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Concept of installation of cable terminations on 110-400 kV live line poles

Koncepcja montażu pod napięciem głowic kablowych końcowych na słupach linii 110-400 kV

Introduction

Modernization and reconstruction projects of overhead lines, ranging between 110 and 400 kV, are related to intensive expansion of infrastructure in our country in recent years. It applies in particular to construction of roads, railroads, sports and cultural facilities, including highways, sports stadiums, which leads to installation of cables on various lengths of sections, which frequently enter dense built-up areas of urban agglomerations. Expanded infrastructure, formal-legal regulations cause difficulties to acquire land for overhead lines. Therefore, despite higher costs, projects involve installation of 110-400kV cable lines more often than in the past [1],[6],[7]. The most frequent projects involve construction of 110kV cable lines, which cost is nearly twice as high as overhead lines. Installation of cable lines requires high quality installation works, including terminations on line poles and support structures of stations.

In order to avoid inconvenient outages, electrical companies conduct concept works in order to install heads on live lines. These works are described in this report. It discusses the principles of occupational safety and the risk involved in this type of works.

What to build – overhead or cable lines?

At first glance, cable line looks better than overhead line. However, collecting opinions about environmental impact of the line is not that unequivocal. In addition, high cost of line construction plays an important role as well. It is reflected in the cost of electricity, for which consumers want to pay as little as possible. Equally important are formal and technical aspects due to the growing density of infrastructure. Despite the fact that the number of overhead lines will continue to dominate, cable lines will be built more often. Their installation frequently faces problems related to performance of works with uninterrupted power supply to consumers or cutting the time of outages to minimum. Without live-line working technology, effectiveness of these works would be very low.
The compiled comparison between overhead line and cable line in terms of environmental impact based on CIGRE questionnaire shown on Fig.1 indicates that one shall not count on firm support as regards construction of cable lines. It requires careful pleading and convincing to this type of facilities, in order to be ahead of possible doubts of the public and skeptical ecologists.

However, economic necessities require more frequent construction of cable lines and higher levels of voltage. Transmission grid, which becomes denser with every day, requires construction of multi-circuit and multi-voltage lines, whereas aesthetic reasons require searching for new designs of poles. Pipe poles have been the most popular designs used currently in Poland. (Fig. 2a,2b)

Contractors more frequently face the necessity to limit or eliminate outages, making sure that the reconstructed overhead line fulfilled its role throughout the works. Due to maintenance reasons, only sometimes outages are allowed during weekends and holidays. In order to prepare technology of cable line installation works on live overhead line poles, models of standard poles in 1:30 scale were prepared (Fig.3). Various types of works were analyzed on these models: live-line working and in the proximity of live line, and using short breaks in power supply. (Fig.4) It is planned to use models in the training process of service personnel.

Table 1

<table>
<thead>
<tr>
<th>Rated voltage of equipment</th>
<th>Zone live-line working</th>
<th>Zone works in the proximity of live line</th>
</tr>
</thead>
<tbody>
<tr>
<td>kV</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>110</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>220</td>
<td>1600</td>
<td>3000</td>
</tr>
<tr>
<td>400</td>
<td>2500</td>
<td>4000</td>
</tr>
<tr>
<td>750</td>
<td>5300</td>
<td>8400</td>
</tr>
</tbody>
</table>

Many factors related to safety and risk of works conducted were used in analyses of the work process. National and international regulations specifying safe distances serve as foundation of an analysis for carrying out installation works.

In 2013 state-owned regulations related to occupational safety and health [2], [12] had been changed and the regulations compatible with PN-EN 50110 had been inputted. Thereupon prevailing executory distances which mark the working live zone and near the high-voltage itself have been collected in table 1.
The analyses also considered possibilities of using even shorter distances determined based on PN-EN 61472. Fig. 5 shows a model of 110 kV cable line installation technology on a pole with live line at the same level of voltage. Tab.2 shows projected methods of work in installation technology.

The described installation of cable lines was accepted with adherence to occupational safety regulations, not allowing for risk higher than medium according to expert’s assessment. It is assumed that effects of electrostatic and electromagnetic induction, manifested with electric charge on large metal facilities, for instance cross arms that are installed, are handled by using complete shielding clothing.

The method of electrical testing of cable line and its admission to grid operation remain a problem. Examples of testing high-voltage cables with the use of AC and DAC voltage-measuring tests were illustrated on Fig.6. AC and DAC voltages used in operation testing and partial discharge measurement methods were characterized in Tab.3. Due to significant effects of breakdowns caused by damages of high-voltage cable insulation during their operation, such cables undergone extensive quality testing after production process, taking into consideration voltage testing combined with partial discharge detection. In addition, after installation of cable in field, post-completion testing takes into consideration various types of voltage testing, some of which can be used along with partial discharge measurement diagnostics. [4],[9]

![Fig. 5. Original, patented in Poland solutions of single-circuit and double circuit line cable poles acc. to [3]](image)

**Table 2**

<table>
<thead>
<tr>
<th>Principal stages of work</th>
<th>Work in the zone</th>
<th>Installation guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting and installation of cross members for low voltage surge arresters</td>
<td>In the proximity of live line</td>
<td>Works are conducted outside the live-line working zone</td>
</tr>
<tr>
<td>Lifting cables to the pole</td>
<td>In the proximity of live line</td>
<td>Lifting equipment cannot short-circuit various potentials</td>
</tr>
<tr>
<td>Installation of cable heads</td>
<td>In the proximity of live line</td>
<td>Works are conducted outside the live-line working zone</td>
</tr>
<tr>
<td>Installation of low voltage surge arresters</td>
<td>In the proximity of live line</td>
<td>Works are conducted outside the live-line working zone</td>
</tr>
<tr>
<td>Connection of cable line with low voltage surge arresters by wires</td>
<td>In the proximity of live line</td>
<td>Works are conducted outside the live-line working zone</td>
</tr>
</tbody>
</table>

In practice, partial discharge diagnostics is performed most frequently on cables disconnected from operation during the time of measurement (off-line).

Quality and reliability of cable line installation is evaluated within post-installation commissioning testing – made after factory testing, which is aimed at checking for cable damages during transport, storage and installation. As a matter of fact, not only cable, but also the main components of prefabricated cable accessories (i.e. control cones, coupling parts) are subject to quality testing before leaving the factory. However, the effects of transport and correctness of installation can be assessed only after completion of installation in field. Currently, works continue on test methods for the needs of installation of cable line on live
line poles (Fig.7), allowing installation of cable termination the
ground, and through visual inspection and supervision of pulling
the line to the pole – confirmation that there are no events expos-
ing the cable to mechanical damage, connection of this cable to
to voltage according to the methods indicated in Tab.2.

From the technical point of view, it was considered to move
away links on the line with the use of hot sticks, an additional com-
posite insulator, shown by the Polish team during the conference
ICOLIM’2000 in Spain. The use of gas bypasses was considered
as well. The use of insulation ladders and hoists with an insulation
arm was also considered for performance of live-line works.

In recent years, several temporary lines purchased in Cana-
da and the USA have been used in Poland. Their use is also
considered during installation of cable lines, in order to move
power supply to temporary line, performing installation works on
the cable line at a work station that is not in the immediate pro-
ximity of wires and voltage.

Southen-american experiences (cittes’2013)

Questions noted herewith this paper was confronted with
the specialists on energetic from South America during last
year’s CITTES’2013 Conference, which took place in Concordia.
[11] In order to transfer (take over) the load of the circuit of elec-
tric disconnector, shunts were used for the devices operating at
110kV at one of the shows (Fig.9-10).

The similar solution can be applied in a project viewed by
the authors, provided that the current value measured in circuit ,
allows to that particular maneuver without any additional switch.
The attachment to the type of shunt (when it is a overhead line)
can be realized with its eventual short switching off.

Participants of concept works had considered several possi-
bilities to avoid installation errors described in [8], as well as reduc-
tion or elimination of threats resulting from overhead line operation.
Currently in Poland, live-line working and works in the proximity of
live line usually require blocking of automatic reclosing. Works can-
not be conducted during thunderstorms within a 10-km radius.

Fig. 7. Traditional installation of high-voltage cable terminations on
a pole in special tents or on the ground and pulling up on the pole

Fig. 8. Use of temporary line can facilitate installation of cable line [10]
Marking: 1-foundation plate, 2-articulated plate, 3-movable boom for
lifting, 4-segment, module of a tower, 5-movable plate for installation
of insulators and ropes, (based on www.towersolutions.ca)

Fig. 9. One of the possible shunts usage which has been shown on
the CITTE’2013 Conference. It is also posible to use it in the case
which has been analized in this paper

Fig. 10. General view of the shunt disconnetor and view
of the shant itself. (CITTES’2013)
Conclusions

More frequent use of cable lines supplementing series of 110 - 400kV overhead lines becomes an economic need. In the same time, there is a growing need to keep the existing lines in operation, reducing to minimum power outages for the purpose of installation works. Therefore, development of a concept for installation of cable heads on 110 -400kV live line towers is rational. Performance of technical analyses indicates a wide variety of techniques – typical of live-line working – that can be used. Meeting of expectations related to keeping high indexes of power supply continuity has to be accompanied by safe organization of work processes with a justified level of risk.

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