DESIGN AND CONSTRUCTION OF 6-500 kV CABLE LINES. ISSUES TO BE SOLVED

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Our country has already accumulated considerable experience in the design and construction of cable lines of classes up to 500 kV with insulation made of cross-linked polyethylene. At the same time, there are still a number of unresolved problems in this area, both long-known and recently appeared during the operation of cable lines. Let's discuss some important problems in the construction of cable lines with XLPE insulation.

Keywords: cable line, single-core cable, three-core cable, XLPE insulation, cable joint, screens cross-bonding, link-box, well for link-box, cable pipe, network neutral.

1. INTRODUCTION

Currently, in 6-35 kV networks, most of cables laid are single-core or three-core cables with cross-linked polyethylene (XLPE) insulation. If we talk about 110-500 kV networks, then absolutely all new cables are single-core cables with XLPE insulation.

The industry is ready to produce various cable types, but, unfortunately, not all new products are convenient to install and operate. For example, recently one of the plants announced the production of three-core cables with XLPE insulation of 6-35 kV classes, having not round cores, but sector ones. According to the developers, thanks to this shape of the core, it was possible to minimize the outer diameter of the cable, reduce its weight and cost, and achieve better flexibility. However, in general, installation organizations negatively perceived the information about the appearance of such a cable, explaining their reaction to potential problems that the installer of cable joints and terminations will have when he tries to remove the semi-conductive layer from the cable XLPE insulation having a complex shape, especially in the absence of a tool for non-circular cores.

Another example of not the most successful cable products, in my opinion, are single-core armored cables [1]. In particular, Lukoil's power engineers have already abandoned the use of such cables for 6-35 kV classes, and the main argument here was the significant loss of active power in armor made of aluminum wires.

The presence of such losses in the armor in the catalogs of cable products is not even mentioned, that is, the situation is completely identical to the one that was already 5-10 years ago, when there was no information about losses in the copper screens of single-core cables. The lack of this information then caused a large number of errors in the design of cable lines, led to damage of some cable lines immediately along the entire route and the need for line complete replacement.

Unfortunately, the pace of regulatory documents development will always lag behind the pace at which factories and design organizations offer more and more new technical solutions, and therefore it remains to advise interested specialists to be more careful about cable networks, where the cost of error is extremely high. I would also like to hope that the norms will be updated periodically.

2. NEW STANDARD ON POWER CABLES

In the country, there are several regulatory documents on power cables that were developed about 5-7 years ago, mainly due to the efforts of PJSC "FSK EES". Some experience has accumulated in recent years, and it would be useful to make additions and clarifications to these norms. Since this is not an easy task for the standards put into action, certain hopes were relied on a completely new document, the preparation of which was launched by national company PJSC "Rosseti". We are talking about a new GOST "Cable lines of voltages from 6 to 500 kV. Requirements for technological design".

The specified GOST was originally intended as a document dedicated only to single-core 110-500 kV power cables, but it became clear that there were many questions about other cables, as a result of which classes 6-35 kV, three-core cables, and underwater cables were added. In mid-2016, the final version of the draft GOST was discussed at a conciliation meeting, at which, as expected, a deadlock situation arose. On the one hand, the presented edition formally meets all the requirements of the terms of reference for its development, but on the other hand, the wording is too general and streamlined, in the style of international documents, and in this form, GOST is unlikely to be needed by anyone in the country.

Unfortunately, for developing such an important regulatory document the budget was given of only 5 thousand euro. In this situation it was irrational to believe that the document would be good enough an could solve all the problems of 6-500 kV cable networks (each of problems is a topic for a separate scientific study and a series of experiments). Therefore, I think that it is still better to approve the existing version of GOST, because even generalized formulations will avoid gross errors that are still encountered in the design of networks.

If we talk about issues that, regardless of the fate of GOST, it is better to pay attention to in the near future, then, in my opinion, they are as follows:

- study of the causes of cable joint damages;
- putting things in order with nodes of 6-500 kV cable screens cross-bonding;
- restoring order in the construction of cable lines in pipes;
- limiting the use of single-core cables in 6-35 kV networks with an isolated (compensated) neutral and switching to the use of three-core cables in such networks;
- introduction of resistive neutral grounding in 6-35 kV cable networks and, first of all, in those networks where there are many single-core cables.

3. CABLE JOINT DAMAGES

Cable joint damages are traditionally associated with careless or poor-quality joint installation, but there are already several lines where it is obvious that reasons are different. For example, in one of cities of the south of the country, about a dozen damaged joints were recorded on new 110 kV cable line in a short time. The situation is similar in Qazaqstan, where about 15 joints have already been damaged on new 220 kV lines in a couple of years.

In both cases, we are talking about joints of well-known manufacturers with a good worldwide reputation, and therefore it is necessary to look for the causes of such massive accidents not only in joints themselves, but also in third-party factors. Interestingly, almost all accidents occur directly at the time of the line's switching to the network or immediately after it, but otherwise the operating conditions of these 110 and 220 kV lines differ.

If we talk about 110 kV, cable lines are very often switched there, which is necessary for dispatchers to maintain the voltage level of 50 Hz in a network that is not equipped with the necessary means of compensating the reactive power of cables. In particular, at night, when the load drops in the network, the reactive power generated into the network by the capacity of the cables, leads to an increase in voltage in network busbars, and in order to prevent voltage increases of industrial frequency, some lines have to be disconnected dozens or even hundreds of times during the year.

If we talk about 220 kV, then the line is not purely cable, but mixed, i.e., it has both cable and air sections. At this facility, the annual number of commutations is already much smaller, and they are caused either by lightning overvoltages in the air section, or by planned shutdowns for repair work (including the replacement of some next damaged joint).

EMTP calculations carried out both in the 110 kV network and in the 220 kV network, taking into account the specifics of both objects, showed that switching overvoltages, the magnitude of which would be dangerous for a new serviceable cable joint, do not occur. Therefore, there is reason to believe that the cause of the joint damages lies in a decrease in the electrical strength of cable joints, and this may be due to the following prerequisites:

– a large number of line commutations (switching), each consumes an insulation resource (rather refers to the case of 110 kV, where there are too many such commutations);
– lightning discharges into the air section, the appearance of lightning overvoltages and their transition to the cable section (rather refers to the case of 220 kV, partly because not all transition towers were equipped with 220 kV metal-oxide surge arresters);
– mechanical stresses in the cable joint that occur under conditions of soil pressure on joint, which has insufficient mechanical protection.

Each of the hypotheses expressed requires a series of studies, but at the end, there is hope to explain the ongoing processes and adjust projects to prevent similar accidents in the future.

4. SCREENS CROSS-BONDING

During the construction of cable lines of voltages from 6 to 500 kV, made with single-core XLPE-insulation cables, in some cases it is necessary to equip screens cross-bonding. Screens cross-bonding of the high voltage cable line laid in the ground is usually carried out in cross-bonding link-boxes placed in wells.

Cross-bonding wells should have the following important properties:

– mechanical strength under conditions of ground and transport pressure;
– tightness (protection against penetration of rain and ground water);
– electrical safety for personnel and third parties;
– resistance to aggressive environment (road chemical reagents etc.);
– combustibility of the class of FV-0, according to GOST R 28157-89 [2];
– preservation of all properties throughout the lifecycle of the cable line.

To the greatest extent, these requirements are met by polymer cable cross-bonding wells of full factory readiness (Photo 1), which in all respects surpass traditional reinforced concrete wells that leak all the time (Photo 2) and gradually collapse (Photo 3).

In addition to solving two problems reflected in Photos 2 and Photo 3, the use of new polymer wells will allow you to get rid of another, no less urgent issue: we are talking about the safety of people when they are near the well or inside it. Currently, the well requires a grounding resistance of 0.5 Ω, which remains on paper, and at the facility, installers manage to achieve only 4-6 Ω, which is not always enough to protect people from damage by step voltage or touch voltage.

In the article [3] it was stated that the transition to polymer wells instead of concrete, will automatically ensure safety, and for a well it will be enough to have an easily achievable grounding resistance of 10-20 Ω.

Photo 1. Installation of polymer wells for link-boxes.

Photo 2. A concrete well filled with water.

Photo 3. The collapse of the ceiling of a concrete well.

5. CABLE LINES LAID IN PIPES

Ten years ago, during the construction of cable lines, pipes were used mainly at short intersections with roads and utility networks, but over the years an increasing number of cable lines have got extended pipe sections. This is caused by two reasons: the development of capabilities of the horizontal directional drilling (HDD), and the increased complexity of open excavation (trench digging) in urban conditions.

Polymer pipes in which cable lines are laid must be able to retain all their mechanical properties throughout the life of the cable, which will allow unhindered removal of the cable from the pipe if necessary. The ability of a polymer pipe to retain its properties when heated (for example, by the heat of a laid cable) is called heat resistance. Pipes in which cables with XLPE insulation are laid must be heat-resistant at a temperature of at least 90 °C.

As follows from the conclusions of the Federal Testing Center, the use of cold-water pipes made of low-pressure high-density polyethylene (HDPE) during the construction of power cable lines is unacceptable, because this material is heat-resistant at a temperature of only 20-40 °C. For the same reason, during the construction of 6-500 kV cable lines with XLPE insulation, ordinary red double-walled corrugated pipes cannot be used, because they are also based on the mentioned HDPE.

Having lost the opportunity to supply conventional HDPE pipes to energy facilities, pipe plants are opening power cable divisions, trying to offer the same HDPE pipes to the market, but in a veiled form. For example, such plants in the manufacture of HDPE pipes paint them in bright red, and in the designation of the pipe add an explanation like "electro".

How to check the consumer properties of the pipe supplied to the cable facility and its suitability for the needs of cable networks is a serious issue that needs to be discussed. In the meantime, we can say that HDPE is a combustible material and the appearance on the cable market of non-combustible polymer pipes of the FV-0 category according to GOST R 53313-2009 [4] will partially complicate the work of unscrupulous suppliers.

Another fundamental difference between cable pipes and water or gas pipes is that power cable pipes are classified not by diameter and dimension ratio SDR, but by diameter and ring stiffness SN.

In addition, it should be said that some plants mistakenly offer pipes for 6-500 kV networks manufactured according to GOST R IEC 61386-2014 "Pipe systems for laying cables", apparently believing that network companies will pay attention only to the famous name of IEC. At the same time, the section "Scope of application" of this document states that it applies only to low-voltage networks of voltages up to 1 kV AC and up to 1.5 kV DC.

Obviously, this GOST R IEC 61386-2014 has nothing to do with high-voltage cables of 6-500 kV classes and the presence of a certificate of compliance with the requirements of this regulatory document does not give grounds to supply pipes to 6-500 kV networks. This is exactly the position taken by the Federal Testing Center, and it is set out in a series of official letters from different government organizations.

6. NEUTRAL GROUNDING USING RESISTOR

Three-core cables have traditionally been used in 6-35 kV medium voltage networks with isolated or compensated neutral. Therefore, there were no special problems in cable networks with finding a single-phase ground fault, because in case of damage to one of the phases of a three-core cable, the fault would quickly develop to a two-phase and three-phase short-circuit, which would be disconnected by conventional current relay protection.

The appearance of single-core cables in 6-35 kV networks has led to the fact that, unlike a three-core cable, fault on one of the phases rarely spreads to the other two, and the operating organization has a problem finding a single-phase ground fault location, and this problem has not yet found a reliable solution. The way out of the situation is seen in the use of not a single-core, but three-core cables with XLPE insulation in 6-35 kV cable networks, at least on those lines where a core cross-section of more than 240-300 mm^2 is not required. Another way out of the situation may be the transfer of the 6-35 kV network to resistive neutral grounding and selective disconnection of single-phase ground faults.

7. CONCLUSIONS

The cable industry is still developing and transforming quite dynamically, operational experience is accumulating, new solutions and new problems are emerging. To discuss lots of topical issues, in my opinion, it is important to periodically hold meetings, conferences, presentation days.

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