealed cable structures (Fig. 2) using the latest generation of insulating and electrically conductive compositions, designed for high service life; cable production in accordance with the requirements of

Table 1.

No.	Nominal voltage, kV	Pressure	Conductor section, mm^2	Maximum working tension electric field, kV / mm	The greatest operation by Condition for 2016, years
1	2	3	4	5	6
1	110	Low Pressure	15-625	0,6-8,5	13
2	110	High Pressure	270-500	7,5-8,0	12
3	150	Low Pressure	350-625	10,0	9
4	220	Low Pressure	350-625	8,5-9,5	11
5	220	High Pressure	550-1200	9,5	10
6	380	High Pressure	550	11,5	7
7	380	High Pressure	550	13,0	6

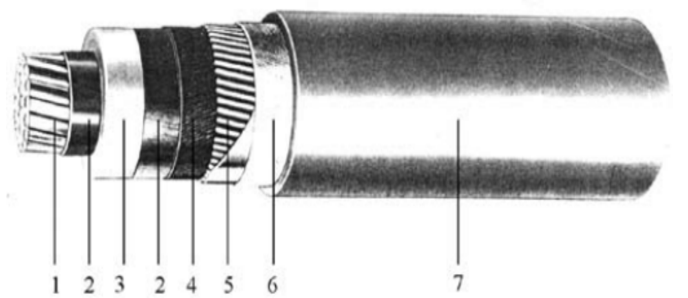

Fig. 1. The design of the cable brand (cable with isolation from stitched polyethylene sheath in longitudinal the sealing) 1 × 240/35 mm^2 - 10 kV:

1 - Aluminum conductive core with a cross section of 1 × 240 mm^2;
2 - Electrically conductive extruded screens;
3 - Insulation made of cross-linked polyethylene with a thickness of 3.4 mm;
4 - Electrically conductive water-swell able tapes;
5 - Screen made of copper wires with a cross section of 35 mm2 (screen section according to the conditions of short circuit currents);
6 - Separation winding with alum polymer tape;
7 - Outer sheath of polyethylene.

IEC and CENELEC standards with confirmation of cable reliability in two-year tests in a humid environment (water) (Schieweck and Salthammer, 2006).

Experimental part

The above methods are intended for testing and diagnostics of cables with polyethylene insulation and are used mainly in distribution cable networks of foreign countries. Power cables with impregnated paper insulation in the CIS countries and in our country remain the main type of cables in electrical networks with voltage up to 35 kV, which are mainly operated to the limit of their condition. The most effective methods of non-destructive diagnostics used for such cable lines can be the method of measuring and locating partial discharges in CL, as well as the analysis of the return voltage in cable insulation. Defects in isolation have a beneficial effect on the acceleration of aging of insulation, because are the main reason for the formation of water and / or electrical treeing, reducing the electrical strength of cables and the reliability of CL (the actual resource is only 8–15 years instead of the required 30–40). At the same time, channels of incomplete breakdown are formed, in which the developing PD are growing very intensively and for some time they isolate the system (Table 1). The method of measurement and location of partial discharges in the cable are shown in the table. The experience of operating CLs with a voltage of 6-35 kV, it was found that the main reasons for the decrease in dielectric strength of insulation are the effects of PD and high temperatures.

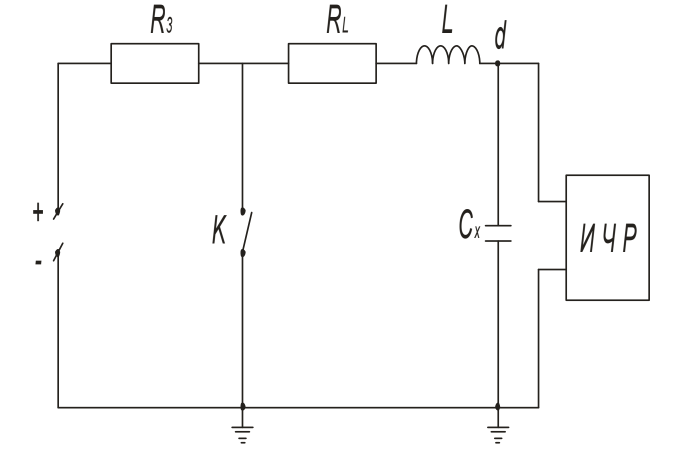

Fig. 2. Diagram of measuring partial discharges in CL:

P_3 - charging resistance; R_L - resistance of the inductor; L – windings of inductor; K - high voltage switch; PDM - partial discharge meter; c_x - cable capacity.

To assess the insulation status of all types of cables using partial discharge characteristics, the PD measurement method is implemented with oscillating damping voltage, which allows determining the magnitude and location of the partial discharge, their number in local CL areas, occurrence and damping voltage, tgb value. According to these parameters, a reasonable conclusion about the technical condition and problem areas of diagnosed PD can be issued. System diagnostics are performed on a cable line that is disconnected from both sides. Localization of PD in CL is carried out using the method of reflect meters, according to the results of the registration of two pulses from the same pulse reflected from the end of the CL. The processed and counted pulses are represented on the map of defective areas of the CL for all three phases and for each phase of the CL separately. The limit values of the PD levels in each country may differ slightly from each other and are expressed in terms of pc. To assess the insulation status of all types of cables with voltage up to 35 kV, the method of monitoring the characteristics of the PD is the OWTS system (Oscillating Wave Test System) of the Seba KMT Company (Richard, 2013).

RESULTS AND DISCUSSION

The OWTS system consists of a high-voltage unit, a signal processing unit, and a laptop with an adapter for wireless communication with a high-voltage unit, including a DC voltage source and a resonant coil with an integrated switch for generating an alternating test voltage (Fig. 2). The management of the system, storage, analysis and evaluation of the results of measuring the characteristics of PD are performed using a laptop using special software. The most common systems are OWTS 25, OWTS M 29, OWTS M 60 with an output voltage of 25, 28 and 60 kV, respectively. The OWTS system, which is disconnected from both sides of the CL line, is being diagnosed. Before the diagnostics, the system is calibrated to clarify the length of the line and determine the expected amplitude of the CR, and then each of the three phases is charged with a constant voltage of a set value (less than the amplitude of the line voltage CL) (Baccani *et al.,* 2007; Shi, 2004). After charging, the CL phase is connected via a resonant coil to a grounded cable shield with an electronic switch. When the cable is discharged, damped sinusoidal oscillations occur. The wave initiates a CR in CL isolation, which is fixed and stored in the memory of the OWTS computer for processing and determining the amplitude and location of the PD along the length of the CL. Localization of damage sites of CR in CL is carried out using the method of reflect meters according to the results of registration of two pulses from the same PD-primary pulse reflected from the end of the CL. When using the OWTS system, the difficult stage of diagnostics is to evaluate the results of the process of determining and formulating a conclusion on the results of measuring and localizing PD. It should be noted that 1000 pc was adopted as the limit value of the PD level in the FRG, in Italy - 1200 pc. In the CIS countries, the limiting state of the Czech Republic exceeds 5000-10000 pc, the technical condition is estimated by the worst of the three parameters — the maximum value of the partial discharge, the voltage of occurrence of the partial discharge and the average number of partial discharges in a local place during one measurement cycle (Schieweck and Salthammer, 2006; Richard, 2013; Saitov, 2016; Baccani, 2007). So, for example, on CL 6 kV with impregnated paper insulation in Russia, the period of re-diagnosis or repair with PD values up to 1200 pc for 5 years, up to 7500 pc for one year, 15000 pc for a year, followed by diagnostics , over 15,000 pc is not subject to operation. In CIS countries, the application of the limit values of the criteria of European countries seems impractical, since it is characterized by the operation of power cable lines to their limit state. The level of the PD at the same time on the CL can reach 15,000 - 40000 pc. In such cases, the evaluation of the technical condition of a CL may consist of several diagnostic parameters, for example, up to 1000 pc should be diagnosed after 5 years, 2500 pc - after two years, 10,000 pc - after 1 year, and above 15000 - 20000 pc - can be repaired during of the year.

Conclusion

At 2000 enterprises of electric networks of the Russian Federation, a wide experience of using the OWTS system diagnostic method is available at limited liability company "Test" with a voltage of 6–35 kV. From the surveyed more than 65% CL, a conclusion was made about the unsatisfactory state of isolation (Zita Pápay and Ákos Török, 2007; Schieweck and Salthammer, 2006; Richard, 2013). Problem areas in CL are predominantly noted in the coupling and end sleeves. According to the results of cable lines diagnostics using the OWTS system in the Russian Federation, standard indicators were developed for assessing the technical condition of power CLs operating in Russia with different types of insulation (BMPI, SPE, PVC). Diagnosis of the technical condition of the CL is performed by the worst of three parameters: the maximum value of the PD in a local location; voltage of occurrence of the Czech Republic (on the amplitude value); the average number of PD in a local place for one measurement cycle. Nowadays, the test of high voltage ultra-low frequency (0.1 Hz) is the most common and most enterprises use it not only for testing the insulation of cables made of cross-linked polyethylene, but also for conventional paper-oil-insulated cables. Due to the lack of standards for testing SPE cable with insulation, each power station enterprise on the basis of accumulated experience selects the value of the test voltage and the duration of the test. Conclusions: For power cables of various designs and insulation with voltage of 6-35 kV, the most efficient and cost-effective one should use the gentle test method with alternating voltage of ultralow frequency of 0.1 Hz and equipment available in mobile laboratories. The team of authors is grateful to (Ph.D) Saitov E.B for his valuable advice and discussion of the experimental results.

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