REFERENCES

[1] ISSA Guideline for the selection of personal protective equipment when expose to the thermal effects of an electric fault arc, 2nd Edition 2011
[2] Dudek B., Nowikow J., Skomudek W.: Complete arc flash personal protective equipment for electricians, X ICOLIM'2011 Zagreb, Croatia
[3] Ziehmer R., Rotter G.: PPE – Arc-fault-tested protective gloves, X ICOLIM'2011 Zagreb, Croatia
[4] Schau H., Ehrhardt A.: Proving tripping safety and immunity against malfunctions of the typical arc detection components of a novel electric fault arc protective system, X ICOLIM'2011 Zagreb, Croatia
[5] Philips J., Frain M.: A European view of arc hazards and electrical safety
[6] Dudek B.: Increasing the safety of use of electrical installations, FISUEL International Forum Warsaw, 28-29 November 2013

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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.

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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.

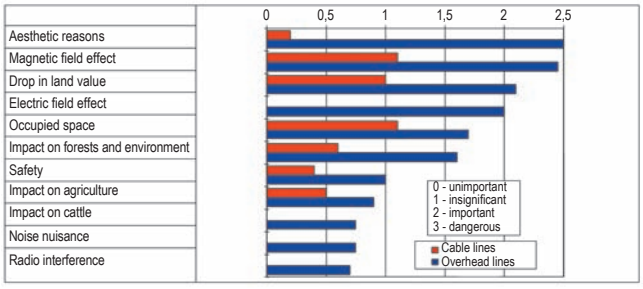

Fig.1. Comparison of overhead line with cable line in terms of environmental impact based on CIGRE questionnaire

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)

Fig. 2a. 110 kV cable line poles installations [5]

Fig. 2b. 110 kV cable line poles installations [5]

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.

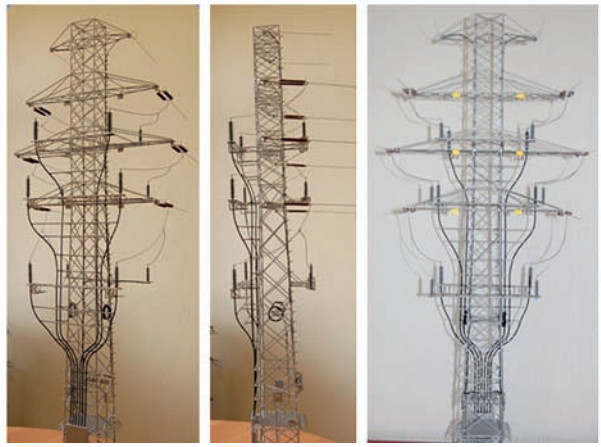

Fig. 3. Model 1:30 of 110 kV double-line cable pole

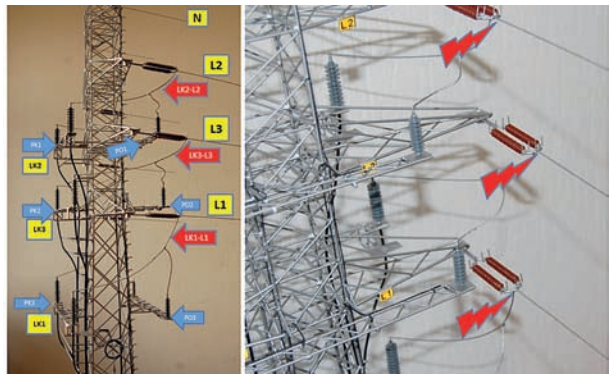

Fig. 4. Modeling of 110 kV cable line installation technology. Marking: yellow rectangles – phases L1, L2, L3 of overhead line, LK1, LK2, LK3 of cable line; Stages of installation: blue arrows PK1, PK2, PK3 and PO1,PO2,PO3 – installation of cross arms for cable termination and light voltage surge arresters; red arrows – connection of cable line to overhead line: LK1-L1, LK2-L2, LK3-L3

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 ocupacional 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.

Table 1

The minimal interspace in air from unshaded fixings or their deliverables are placed in live, are demarcating the outer perimeters of a working zone [12]

Rated voltage of equipment	Zone	
	live-line working	works in the proximity of live line
kV	mm	mm
110	1000	2000
220	1600	3000
400	2500	4000
750	5300	8400

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.

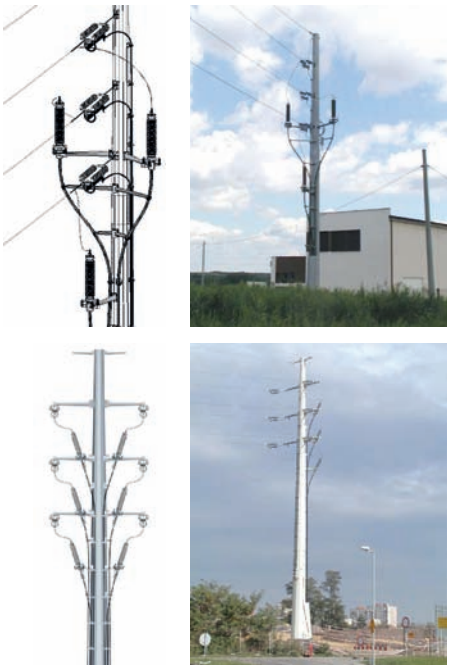

Fig. 5. Original, patented in Poland solutions of single-circuit and double circuit line cable poles acc. to [3]

Table 2

Installation of cable line on a pole of live overhead power line – stages of works

Principal stages of work	Work in the zone	Installation guidelines
Lifting and installation of cross members for cable heads	In the proximity of live line	Works are conducted outside the live-line working zone
Lifting and installation of cross members for low voltage surge arresters	In the proximity of live line	Works are conducted outside the live-line working zone
Lifting cables to the pole	In the proximity of live line	Lifting equipment cannot short-circuit various potentials
Installation of cable heads	In the proximity of live line	In tents; it may be necessary to move wire links using live-line working technology
Installation of low voltage surge arresters	In the proximity of live line	It may be necessary to move wire links using live-line working technology
Connection of cable line with low voltage surge arresters by wires	In the proximity of live line	
Connection of cable line	Live-line working	From a hoist with insulation arm
	With short power outage (no power supply)	From insulation ladder
	With power outage	Maximum in two days
In all stages of work, workers on poles use 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. 6 Examples of operation testing of high-voltage cables with the use of AC and DAC voltage testing [4]: a) testing after installation of XLPE 380 kV cable with the use of resonance testing equipment, b) testing after installation of 150kV oil cable with the use of self-extinguishing, voltage, oscillating wave DAC, c) measurement of partial discharge of 150kV gas cable with the use of DAC

Table 3

Ac and dac voltages used in operation testing and partial discharge measurement methods [4], [9]

No.	TYPE OF VOLTAGE TEST	DESCRIPTION
1)	Test with the use of alternating current (AC) – test with the use of alternating current with 20-300 Hz in frequency, primarily sinusoidal	– test parameters: 1.7 U_0 /1 hour (lower values of voltage and test time are also allowable) – test with parameters U_0 /24 hours can be an alternative
2)	Test with the use of alternating current and nonstandard method of partial discharge measurement (see Fig. 6)	– partial discharge measurement in μV in the radio frequency band (up to 500 MHz) – partial discharge detection in cable accessories
3)	Test with the use of alternating current and partial discharge measurement according to standards IEC60270 / IEC885-3 (see Fig. 6 b,c).	– partial discharge measurement in pC (picocoulombs) – partial discharge location in cable insulation – partial discharge location in cable accessories

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 exposing the cable to mechanical damage, connection of this cable to voltage according to the methods indicated in Tab.2.

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

Participants of concept works had considered several possibilities to avoid installation errors described in [8], as well as reduction 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 cannot be conducted during thunderstorms within a 10-km radius.

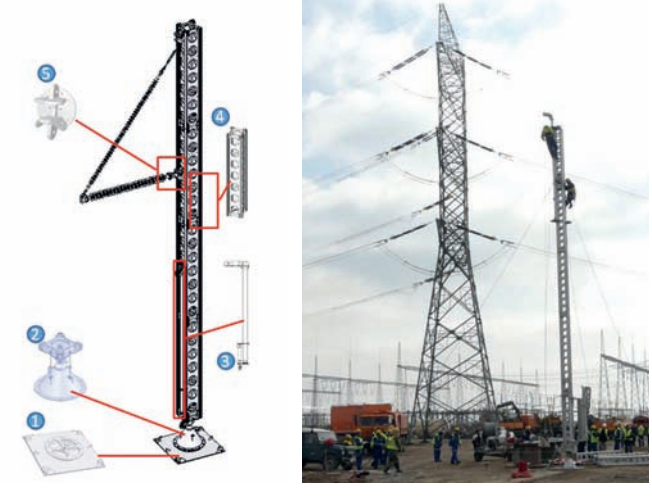

Fig. 8. Use of temporary line can facilitate installation of cable line [10] Marking: 1-foundation plate, 2-articulated plate, 3-movable boom for lifting, 4-segment, module of a tower, 5-movable plate for installation of insulators and ropes, (based on www.towersolutions.ca)

From the technical point of view, it was considered to move away links on the line with the use of hot sticks, an additional composite 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 Canada 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 proximity 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 electric 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.

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

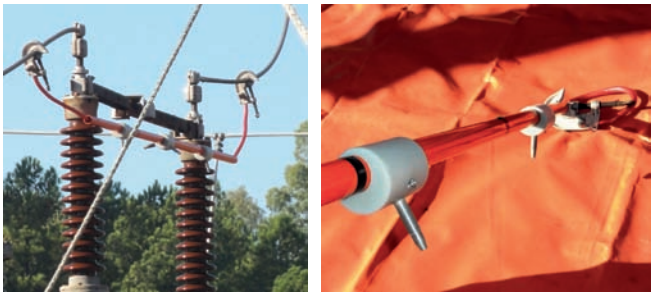

Fig. 10. General view of the shunt dissconnetor and view of the shant itself. (CITTES'2013)

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.

REFERENCES

[1] B. Dudek, S. Widlas.: Modern technology of electrical equipment maintenance – live-line working in Poland, CIGRE Regional, RSEEC 2012 Innovation for future! Section E Live Working, Sibiu, Romania 2012 p.38-47

[2] Z. Gacek, B. Dudek: Getting closer to electrical equipment – analysis of safe distances in practice, according to experiences in the country and abroad, Materials for the 10th Conference – Live-live working on low-, medium- and high-voltage power grids in Poland and the world, Łódź, 2010

[3] T. Musiał: Single- and double-circuit 110 kV lines – cable-overhead connections with the use of pipe poles

[4] E. Gulski, A. Rakowska, K. Siodła, P. Chojnowski: Role of operation testing and diagnostics of high-voltage power transmission cables with the use of sensitive measurement methods

[5] R. Nowicki, D. Słowiński: Selected issues related to 110 kV cable line design, 8th Conference on power cable lines – present condition, new techniques, PTPiREE Łódź 2011

[6] S. Widlas: Construction of 110 kV cable line along with fiber-optic routing for powering the National Stadium in Warsaw, 8th Conference on power cable lines – present condition, new techniques, PTPiREE, Łódź 2011

[7] B. Kubacki: Cabling of existing high- and low-voltage overhead lines. 220 kV cable line design – station (400kV)/220 kV/ 110 kV Świebodzice, 8th Conference on power cable lines – present condition, new techniques, PTPiREE, Łódź 2011

[8] A. Cichy: Installation of high-voltage cable lines based on experiences of Tele-Fonika Kable, 19th Training – Technical Conference KABEL 2012, Zakopane 2012

[9] E. Gulski, A. Rakowska, K. Siodła: Advanced methods for performance of voltage testing and diagnosis of the condition of high-voltage cable lines, 8th Conference on power cable lines – present condition, new techniques, PTPiREE, Łódź 2011

[10] G. Kochan, B. Dudek: Use of temporary line as an element for optimization of work of the transmission grid, Spektrum no. 9-10, 2012

[11] Dudek B., Widlas S.: Concept of Installation of Cable Heads on 110-400 kV Live Line Poles, Ref. 027 CITTES'2013, Concordia, Argentina

[12] Rozporządzenie Ministra Gospodarki z dnia 28 marca 2013 r. w sprawie bezpieczeństwa i higieny pracy przy urządzeniach energetycznych (Dz.U. z dn. 23 kwietnia 2013, poz. 492)