Initial training

1. Earthing according to rules in NSI-4
2. Fixed strap as safety measure against fall form height
3. Evacuation of injured from height
4. Assembly of working platform 21m
5. Replacement of insulators on strain support (chain 4x21>2x21)
6. Replacement of insulators on straight-line support (chain 2x21>1x21)
7. Sag adjustment
8. Repair of damaged wires
9. Safe work on carts
10. Measurement of bolt connection resistance and possible repair
11. Adaptation of strain support for work as straight-line support

There are ongoing works on the programme and training in the scope of work techniques in vicinity zone and of live works as well as various aspects of work safety both on turned-off as well as live lines [2]-[4].

REFERENCES

[1] B. Dudek, K. Mikołajczyk, L. Rogiński: Replacement of an existing ground wire by OPGW; experiences of the Polish work on the energized 400 kV overhead power line, Zagreb, ICOLIM'2011

[2] A. Balawender, B. Dudek: 220-750 kV overhead transmission lines live work, Toruń, ICOLIM'2008.

[3] J. Andruszkiewicz: Zagrożenia związane z oddziaływaniem napięć i prądów linii elektroenergetycznej przy pracach w pobliżu napięcia, Eltel Networks 2011

[4] L. Grzeszkiewicz, M. Schwann: Technical equipment of training field for practical teaching live voltage technology, Toruń, ICOLIM'2008.

[5] R. Tochman: Modern Polygon for Network Technologies, Presentation of Eltel Networks Olsztyn SA, Warsaw, 29.10.2013.

Wojciech Lubicki, Bogumił Dudek [1)]

PSE Inwestycje S.A.

Eighty years of Polish experiences in technology of live-line working and impressions from all 10 ICOLIM conferences

80 lat polskiego doświadczenia w dziedzinie technologii PPN oraz impresje związane z wszystkimi 10 konferencjami ICOLIM

Introduction

Historically, live-line technologies (PPN) in Poland have been started since 1933, so 80 years ago, while a regular and continuous progress in the development of PPN techniques next year will reach 40 years.

During the 75th anniversary of these works, Polish power engineers organized the European conference ICOLIM'2008, which was also attended by representatives from many countries including South America [1-10]. In addition, Poland has been organizing national conferences dedicated to this topic since 1988. Regular development of live-line working in Poland took place since 1975, when we started taking advantage of French experiences with low voltage lines, Irish experiences with medium voltage lines, as well as Hungarian, German, Russian, Italian and American experiences with high voltage lines 110-750kV.

Fig. 1. First live Line working in Poland (1933)

[1)] Wojciech Lubicki and Bogumił Dudek are PSE Inwestycje S.A. employees, 40-056 Katowice, Poland (e-mail: wojciech.lubicki@pse.pl, bogumil.dudek@pse.pl).

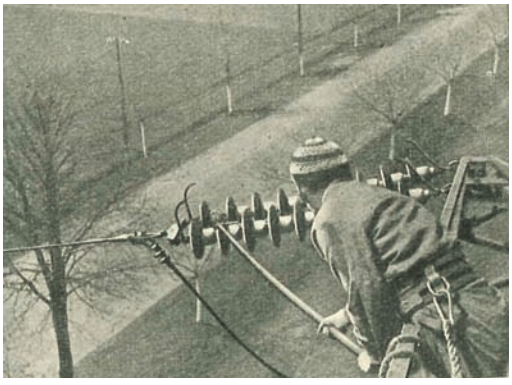

Fig. 2. Measuring the voltage distribution (1935)

Starting from 2003, we have been watching attentively organization of conferences dedicated to live-line working in Argentina, following achievements of South American power engineers, in both theory and practice.

The internet and globalization process opened new opportunities for exchange of experiences, contributing to development of power engineering in the scope of live-line maintenance technology and modernization of transmission and distribution power lines. An easier access to technical information and practical applications of live-line working around the world allow to believe that European and South American power engineers will find a common, regular platform for exchange of their experiences.

Polish experiences in live-line working

A great effort put in live-line maintenance techniques results from the necessity to meet the needs of customers in an unnoticed (power outages are noticeable) and discrete way, confirming superior quality of power supply that is the source of income of the power industry. Live-line working technology is also a source of satisfaction of power engineers themselves, since performance of works requires anticipation and imagination, discipline and coordinated teamwork, resulting in greater workplace safety. Development of this technology results from managers' broadened knowledge, confirming that it is worth investing in power equipment maintenance technology rather than agree to power outages guaranteed by contracts and the Energy Law. It improves prestige of the company, providing to customers utmost diligence in performance of works in relation to their expectations.

In 2011, three important conferences dedicated to live-line working technology were organized. Another European ICOLIM'2011 took place in the end of May and the beginning of June of the last year in Zagreb, Croatia. Slightly earlier, in mid-May, after five years of break, the ESMO'2011 conference was hosted by the Americans. It took place in Providence, the capital of the state of Rhode Island, USA. The fifth congress of live-line working took place in the end of August and the beginning of September in Salta, Argentine, gathering power engineers from South America, who organize biennial meetings within the CITTES Association. All conferences were organized in a similar way: theoretical – report part allows for exchange of experiences supported by theoretical considerations; exhibitions – possibilities for getting acquainted with products offered by manufacturers; and finally, live presentations showing the most important works and accomplishments of maintenance teams. This type of meetings is worth continuing.

Considering experiences around the world, across the European Union and also in Poland, one of the most interesting field, making possible improvement of power supply quality is live-line maintenance technology of power grids, installations and equipment. Workers servicing equipment are provided with greater workplace safety in comparison to traditional methods, whereas customers and corporate clients using this energy medium can count on comfort related to a new quality of its supply. Benefits are generated by enterprises trading in energy and the network operator, who has new possibilities for maintenance of equipment.

Since 2013 new Legal regulations binding in Poland allow for the use of live-line maintenance technology of power grids, installations and equipment. Works on power equipment and installations, depending on applied methods and measures assuring safety can be performed:

1) with power on,
2) in the proximity of power on,
3) with complete power off.

Design, production, import, construction and operation of equipment, installations and grids should assure rational, fuel- and energy-efficient use adhering to the Energy Law:

1) reliability of cooperation with the power grid,
2) safety of service personnel and the surrounding after meeting the requirements of environmental protection,
3) compliance with requirements of separate regulations, in particular regulations related to the Building Law, electric shock protection, fire protection, technical inspection, (…), Polish Standards implemented for mandatory use or other regulations resulting from power generation technology and the type of fuel that is used.

Starting from 2003, the use of Polish Standards has been voluntary in Poland; however it does not mean insubordination, and companies more often reach for standardized requirements, since they facilitate easier transfer of products and services playing a growing role in the European Union. The Polish equivalent of the Technical Committee 78 of the IEC is the Committee no. 72 for protective power equipment and live-line working of the Polish Committee for Standardization.

Polish legal regulations are conducive to development of live-line maintenance technology, which due to its nature makes possible work almost anytime. However, due to the cost of popularization of this technique, the range of use of live-line working technology is still insufficient.

During the ICOLIM'2008 conference, was presented an organized classification system of works for live-line technology, see Fig. 1.

Live-line maintenance technology of power grids is supported in a natural way by technology of works in the proximity of power on; therefore, leaving equipment with power on during works, one should consider works in the strong electromagnetic field generated by high-voltage equipment as a separate issue.

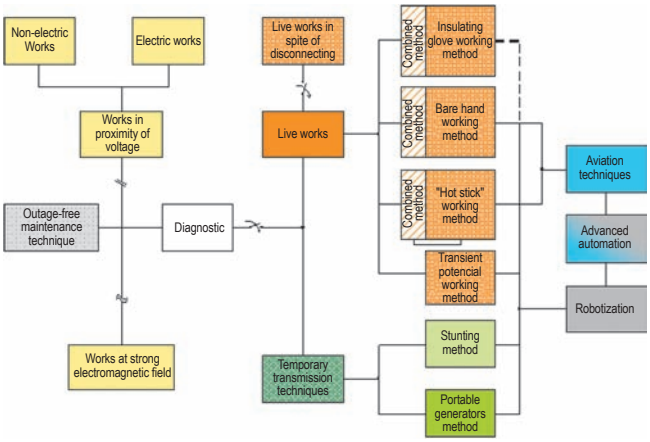

Fig. 3. Present operation on power grids with the use of live-line maintenance technology [1],[3],[10]

In the technology of life-line working applied directly in grid repairs several methods are being used:

- Method of work "in direct contact"

Easy to work, relatively uncomplicated design of tools and insulation materials make that the method is commonly used in power grids up to 1 kV, including overhead lines with bare or insulated wires, cable lines and switching equipment. This method can be used at a limited range on equipment over 1 kV, particularly since implementation of dielectric gloves and sleeves designed for voltage 36 kV. Practically all service activities on all types of equipment up to 1 kV can be performed with power on. For these works, all accessories are made in Poland. In recent years, some of the new products included a set of individual devices resistant to thermal activity of electric arc, including helmets with face screen, chin and neck protection. Women-only crews for live-line working have been reported as well; however, their participation on a larger scale faces occupational barriers.

- Method of work "from the distance"

The method of work "from the distance" consists in work with power on with the use of tools placed on hot sticks for live-line working by a worker staying on ground potential. This method is used primarily on medium-voltage grids (1-30 kV) and 110 kV voltage. It is used in maintenance of power equipment with power on – on medium-voltage stations and overhead lines, maintenance of disconnectors and replacement of insulation with the use of hot sticks, and low-voltage lines for permanent disconnection of branch lines by cutting off wires. Skillful use of this method can be used by rescue services, which without waiting for the Power Emergency Service can effectively commence rescue operation, requiring release of the facility from voltage (but they have to undergo specialized training). The most popular methods for maintenance of equipment include dry and wet methods as well

Fig. 4. Live-line working on low-voltage overhead line

Fig. 5. Installation of cable splicing kit on low-voltage cable

Fig. 6. Works on low-voltage cable joint

Fig. 7. Connection of a branch line to medium-voltage compact line using the method from the distance

Fig. 8. Connection of a branch line to medium-voltage compact line using the method from the distance

Fig. 9. Replacement of insulator chain (long rod) on 110kV line

Fig. 10. Refilling cable heads – using the method from the distance

Fig. 11. Replacement of insulation on 400 kV line

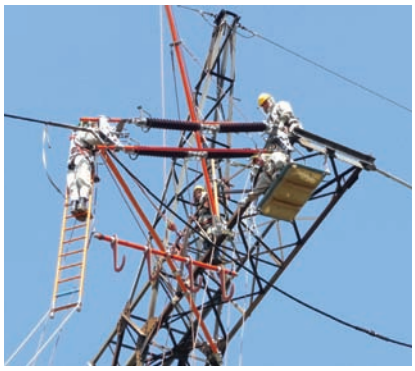

Fig. 12. Replacement of insulation on 220 kV line

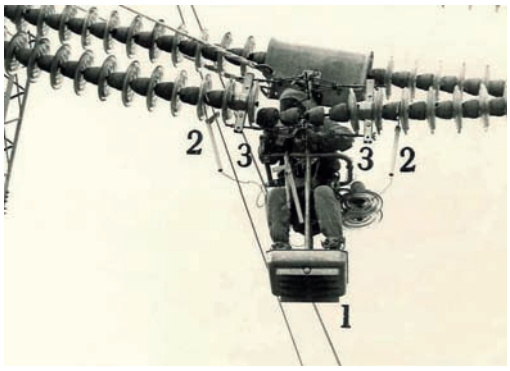

Fig. 13. Replacement of insulation on 750kV line (technology Hungarian) 1: chair assembler, 2: potential equalizer, 3: clevis screw adapter

as adding oil to cable heads. In addition to the commercial power industry, it is also used by industrial power production and DC railroad overhead lines with 3 kV in voltage.

- Method of work "on the potential"

The method of work "on the potential" consists in insulating worker from ground potential and other potentials than his own. This condition can be met with overhead lines and stations of the highest voltage, in which the distance between wires of different phases and parts of line with varied potential is sufficiently high. Insulation is achieved by using various methods, most frequently the use of lifts with insulation arms, ladders, footbridges and insulation cranes; composite insulators and insulation ropes are frequently used to assure insulation gaps. Mostly imported accessories are being used. In Poland, protective clothing was designed for electric field based on a dense net creating fabric from silver tinsel threads (2x10 mm alongside the warp) and parts of insulation equipment, e.g. insulation crane.

- "Combined" method of work

The combined method (combination of the 3 methods above) consists in performance of activities comprising maintenance procedure according to the principles of the method of work in direct contact, from the distance and on the potential. This method consists in utilization of components from three different methods in one work process. An example can be replacement of overhead lines with insulated lines. These works also incorporate lifts with the insulation arm.

Fig. 14. Live-line working performed from hoist cage – combined method

- Methods of works "on non-established potential"

This method is used primarily in transmission grid. Its primary advantage is a possibility of using shorter sticks than in the method of work from the distance. It is used sporadically as a supplement to other live-line working possibilities.

The use of mentioned methods with power on in grids with various levels of voltage are shown in Table 1.

Table 1

Possibilities for performance of live-line working on Polish power equipment

Method/facility	Power equipment					
	OSD – Distribution Grid Operator			OSP – Transmission Grid Operator		
	Installations	Distribution, industrial grid		Transmission Grid		
	up to 1 kV	1-30 kV	110 kV	220 kV	400 kV	750kV
in direct contact	+	+	-	-	-	-
from the distance	+	+	+	-	-	-
on the potential	-	-	+	+	+	+
combined	-	+	-	-	-	-
on non-established potential	-	-	-	+	+	+

Non-electrical works in the proximity of power on are usually performed in the scope of painting steel of poles by trained crews, for which live-line working teams prepare work area. Preparation consists in covering of insulators to prevent paint from dripping and installation of fences around zones outside permitted distances. Due to the electric field and induction phenomena, all painters use clothing that protects them against the influence of the electric field.

Electrical works in the proximity of power on are usually performed in the scope of replacement of shieldwires with fiber-optic wires of the OPGW type. These technologies are based on foreign equipment. Just like the painters due to the electric field and induction phenomena, all workers wear clothing that protect them against the influence of the electric field, whereas work stations (hoist and tensioner) are equipotential.

Diagnostics of equipment continues to develop and in addition to regular thermal-visual measurements, it uses testing of corona discharge on transmission grids with the use of helicopter. Incomplete testing methods are used more frequently as well.

Fig. 15. Painting of 400 kV line

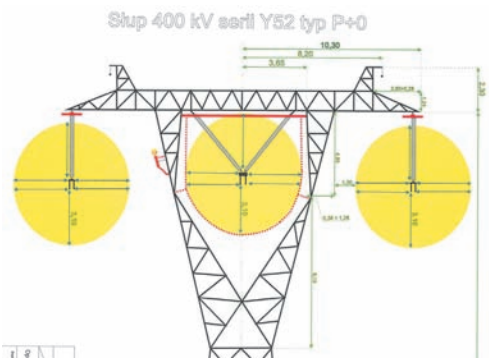

Fig. 16. Distance analysis for painting technology

Fig. 17. Replacement of shieldwires on OPGW on 400 kV line

In addition to live-line working technology, the second most important range of application is temporary transmission techniques. It consist of various types of shunts and portable generators. In group of shunts could be found: temporary lines, implemented by few companies, mobile by-pass bays and other devices, and also extend the application of transportable temporary cable lines. These methods are known from solutions used in non-voltage conditions, e.g. transmission stations equipped with rails, by-pass bridges, and on lower voltage equipment – various types of service by-passes. In live-line maintenance technology, by-passes are used in both stationary equipment, enabling inspections, repairs and overhead transmission lines, facilitating replacement of wire links.

Fig. 18. By-pass technics (220 - 400 kV line) – temporary line

Fig. 19. Demonstration connecting the generator to the busbar switchgear ([8], Zielona Góra 2013)

On lower levels of voltage, portable cable ropes are used that can be fastened and unfastened during work, or used for connections with very short breaks. The use of portable generators, known primarily from power generating units, serves as the foundation for designing guaranteed power supply systems, supplemented by accumulator batteries. Methods of connecting and using portable generators become more popular in Poland as a result of more frequent weather anomalies: in winter – related to hoar frost and wet snow, and in summer – related to very high temperatures oscillating around +40°C, which were extreme temperature during design, causing many breakdowns. Today, work of equipment is adjusted to temperatures +60°C or even +80°C, using live-line working technology, where possible.

We can actively notice progress in the use of artificial intelligence and robotization, also in Argentine and Brazil, where the initial applications generate measurable benefits for the power industry. Poland has also initiated works of this type. Similarly, the use of aviation technology, which has been applied by the power industry as a supplement to construction technology, has been successively developed since 1994 in the scope of regular inspections, particularly transmission grid and its diagnostics, for design purposes and support of operation processes. Since 2007, in addition to helicopters, preparation works have been continued on implementation of small crewless versions.

Fig. 20. The Polish unmanned helicopter during demonstration ([8], Gdańsk 2007)

Uninterruptable power supply in the light of European Union directives has an opportunity for dynamic development in every country, in which customer is the focus of attention. According to experiences to date, the use of these techniques is also safer

to workers. Uninterruptable power supply techniques allow to eliminate almost completely so-called scheduled outages. In addition, they lead to significant reduction of emergency shutdowns thanks to their practical assets.

From the point of view of the customer, quality standards of grid operations should be gradually improved, but new, additional costs are incurred. Customers also play the key role in assuring improvement of the quality. Due to this fact, the most important issue will be to reach compromise between the quality and the energy transmission and distribution cost.

Polish specialists participate in the works of various international committees involved in the topic of live-working technology, namely IEC, CENELEC, UNIPEDE, ISSA, and during organization of ICOLIM conference. They also follow technical progress presented during American conferences ESMO and activity of CIGRE. These experiences broaden knowledge, strengthen ties between specialists, allow for quick transfer of technology and equipment, leading to improvement of competitiveness of power companies, and greater reliability of power supply to customers improving with every year.

The Polish Committee for Security in Electrical Engineering (PKBwE) SEP is a member of ISSA, which in recent years developed the rudiments for a new look at selection of personnel for performance of electrical works, particularly live-line working. Another significant work is a guide to selection of clothing protecting against thermal effect of electric arc. Shortly, the use of this type of clothing will be mandatory; however its selection to working conditions will depend on evaluation of risk. Methods of assessment and evaluation of risk will be one of the bases for organization of work, which allow work with the use of any method, in order to assure the highest degree of accident-free environment for identified electric threats. In statistics to date, live-line working is a very safe technique (no fatal accidents were reported during these works), serving customers for whom uninterrupted power supply is of utmost importance.

Impressions from all 10 ICOLIM conferences

Technical and scientific conferences such as ICOLIM in Europe, ESMO in North America, CITTES in South America and a global CIGRE supply in recent years, many descriptions of specialized technology, theoretical considerations which should be noted [10].

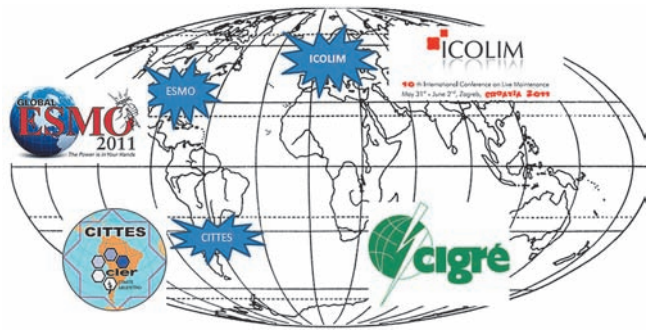

Fig. 21. LW conferences around the world

Inherent advantage of ICOLIM conferences is observed in presentation of huge effort put in live-line maintenance techniques. Additionally live-line working technology is also a source of satisfaction of power engineers themselves, resulting in greater workplace safety. It improves also prestige of the company, providing to customers utmost diligence in performance of works in relation to their expectations.

In Europe, the richest history have CIGRE sessions. During the CIGRE sessions live-line techniques are important issue from time to time. The permanent place among the conferences took ICOLIM dedicated to just these issues. This are an interdisciplinary conferences, with interesting frame using high performing audio-visual techniques, bringing together exhibitors and transforming theory into practical actions implemented through demonstrations of work. Organization of conference is also the enormous project, participants represents dozens of countries, often from different continents.

The initiator of the conference and the first organizer was PhD. Bela Csikos.

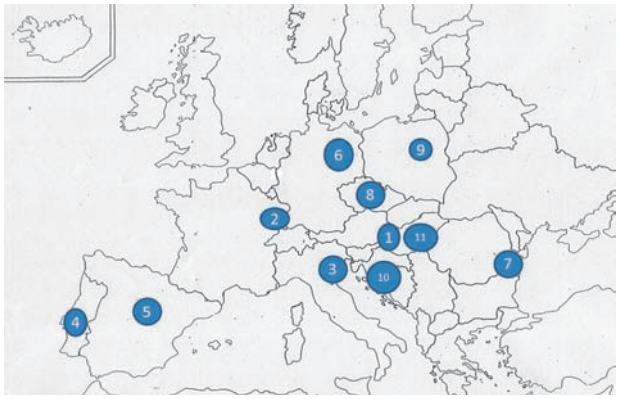

Fig. 22. Location of ICOLIM conferences

Fig. 23. Logos of all Conference ICOLIM

Fig. 24. Working meeting in 1987 on LW in Poland (dr B. Csikos on the left side, B. Dudek in the middle and A. Kimpian on the right side)

Fig. 25. ICOLIM'1992 – live-line demonstration using a anti-magnetic field shield concept of dr B. Csikos

Fig. 26. ICOLIM'1996 key demonstrations according to J. Meixner

Fig. 27. ICOLIM'2000 It is possible to work on live line – international cooperation of 5 country members

Thanks to his work, in Poland began operation of 750 kV transmission line.

Find also below some ideas from the previous conference ICOLIM in one word:

- 1992 concept of protection against the influence of the magnetic field
- 1994 research center and laboratories
- 1996 washing isolation from helicopters
- 1998 high values combination of merit and social, participation in EXPO'1998
- 2000 the work of the international brigades, women's brigade on the lift
- 2002 increasing the height of the pole of the energized line
- 2004 insulation tower installation for substation's work
- 2006 exchange of experiences and unexpected gala at the castle in Prague
- 2008 take advantage of the experience of other experts and strengthen the bonds of specialist
- 2011 robotic insulation arm

Fig. 28. ICOLIM'2011 Energy Connects Countries, ICOLIM Conferences Connect People

REFERENCES

[1] Special edition of the occasion of ICOLIM'2008 Energetyka nr 5, 2008

[2] Dudek B., Kołakowski T.: Power sector and anniversary of the century live-line technology around the world and eightieth anniversary PPN in Poland, Energetyka nr 3-4, 2012Special edition of the occasion of ICOLIM'2008 Energetyka nr 5, 2008

[3] Dudek B.: Live-line-working in electrical engineering – live-line maintenance techniques of distribution power grid, INPE (manual). Textbook 32, October 2010

[4] Dudek B.: Live-line-working in electrical engineering – live-line maintenance techniques of transmission power grid, INPE, (manual). Textbook 36, May 2011

[5] Report CIGRE 561 Live Work – A Management Perspective, Joint Working Group B2/B3.27, December 2013

[6] Materials from European conferences – ICOLIM from the years 1992 - 2011

[7] Materials from American conferences – ESMO from the years 1977 - 2011

[8] Materials from national live-line working conferences from the years 1988 - 2013

[9] Materials from South American live-line working conferences - CITTES from the years 2003 - 13

[10] B. Dudek, S. Widlas: 80 years of Polish experience in technology of live-line working, CITTES Concordia, Argentina 2013