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Using live working technology in the installation of AMI elements

Wykorzystanie technologii PPN do montażu urządzeń AMI

NOMENCLATURE
AMI - Advanced Metering Infrastructure.

Introduction

THE present EU legislation poses a number of very serious challenges for the power sector. Such challenges included

the fulfilment of the requirements included in the so-called Climate Package, which imposes the limitation of greenhouse gas emission by 20%, raising the share of renewable energy sources in the energy balance to 20% and increasing the energy efficiency by 20% by the year 2020. Another major step involves the activities included in the Directive of the European Parliament and of the Council on energy end-use efficiency and energy services. According to this document, the domestic indicative target within energy savings should amount to 9% of average annual energy consumption in the 9th year after the Directive comes into effect. It means that until 2016 our member state should generate energy savings of 9%.

Moreover, according to EU guidelines, member states are obliged to introduce a so-called smart grid, and in particular smart measuring systems. This is one of the mechanisms to boost the efficiency of energy consumption, which is listed both in the Directive on energy end-use efficiency and energy services and in the Directive of the European Parliament and of the Council 2009/72/EC of 13 July 2009 concerning the common rules of the internal market in electricity and repealing Directive 2003/54/EC.

The introduction of solutions related to the development of a smart grid, including smart measuring systems, has numerous advantages related, among other, to the limitation of energy consumption. Introducing smart measuring systems goes beyond a technical solution applied in the energy sector, as it provides also the two-way communication between a power company and a customer. Owing to this solution, an energy consumer will have non-stop access to information on the present energy consumption and its prices, which should allow one to manage energy consumption reasonably, use cheaper tariffs and influence the value of bills. These arguments show clearly how important the launch of the above-mentioned solutions is, considering in particular the obligations resulting from the Climate Package and the indicative target given in the Directive on energy efficiency.

ENERGA-OPERATOR SA was the first power distribution company in Poland to start working on the implementation of smart grids and smart measuring systems already in 2010.

The installation of AMI (Advanced Measuring Infrastructure) equipment involves mounting and connecting AMI meters at end users as well as the assembly and connection of balancing measuring cabinets that house balancing meters, concentrators, and communication modems in MV/LV substations.

The installation of AMI meters at end customers is carried out after interrupting electricity supplies. At the project implementation stage it was concluded that the impact of electricity supply interruptions on the SAIDI index would be minor, contrary to the impact of interruptions of electricity supplies necessary to install and connect a balancing measuring cabinet in MV/LV substations. The installation and connection of a measuring balancing cabinet in indoor MV/LV substations, in most cases, is carried out without any interruptions in electricity supplies to customers, owing to low voltage circuit back-up. The installation and connection of measuring balancing cabinets in MV/LW pole substations, due to the limited capacity of using back-up input circuits, would necessitate the disconnection of a substation and thus decrease the value of the SAIDI index. As a consequence, a decision was taken to use the live working technology to install AMI infrastructure elements. The project of developing this technology was commissioned from in-house engineering and technical resources of the Branch in Olsztyn and the Headquarters of the Company. The developed live working technology is a new method in Poland, used only by installation teams of ENERGA-OPERATOR SA within the implementation of the AMI project.

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A typical pole MV/LV substation

A typical pole MV/LV substation comprises a pole made of pre-tensioned prestressed spun concrete, on which the following are installed: a supportive structure, fittings and equipment and other elements of the substation. The electricity distribution is carried out with pole safety disconnectors or low-voltage switchgear (suspended or detached and installed on a foundation). In case of pole MV/LV substations where the electricity distribution is provided by pole safety disconnectors or suspended low-voltage switchgear, the application of a suspended balancing measuring cabinet has been proposed. Figure 1 presents a typical pole MV/LV substation, where the distribution of electricity is provided by pole safety disconnectors with the proposed mounting location for current transformers and a balancing measuring cabinet.

Figure 2 presents the low-voltage suspended switchgear together with the proposed location for installing a measuring balancing cabinet. With regard to pole MV/LV substations where energy distribution is provided with detached LV switchgear installed on a foundation, a detached measuring balancing cabinet has been proposed, also on foundation. Figure 3 shows the detached LV switchgear on foundation with the proposed site for installing the detached balancing measuring cabinet on foundation.

1 – Location for installing current transformers
2 – Mounting holders
3 – Terminals in a casing pipe
4 – Balancing measuring cabinet

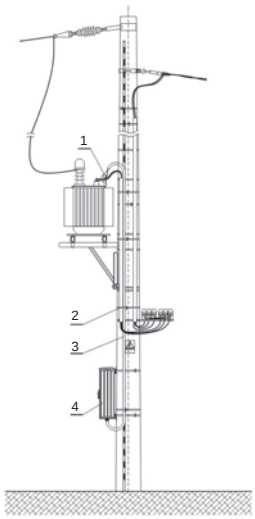


Fig. 1. View of a typical pole MV/LV substation where electricity is distributed with pole-mounted safety disconnectors in a suspended balancing measuring cabinet (source: M. Socha, LAMEL)

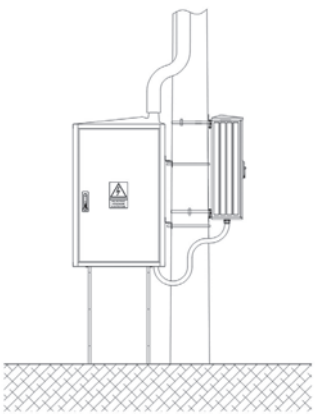


Fig. 2. View of a LV switchgear in a pole suspended MV/LV substation with a suspended measuring cabinet (source: M.Socha, LAMEL)

1 – MV/LV substation pole
2 – detached LV switchgear on a foundation
3 – balancing measuring cabinet

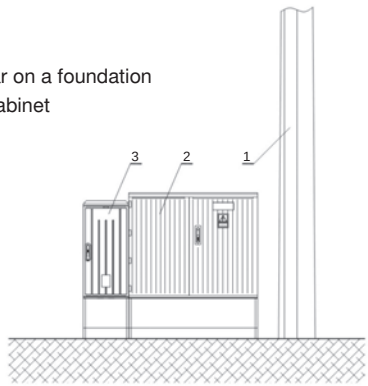


Fig. 3. View of detached LV switchgear on a foundation with a pole MV/LV substation with a balancing measuring cabinet on a foundation (source: M. Socha, LAMEL)

Balansing Measuring Cabinet

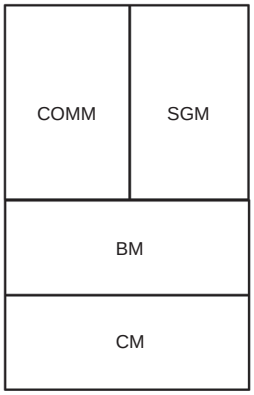
Three technical solutions of balancing measurements in the MV/LV substation have been proposed in order to implement the AMI project. The first solution is a mounting plate installed in the LV switchgear of the MV/LV substation (suspended or detached). This technical solution is applied primarily in new stations and in situations where there is enough space in the switchgear to install a mounting plate. A second solution is a balancing measuring cabinet that is suspended or detached on a foundation, which houses the same mounting plate as in the first technical solution. This technical solution is applied first and foremost in already operated substations.

A mounting plate of a balancing measuring cabinet consists of 4 basic modules:

- a connection module (CM) that comprises the installation apparatus and a terminal strip,
- a balancing module (BM) that consists of an electricity balancing meter and a concentrator in a shared housing, which is supplied by and collects metrological data from the LV grid via the 3-phase measuring semi-indirect system in the PLC technology,
- a communication module (COMM) that is fitted with a communication device that facilitates the transmission of metrological, remote control, and monitoring data between a source device and the measuring, control, and monitoring system, and
- SMART GRID module (SGM).

The view of a mounting plate in a vertical arrangement with the division into modules has been presented in Figure 4. The view of a typical balancing measuring cabinet is shown in Figure 5.

As the balancing measuring system of a pole MV/LV substation is a semi-indirect system, current transformers are an indispensable element of the AMI infrastructure. In case of a pole MV/LV substation, where the energy distribution is provided by pole safety disconnectors, a decision has been taken to use overhead current transformers installed in cycloaliphatic resin, resistant to the impact of atmospheric conditions. In case of other substations, built-in current transformers are used. The view of overhead current transformers installed in cycloaliphatic resin is presented in Figure 6, while current transformers are shown in Figure 7.



Module determination:
BM – a balancing module
SGM – a smart grid module
CM – a connection module
COMM – a communication module

Fig. 4 View of a mounting plate with modules in a vertical arrangement (source: by M.Schwann)

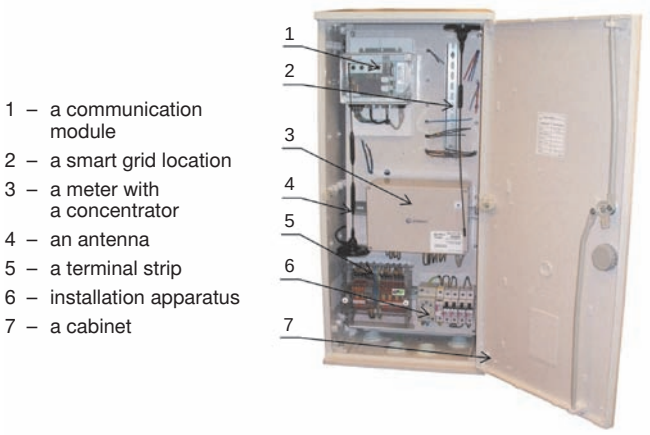


Fig. 5. View of a typical balancing measuring cabinet installed in pole MV/LV substations in the area of ENERGA-OPERATOR (source: M. Socha, LAMEL)

Fig. 6. View of a current transformer resistant to atmospheric conditions (source: M. Schwann)

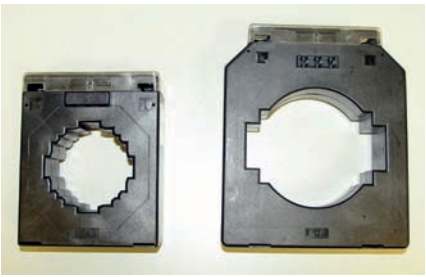


Fig. 7. View of built-in current transformers resistant to atmospheric conditions (source: M. Schwann)

Mounting and connecting elements of the AMI infrastructure on a pole MV/LV substation with the live working technology

The engineers delegated to develop the technology of mounting and connecting the AMI infrastructure elements on a pole MV/LV substation have decided first to use the existing live working technology applied on MV overhead lines with a lift fitted with an insulation arm and the technology of live working on LV switchgear.

The work related to mounting and installing the above-mentioned devices and equipment comprises several stages. In the first stage, which precedes the performance of live work, overhead current transformers have to be selected, the LV balancing measuring cabinet has to be installed and the conductors installed in a casing pipe on a pole. Figure 8 presents the MV/LV substation selected for the test of the live working technology in order to install and connect the AMI infrastructure elements. Figure 9 presents the installation of the balancing measuring cabinet on a substation pole.

The next step is to insulate the working zone, both on the MV and LV side, which is the beginning of the part of work carried out in the live working technology. The insulation of a working site on the MV side is carried out based on the Manual of live working in overhead 15 and 20 kV grids and based on the Planned Work Form. The wiremen who carry out the work wear electro-insulation gloves. The insulation of the working site and all work at heights are carried out from a stabbing basket with an insulation arm. The insulation of a working site on the LV side is carried out based on the Manual of live working on overhead cables and switchgear up to 1 kV. Figures 10, 11, and 12, present the insulation of the working site on the MV and LV sides.

Fig. 8. View of the pole MV/LV substation selected for the test of live working technology to connect the AMI infrastructure elements (source: M. Schwann)

Fig. 9. Mounting a balancing measuring cabinet on a MV/LV substation pole (source: M. Schwann)

Fig. 10, 11, 12. Insulating a working site on the MV and LV sides on the pole MV/LV substation (source: M.Schwann)

Next, a location for connecting the current wires of the balancing measuring cabinet has to be selected. They may be connected at the transformer terminals. The next step is to conduct the connection wires of the secondary winding of current transformers and the voltage wires via the casing pipe and to mount an insulation casing of a wire terminal on all wire terminals. After that, the current transformers are to be laid close to their target installation site, i.e. on a radiator tank at transformer terminals. Laying the current transformers on a radiator tank has been presented in Figure 13.

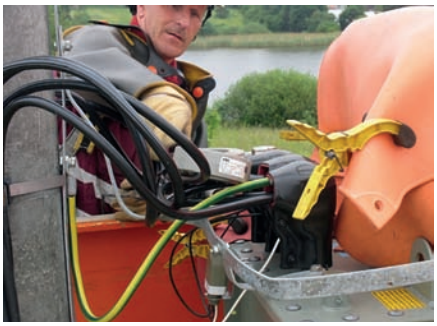


Fig. 13. Laying current transformers on the radiator tank (source: M. Schwann)

Next, the casing pipe is to be conducted into a proper gland in the lower part of the balancing measuring cabinet and the casing pipe is to be installed onto a pole with grips installed with steel tape. The next step is to connect the connection wire terminals of secondary winding of the current transformer for the first and consecutive phases in the short-circuited terminals of the terminal strip in the balancing measuring cabinet. After that, the protective-neutral wire and the phase wires of voltage conductors are to be connected to the proper terminals of the cabinet strip. At the other terminals of voltage conductors, the suitable terminals or sleeves are to be pressed, depending on the selected location of connecting the voltage conductors. After that, the protective-neutral wire and the phase wires are to be connected to a selected site of their connection, e.g. transformer terminals.

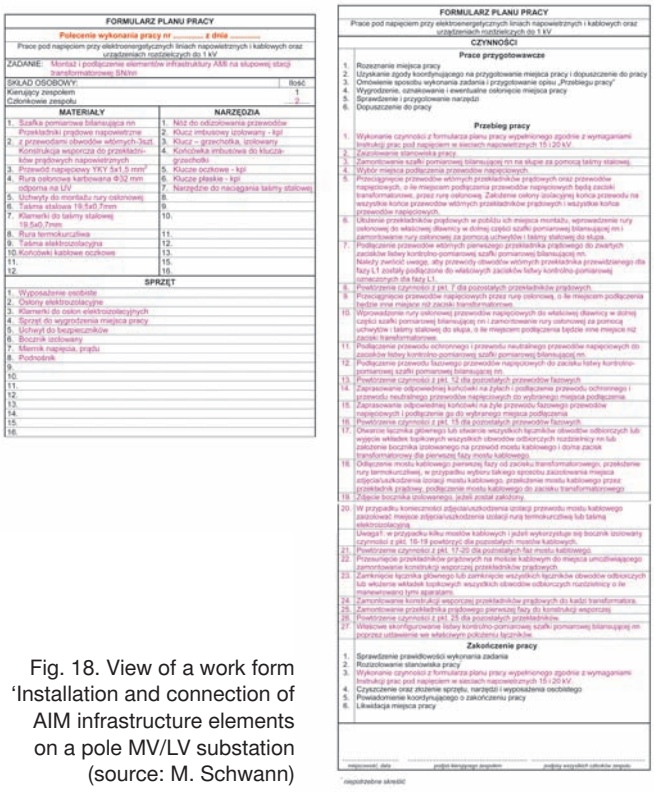
Fig. 14. Mounting a casing pipe of connection conductors (source: M. Schwann)

The next stage of the technology, i.e. mounting the connected current transformers on the cable bridge of the MV/LV substation, can be carried out in two ways: live with an insulated shunt or with disconnected voltage by opening the main disconnector of the LV switchgear. So far, ENERGA-OPERATOR SA has not developed any special terminals for such a shunt and only the second method is used at present.

Work related to mounting current transformers is to be started by opening the main disconnector of the LV switchgear. Next, the first phase of the cable bridge is to be connected to the transformer terminal, conducted through the current transformer and connected back to the transformer terminal. This activity is to be repeated for other phases. Current transformers are to be shifted on a cable bridge to such a location that they make it possible to install first the supportive structure of the transformers to the radiator tank and next the current transformers to the already installed supporting structure. Figures 15 and 16 show the installed current transformers on a cable bridge of a pole MV/LV substation.

Fig. 15, 16. Insulating a working station on the MV and LV side on a pole MV/LV substation (source: J.Sztukowski)

Fig. 17. View of a transformer with installed current transformers (source: P. Iwaniuk)



FORMULARZ PLANU PRACY

Polecenie wykonania pracy nr ..... z dnia .....

Prace pod napięciem przy elektroenergetycznych liniach napowietrznych i kablowych oraz urządzeniach rozdzielczych do 1 kV

ZADANIE: Montaż i podłączenie elementów infrastruktury AIM na słupowej stacji transformatorowej SN/nn

SKŁAD OSOBOWY:	Ilość
Kierujący zespołem	1
Członkowie zespołu	2

MATERIAŁY	NARZĘDZIA
1. Szafka pomiarowa bilansująca nn Przekładniki prądowe napowietrzne	1. Nóż do odizolowania przewodów
2. z przewodami obwodów wtórnych 3szt. Konsolka wsporcza do przekładników prądowych napowietrznych	2. Klucz imbusowy izolowany - kpl
3. Przewód napięciowy YKY 5x1,5 mm²	3. Klucz – grzechotka, izolowany
4. Rura osłonowa karbowana Φ32 mm odporna na UV	4. Końcówka imbusowa do klucza-grzechotki
5. Uchwyty do montażu rury osłonowej	5. Klucze oczkowe - kpl
6. Taśma stalowa 18.5x0.7mm	6. Klucze płaskie - kpl
7. Klamerki do taśmy stalowej 19.5x0.7mm	7. Narzędzie do naciągania taśmy stalowej
8. Rura termokurczliwa	8.
9. Taśma elektroizolacyjna	9.
10. Końcówki kablowe oczkowe	10.
11.	11.
12.	12.
	13.
	14.
	15.
	16.

SPRZĘT

1. Wyposażenie osobiste
2. Osłony elektroizolacyjne
3. Klamerki do osłon elektroizolacyjnych
4. Sprzęt do wygrodzenia miejsca pracy
5. Uchwyt do bezpieczników
6. Bocznik izolowany
7. Miernik napięcia, prądu
8. Podpórnik
9.
10.
11.
12.
13.
14.
15.
16.

FORMULARZ PLANU PRACY

Prace pod napięciem przy elektroenergetycznych liniach napowietrznych i kablowych oraz urządzeniach rozdzielczych do 1 kV

CZYNNOŚCI

Prace przygotowawcze

1. Rozeznanie miejsca pracy
2. Uzyskanie zgody koordynującego na przygotowanie miejsca pracy i dopuszczenie do pracy
3. Omówienie sposobu wykonania zadania i przygotowanie opisu „Przebiegu pracy"
4. Wyprodzenie, oznakowanie i ewentualne osłonięcie miejsca pracy
5. Sprawdzenie i przygotowanie narzędzi
6. Dopuszczenie do pracy

Przebieg pracy

1. Wykonanie czynności z formularza planu pracy wypełnionego zgodnie z wymaganiami instrukcji prac pod napięciem w sieciach napowietrznych 15 i 20 kV.
2. Zeszlowanie stanowiska pracy.
3. Zamontowanie szafki pomiarowej bilansującej nn na słupie za pomocą taśmy stalowej.
4. Wybór miejsca podłączenia przewodów napięciowych.
5. Przeciągnięcie przewodów wtórnych przekładników prądowych oraz przewodów napięciowych, o ile miejscem podłączenia przewodów napięciowych będą zaciski transformatorowe, przez rurę osłonową. Założenie osłony izolacyjnej końca przewodu na wszystkich końcach przewodów wtórnych przekładników prądowych i wszystkich końcach przewodów napięciowych.
6. Ułożenie przekładników prądowych w pobliżu ich miejsca montażu, wprowadzenie rury osłonowej do właściwej dławnicy w dolnej części szafki pomiarowej bilansującej nn i zamontowanie rury osłonowej za pomocą uchwytów i taśmy stalowej do słupa.
7. Podłączenie przewodów wtórnych pierwszego przekładnika prądowego do zwartych zacisków listwy kontrolno-pomiarowej szafki pomiarowej bilansującej nn. Należy pwtórzić uwagę, aby przewody obwodów wtórnych przekładnika przewidzianego dla fazy L1 zostały podłączone do właściwych zacisków listwy kontrolno-pomiarowej oznaczonych dla fazy L1.
8. Powtórzenie czynności z pkt. 7 dla pozostałych przekładników prądowych.
9. Przeciągnięcie przewodów napięciowych przez rurę osłonową, o ile miejscem podłączenia będzie inne miejsce niż zaciski transformatorowe.
10. Wprowadzenie rury osłonowej przewodów napięciowych do właściwej dławnicy w dolnej części szafki pomiarowej bilansującej nn i zamontowanie rury osłonowej za pomocą uchwytów i taśmy stalowej do słupa, o ile miejscem podłączenia będzie inne miejsce niż zaciski transformatorowe.
11. Podłączenie przewodu ochronnego i przewodu neutralnego przewodów napięciowych do zacisków listwy kontrolno-pomiarowej szafki pomiarowej bilansującej nn.
12. Podłączenie przewodu fazowego przewodów napięciowych do zacisku listwy kontrolno-pomiarowej szafki pomiarowej bilansującej nn.
13. Powtórzenie czynności z pkt. 12 dla pozostałych przewodów fazowych.
14. Zaprasowanie odpowiedniej końcówki na żyłach i podłączenie przewodu ochronnego i przewodu neutralnego przewodów napięciowych do wybranego miejsca podłączenia.
15. Zaprasowanie odpowiedniej końcówki na żyle przewodu fazowego przewodów napięciowych i podłączenie go do wybranego miejsca podłączenia.
16. Powtórzenie czynności z pkt. 15 dla pozostałych przewodów fazowych.
17. Otwarcie łącznika głównego lub otwarcie wszystkich łączników obwodów odbiorczych lub wyjęcie wkładek topikowych wszystkich obwodów odbiorczych rozdzielnicy nn lub założenie bocznika izolowanego na przewód mostu kablowego i dolna zacisk transformatorowy dla pierwszej fazy mostu kablowego.
18. Odłączenie mostu kablowego pierwszej fazy od zacisku transformatorowego, przekłożenie rury termokurczliwej, w przypadku wyboru takiego sposobu zaizolowania miejsca zdjęcia/uszkodzenia izolacji mostu kablowego, przekłożenie mostu kablowego przez przekładnik prądowy, podłączenie mostu kablowego do zacisku transformatorowego.
19. Zdjęcie bocznika izolowanego, jeżeli został założony.
20. W przypadku konieczności zdjęcia/uszkodzenia izolacji przewodu mostu kablowego zaizolować miejsce zdjęcia/uszkodzenia izolacji rurą termokurczliwą lub taśmą elektroizolacyjną.
Uwaga1: w przypadku kilku mostów kablowych i jeżeli wykorzystuje się bocznik izolowany czynności z pkt. 18-19 powtórzyć dla pozostałych mostów kablowych.
21. Powtórzenie czynności z pkt. 17-20 dla pozostałych faz mostu kablowego.
22. Przesunięcie przekładników prądowych na moście kablowym do miejsca umożliwiającego zamontowanie konstrukcji wsporczej przekładników prądowych.
23. Zamknięcie łącznika głównego lub zamknięcie wszystkich łączników obwodów odbiorczych lub włożenie wkładek topikowych wszystkich obwodów odbiorczych rozdzielnicy o ile manewrowano tymi aparatami.
24. Zamontowanie konstrukcji wsporczej przekładników prądowych do każdej transformatora.
25. Zamontowanie przekładnika prądowego pierwszej fazy do konstrukcji wsporczej.
26. Powtórzenie czynności z pkt. 25 dla pozostałych przekładników.
27. Właściwe skonfigurowanie listwy kontrolno-pomiarowej szafki pomiarowej bilansującej nn poprzez ustawienie we właściwych pokojach łączników.

Zakończenie pracy

1. Sprawdzenie prawidłowości wykonania zadania
2. Rozzalowanie stanowiska pracy
3. Wykonanie czynności z formularza planu pracy wypełnionego zgodnie z wymaganiami instrukcji prac pod napięciem w sieciach napowietrznych 15 i 20 kV.
4. Czyszczenie oraz złożenie sprzętu, narzędzi i wyposażenia osobistego
5. Powiadomienie koordynującego o zakończeniu pracy
6. Likwidacja miejsca pracy

miejscowość, data | podpis kierującego zespołem | podpisy wszystkich członków zespołu

niepotrzebne skreślić

Fig. 18. View of a work form 'Installation and connection of AIM infrastructure elements on a pole MV/LV substation (source: M. Schwann)

The next step is to configure the terminal strip in the balancing measuring cabinet. The final step, after verifying the correct performance of the task, is to remove the insulation and remove the working station. The view of a transformer with installed current transformers has been presented in Figure 17. The view of a completed form of a work plan is given in Figure 18.

Problems

The first problem that occurred during the performance of work was related to loosening the screws of transformer terminals of one of the manufacturers, which are commonly used in Poland, with insulated spanners applied in such work so far for live working on overhead and cable lines and switchgear up to 1 kV. It was not possible to manoeuvre the available tools due to the very small distance between the LV bushings of the transformer (only 8 cm between the LV bushing axes; taking account of the sizes of bushings, transformer strips and insulation shielding, only about 2 cm was left for moving an insulated spanner). Figures 19, 20, 21, and 22 present typical transformer terminals applied in Poland, while Figures 23 and 24 show bushings of the lower voltage of MV/LV switchgear transformers operated in Poland.

Fig. 23, 24. View of bushings in typical MV/LV distribution transformers applied in Poland (source: M. Schwann)

A solution was found that involved designing a new insulated spanner, i.e. a hex ratchet drill, which fulfilled the standard requirements for insulated tools used in live working. The HUBIX company, a known manufacturer of equipment and tools for live working in Europe, accepted the commission. The use of this spanner made the task possible. Figures 25 and 26 show prototype spanners for unscrewing and screwing hex screws of transformer LV terminals.

Fig. 25, 26. View of prototype insulated spanners for screwing and unscrewing hex screws of transformer LV terminals (source: HUBIX)

Wiremen involved in the execution of work reported another inconvenience, namely the insulation of radiator tank surface with a typical sheet, in order to provide protection against incidental touch, was uncomfortable and could contribute to the relocation of the insulation. They suggest a new design of the sheet with a cut and opening adapted to the lower voltage bushing of the MV/LV distribution transformer. The design of an insulation sheet according to such requirements has not been prepared yet.

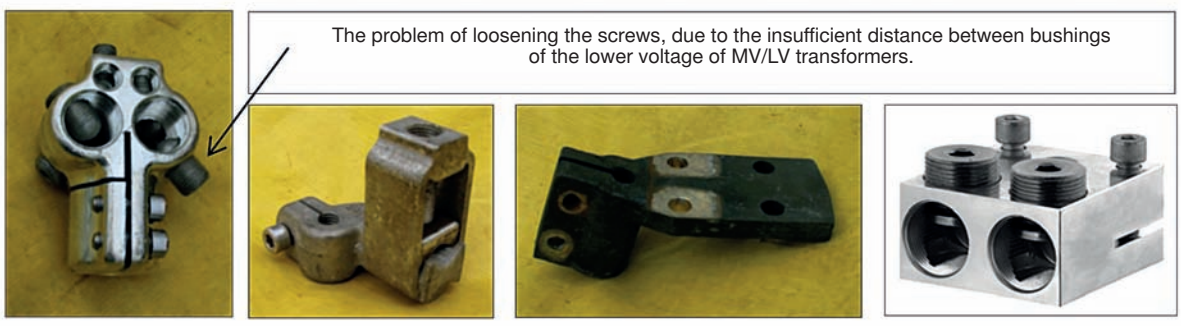


Fig. 19, 20, 21, 22. View of typical transformer terminals used in Poland (source Fig.19, 20, 21: M.Schwann, Fig. 22: Pfisterer)

Summary

Installing AMI equipment on pole MV/LV substations with the live working technology is an interesting alternative to the performance of such work with voltage disconnected. No additional expenditures are necessary, because it is based on existing live working technologies applied in MV overhead lines with a lift and an insulation arm as well as the live working technology applied in LV distribution equipment. This technology will certainly improve the SAIDI index significantly; however, in order to get even better effects in this regard, an insulated shunt has to be designed that makes it possible to shunt the LV cable bridge of a MV/LV pole substation for the period of its disconnection from transformer terminals.

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Polish electricians individual 2nd grade equipment to protect against the thermal hazards of electric arc according to PN-EN 61482

Indywidualne wyposażenie polskich monterów-elektryków w odzież 2 kl. ochrony przed zagrożeniami termicznymi spowodowanymi łukiem elektrycznym zgodnie z normą PN-EN 61482

Statistics of electric hazards

For many years the Association of Polish Electricians is deeply involved in issues related to safe operation of electric and electric power equipment and systems, including safety of both professional personnel and regular users.

Operation safety of electric systems is not limited to the requirement to provide protection against electric shocks but must also take account for overload and short fault currents, switching voltage surges of various nature or voltage fluctuations due to atmospheric discharges as well as numerous thermal effects. Efficiency of protection against such phenomena depends on many factors, including quality of electric system installation, applied protections and the practice to use protective means and measures.

The mentioned efficiency of protection against electric hazards can be measured by the number of fatalities due to electric shocks and the number of fires caused by faults in

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