Serious Accident in the Hungarian Medium Voltage Grid During Live Working

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***Abstract*— Although statistics prove that live working methods are safer than de-energized activities, in some cases accidents may occur due to the neglect of safety rules. Generally, more than one safety factor shall apply individually to guarantee the expected level of safety; however, routine, hurry, or inattention might be very dangerous even during quite simple activities. The rubber glove method is widely used in the whole territory of Hungary and is a common practice in the area of surroundings of Budapest for almost ten years. In the fall of 2018, an unfortunate and serious accident occurred during dismounting a pole-mounted switch. Although the terrain and the geometry were not usual, this looked like a routine job for the practiced crew. While the job was performed, one of the workers suffered a major electric shock. Despite the immediate medical help, permanent damage has occurred. This paper introduces the circumstances of the accident and the measures which were performed by the responsible DSO in cooperation with the training center of BME.**

Keywords—live working, medium voltage, accident, earth fault, pole-mounted switch, combined working method

I. Introduction

It is common to use live working (LW) or live line maintenance (LLM) to reduce consumer outages when maintaining the Hungarian distribution system. The hot stick, rubber gloves, and combined working methods resulting from the combination of the two are also used on the domestic network. There is a complex system of education, practice, and examination to put this into practice [1][2]. Working on a medium voltage grid requires a variety of eligibilities that allow people to qualify after completing the appropriate courses[1]-[4]. The equipment needed for LW work is continuously and regularly tested [5]. The acceptance and periodic tests are performed in a laboratory certified by the LLM Commission and documented by the LLM Certification [5]. There is a medium voltage training facility at the ELMŰ-ÉMÁSZ distribution system operator (DSO) site in cooperation with the Budapest University of Technology and Economics (BME) to skill all the workers in field conditions. Nonetheless, the human factor and the omissions can result in accidents while performing LW. This paper aims to illustrate the circumstances of a severe accident, revealing the causes and highlighting the consequences.

II. A Brief Excerpt from the Accident

The work accident took place on September 26, 2018, on the outskirts of Pányok in the northeastern part of Hungary.

The task was to dismantle and get down the previously substituted pole-mounted switch using the combined live working method. The team consisted of three people, and all three were MV-2 certificated workers fulfilling the job requirement. An insulated bucket truck (Versalift VST-5500–MHI, 46 kV) shown in Fig. 1. and associated live working equipment were used to perform the task. The necessary tools, insulating blankets, and personal protective equipment were available; they had the essential qualification. The weather was good for LW, with temperatures of 15-16 °C, sunny weather, and moderate winds at the time of the accident. On the grid part, a limited operational state was applied (LOS), the power line was prepared and suitable for LW. That task was the second and last one for the working group that day [6][7].

Fig. 1. The location of the accident with the pole and the bucket truck.

Upon arrival, the team assessed the conditions on-site and planned the intervention. Before the work, the role of the work leader was substituted by one of the workers (worker #1) due to a more evenly distributed workload. Thus, the former work leader took place at the workstation while worker #1 observed the task from the ground [6][7].

According to the plan, they started the work on the "A" side of the portal pole. The phase conditions of the pole-mounted switch are in Fig. 2. First, they loosened the pole-mounted switch fixing bolts and placed the "A" side four-branch hoisting rope branches between the L2-L3 and then L1-L2 phases from the bucket. The same operations would have been performed after navigating to the "B" side of the portal pole. It would then have been lifted off the pole-mounted switch with the auxiliary arm [6][7].

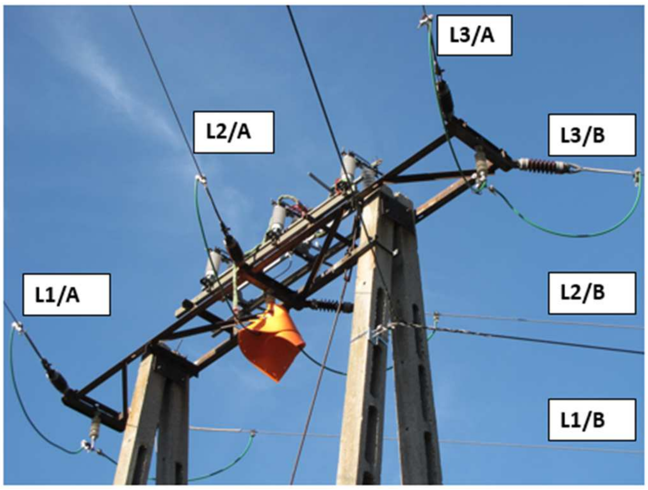

Fig. 2. The phase conditions of the pole-mounted switch are on the "A" and "B" sides.

The work leader and the third personnel (worker #2) approached the pole-mounted switch in the bucket. A total of 3 electrical insulator blankets were used for the "A" side cover. One for the L1 phase conductor, one for the LW insulator of the L2 phase jumper (this was the only cover on the network after the accident), and one for the L2 phase conductor was placed. After placing the insulating blankets, the fixing screws of the pole-mounted switch were removed between the phases L2-L3 (on the "A" side). The two branches of the four-pronged hoisting rope were then passed over the insulators of the middle phase of the closed switch and the other two branches. It was then fixed for lifting from the L3 phase conductor on the "A" side of the pole-mounted switch (Fig. 3). The rope was also set on the "B" side despite the initial plan since the working position was judged to be sufficiently safe [6][7].

Fig. 3. The pole-mounted switch partially prepared for lifting.

Then, the fixing screws were removed between the phase conductors L1 and L2. However, before attaching the third branch of the hoisting rope on the "A" side of the switch (from the L1 phase), the insulating blankets were removed from the L1 and L2 phase conductors, and the buckets were lowered outer the minimum approach distances (MAD). At that point, the protective gloves were removed. The goal was to take on a different work position [6][7].

After that, ascending with the boom, the safety metal contact wire of the handling jib's stift approached the L1 conductor within the MAD. Thus, the operating board in the bucket became energized (since all metal parts must be connected at the boom). The work leader handled the operating board without insulating gloves, so he contacted the phase potential through his left hand. At the same time, his right hand (approaching the grounded structural parts within the MAD) brought a ground potential into the system as a second contact point resulting in an earth fault. Thus, he suffered severe electric shock and burns in the bucket. The schematic drawing of the accident is presented in Fig. 4.

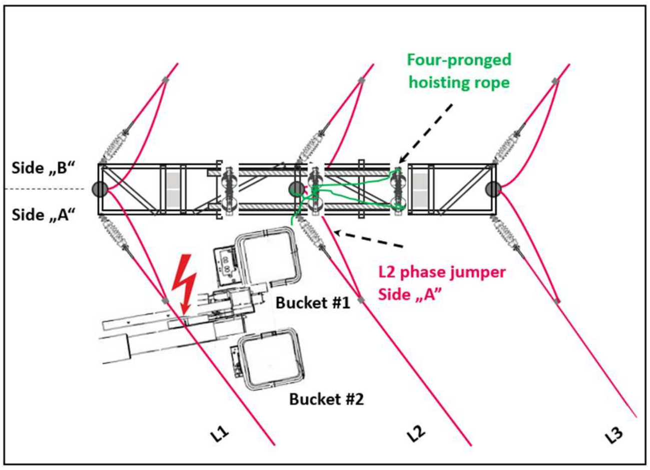

Fig. 4. The top-view of the accident on a quasi-scale drawing.

The injured were taken to hospital in a rescue helicopter. The accident was reported to the occupational safety and health authority. The accident was investigated with the involvement of all concerned [6][7].

III. THE PATH OF THE EARTH FAULT CURRENT

Based on the on-site reports and the evidence, it was possible to reveal the fault's current path during the accident, summarized in Table I [6][7].

TABLE I. THE PATH OF THE FAULT CURRENT.

	Element in the fault loop	**Evidence/Explanation**
A	The jib of the boom contacted the L1 phase conductor.	Melted metal stift on the jib and burn marks on the jumper
B	The metal stift of the jib connected to the operating panel in the bucket	An equipotential connection is present between all the metal parts around the buckets
C	The naked left hand of the work leader touched the operator panel	Arc marks on the operating board;
D	The naked right hand of the work leader touched the grounded part of the pole/cross arm	Arc marks around the L2 insulator and urn marks on the right hand

As described above, the upper boom reached the L1 phase at the metal wire rope securing the jib. This is supported by the fact that the securing metal wire rope has melted due to the fault current, and arc marks have been found on the L1 phase conductor at a distance from the jumper connector of approx. 15-20 cm. Because the metal stift (or the wire rope) is metallically connected to the operating board of the bucket vehicle, it was thus on phase potential. According to the standard for these vehicles, this connection was regular. All metal parts placed around the bucket must be brought to equal potential on a wire or a metal structure, e.g., joint, shaft - through. The work leader controlled the operating board from the bucket with his bare left hand, which connected him to the phase potential. As a result, arc marks were found on the operating board, and the work leader's left hand suffered an electric shock. His fellow also confirmed that he did not wear protective insulated gloves. The loop was finally closed when the leader touched the grounded part of the pole or cross arm with his right hand. This can be reconstructed from the fact that during the field, arc traces were found in the vicinity of the L2 phase conductor's tension insulator - in the direction of the L1 phase - on the cross arm and the pole-mounted switch frame. During the accident reconstruction, arc traces were also discovered at the metal base point of the L2 phase conductor tension insulator. Moreover, the injured person suffered a burn injury to his right hand due to the electric shock [6][7].

IV. Omissions Leading to the Accident

The coexistence of several omissions and deficiencies led to the accident. These are summarized below in Table II [6][7].

TABLE II. Omissions led to the accident.

ID	Omission	Responsible	Relevant regulation
1)	PPE: failure of the work leader to wear protective gloves or arm protector	Work leader	MV-WC-K.211/1.[1]
2)	PPE: failure of the worker to wear protective gloves or arm protector	Worker #2	MV-WC-K.211/1.
3)	Improper use of insulating blankets	Work leader	MV-WC-K.211/1. 2.7 part
4)	Failure to observe prescribed safety distances	Work leader, Worker #2	MV-WC-K.211/3. Table 3.1
5)	Lack of supervisory activity	Work leader	LLM SR 7.3.1[2]
6)	Performing other activities while managing the operating board	Work leader	MV-LLM Education material[3]
7)	Mutual liability as a non-compliance taboo rule	Worker #1, Worker #2	Taboo rules

[1]MV-WC: Medium voltage Working Conditions

[2]LLM SR: Live line working Safety Regulations

[3]MV-LLM: Medium voltage live line maintenance

The first omission was that the work leader most likely took off the protective gloves and arm guards even within the minimum approach distance. This violated the Working Conditions for medium voltage LWs. While only the work leader was injured, the situation was similar for worker #1. Given that he was in the other bucket and the two buckets were at the same height, he was also at risk of injury. The next omission was the improper use of insulating blankets. Three insulating covers were used during the work, one on the L1 phase conductor, one on the LW insulator of the L2 phase jumper, and one on the L2 phase conductor [6][7].

Although blankets did not cover the other jumpers, they should have been, as the sheathed conductor cannot be considered insulated. This should have been done before covering the insulator.

The third problem, relating to non-compliance with the prescribed safety distances, must be addressed separately from the above. According to the rules, no part of the bucket truck should be closer than 30 cm to the bare phase conductor. The required minimum approach safety distance could not be kept during the boom movement before the accident regarding the uncovered network components. All three members stated that they did not know that the metal parts around the bucket were in metallic contact and that the supplementary boom or the jib's metal part could conduct phase potential to the operating board. However, this information is also included in the truck's operation and maintenance manual, and there are warning pictograms placed on the truck, as presented in Fig. 5. [6][7].

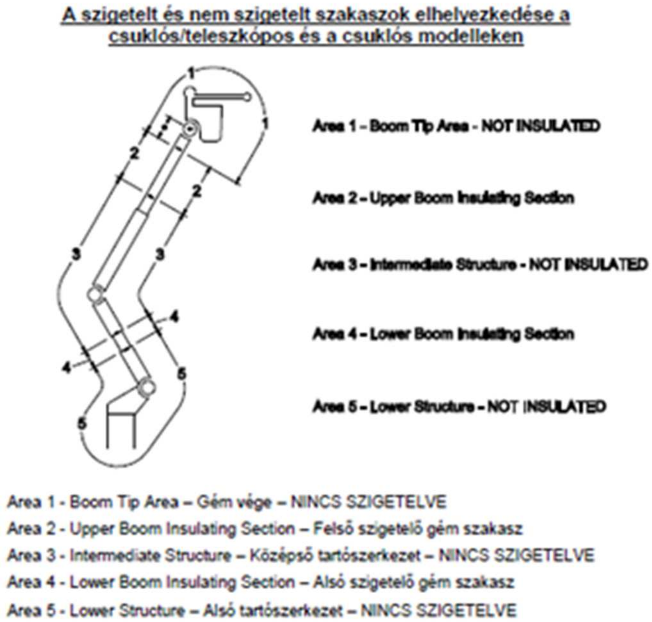

Fig. 5. Warning pictogram on the boom truck.

The subsequent omission can be attributed to the work leader who took worker #1 position due to a more even workload on the team members. Although he handed over the supervision tasks, he did not specify the exact location of worker #1, so worker #1 was in the vicinity of the left rear corner of the bucket truck. During the reconstruction of the accident (Fig. 6), it was established that from this position, looking almost vertically upwards from below the bucket, it was not possible to see how far the workers in the bucket and the upper boom were from the phase conductors. It was also impossible to estimate whether the required safety distances could be maintained. The location of the supervisor (worker #1) was not appropriate [6][7].

Fig. 6. Accident reconstruction on the pole.

The following omission can be attributed to the approach of the ground potential point. Although the exact situation cannot be reconstructed, the most likely scenario was that the work leader tried to reach for the third leg of the four-pronged hoisting rope with his right hand. Its purpose was to secure it to the pole-mounted switch since it was not connected in that position. Fixing the lifting arm at L1 at the "A" side, between the L1 and L2 phase conductors, would have been an obvious and comfortable solution. However, the blankets were removed from the L1 and L2 phase conductors, and the personal protective equipment was also released. Furthermore, the bare left hand of the work leader was on the operating panel at phase potential [6][7].

It is important to note that the phase distances were quite large - 1.8 m - due to the unique, large cross arm - 4.5 m long. These unregular distances could also catalyze the incorrect interpretation of the safety distances.

Finally, the rule of reciprocity liability has also been violated. Neither worker #1 nor worker #2 warned the work leader or each other of the dangers of early removal of personal protective equipment, improper use of insulating blankets, or failure to keep prescribed safety distances [6][7].

V. Actions to Avoid Further Accidents

Following the accident, the concerned DSO identified the causes and developed an action plan to avoid similar situations in the future.

Given that the accident was partly due to improper use of the equipment and disregard for safety distances, the DSO ordered extraordinary refresher training for employees with an LLM certificate. In this training, special attention was paid to the correct use of PPE, a detailed discussion of the importance of safety distances, and the importance of taboo rules through case studies. During the training, the necessary and sufficient use of insulating blankets during the work was also a topic. Furthermore, the boom structure, the distinction between insulated and non-insulated parts, and the role of optimal position selection during interventions were discussed in detail. The roles and responsibilities in the working group and the proper handling of the insulation bucket truck were also addressed in detail. As a next step, the MV-LLM tutorial videos have been reviewed, refreshed, and updated for proper visualization [6][7].

Since the bucket truck was damaged in the accident during the fault current, the DSO also took safety measurements on the vehicle. So that, an extraordinary inspection of the insulated bucket was carried out from the electrical safety point of view. To avoid similar situations in the future, the DSO contacted the manufacturer to investigate whether the jib metal wire could be placed or covered in another way [6][7].

To apply the proper technological steps, the use of PPE has been re-evaluated, and the MV Working Conditions document has been amended accordingly. In addition, a system has been developed that provides multiple-check and multi-site feedback to the workers. As part of this, MV-LLM audits within the company were optimized, and an external partner (BME) was asked to perform independent, quick feedback. Furthermore, a written sequence of operations was introduced for MV jobs before starting each work. In addition, an analysis of the preparedness and experience of LW workers has begun [6][7].

Finally, since the accident, it has been introduced to consider that significantly different work tasks (e.g., switching vs. MV-LLM) should not be recruited for a given day, thus causing time constraints on workers.

The changes introduced and the decisions made aimed to reduce the risk of accidents, thereby increasing the safety of LW's work.

VI. Conclusion

This paper aimed to illustrate an accident during a medium voltage LW job. In addition to a detailed description of the circumstances, the possible path of the fault current and omissions leading to the accident was also presented. Based on the on-site reports, analyses and reconstruction, it can be seen that the coexistence of several minor omissions led to the accident. If the PPE and insulating blankets had been used correctly or the safety distances had been observed, an accident would most likely have been avoided. Unfortunately, as a result of the event, a personal injury occurred. Following the accident, not only the causes of the accident were explored, but a process was launched to make LW work safer. In this context, a non-standard refresher training was ordered for the qualified workers, and the PPE section of Medium Voltage Operation Condition was also revised. With the involvement of an independent, external partner (BME), LW workers are currently receiving continuous and rapid feedback on their work. The internal control system within the company has also expanded. The purpose of the adopted procedures is to prevent similar accidents in the future and thus make LW work safer.

References

[1] CIGRE. Live Work - A Management Perspective (Technical Brochure No 561). Joint Working Group 82/83.27 (JWG 27), December 2013.

[2] Hungarian Safety Regulations of Live-line maintenance

[3] 72/2003. (X.29.) GKM regulation

[4] 60/2005. (VII.18.) GKM regulation for the modification of the 72/2003. (X. 29.) GKM safety regulation

[5] Hungarian Working Conditions for MV-LLM

[6] RCA report – MV-LLM accident, Innogy ELMŰ-ÉMÁSZ Group, 2018

[7] Report on the MV-LLM accident, Budapest University of Technology and Economics, 2018