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# Live Line Maintenance of Transmission Lines: A Review

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***Abstract*— The need for continues and uninterruptable supply of power to costumers has enforced the grid owners to the necessity of performing transmission line maintenance while the line is energized and conducting. This paper provides a review on live line maintenance of transmission line and presents the practical methods and techniques deployed to perform the live line maintenance in the traditional and robotic perspectives and the contribution of many disciplines such as Hydro Québec TE research institute (IREQ) in the field of automating live work. Furthermore, it focuses on the safety considerations during the live line work and how performing the maintenance is safer when the line is energized rather than de-energized. The paper also offers the future vision of live line work in the industry and what developments and goals to be achieved to prevent hazards and increase process efficiency.**

***Keywords—Live transmission lines maintenace; robotic; safety***

## I. INTRODUCTION

Increasing the demand of energy with the presence of aging assets put a high pressure on power transmission network owners on ensuring a reliable and an interruptible supply of power to their respective customers [3]. A case that led to the emerging of techniques to perform the maintenance of transmission line on a live base.

The maintenance of conductors, insulators, structures and other transmission line parts without de-energizing the network is called the live line maintenance of transmission lines. The activities taken under this concept are: repair overhead lines, bus bars, or earthing wires, close distance inspection of the line, and insulators repair, replacement, inspection as well as live line washing of the insulators [18].

Live line maintenance techniques have been researched and applied for more than fifty years with voltages below and up to 500 kV. However, with the continuous contribution on live line maintenance techniques, in April 2008, China has recorded the successful implementation of live line working under 1000 kV UHV in Wuhan which is a huge advancement in the science of live line maintenance [16].

In this paper, the methods and techniques that are deployed to perform the maintenance of transmission line while the circuit is live we be presented. Then, it will be followed by the safety considerations that need to be taken in account while performing the work. At the end of this paper, the future vision of live line maintenance of transmission lines will be stated.

## II. METHODS AND TECHNIQUES OF LIVE LINE MAINTENANCE

The methods and techniques deployed to prevent the significant hazards and the possibility flow of current through workers in live line maintenance are:

### *A. Hot Stick*

Hot stick is a live tool that creates a significant impedance between the line worker and the live equipment in order to prevent hazards the line worker may experience [22]. It is a pole usually made from fiberglass and depending on the tool attached to its end, certain tasks on the live equipment are performed. Such tools are used to replace fuses, open/close switches, lay insulating sleeves, test for voltage, and various other tasks that will prevent the line worker exposing to danger [18].

Fig.1. Live line maintenance using hot stick

Hot stick comes in different lengths to keep the line worker in a certain distance from the live equipment and depending on the voltage the line worker is performing tasks on, the distance from the live equipment needs to be considered accordingly.

Table-1: OSHA Standard for working on Energized Parts

| Voltage (Phase to Phase, kV) | Minimum Clearance Distance (Feet) |
|---|---|
| 46.1 – 72.5 | 3 |
| 72.6 - 121 | 3.4 |
| 138 - 145 | 3.6 |
| 161 - 169 | 3.8 |
| 230 - 242 | 5 |
| 345 - 362 | 7 |
| 500 - 552 | 11 |

### *B. Insulating Glove or Rubber Glove Working*

Insulating gloves protect the line worker from any hazards when direct contact made to the energized equipment.

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However, under this circumstance, more than one protection barrier need to be deployed in the form of insulating gloves. For the 1st point of contact (where the current would enter the body), insulating gloves are utilized to prevent the flow of current through the line worker. However, for the 2nd point of contact (where the current would leave the body) the line worker makes with the ground potential or any other point of contact a work platform or an aerial device bucket truck are utilized to protect the line worker [25].

Fig. 2. Live line maintenance using insulating or rubber gloves

*C. Bare Hand*

Nearly 16% of the maintenance tasks undertaken on live transmission lines in Italy are conducted using the bare hand method. In this method, the line worker is placed at the same potential as the conductor with taking into account keeping safe clearance from ground level [24]. Michael Faraday has proved that electricity between any two similar potential points will be the same. Therefore, if the line worker is shielded with a Faraday's cage and bonded with a similar conductor potential points, then the line worker can work on the conductor and its associated hardware without any hazards, danger, and shock.

Fig. 3. Live line maintenance using bare hand

*D. Helicopter*

A line worker with the necessary insulation requirements can perform the live line working from a helicopter using either the platform or sling method. In the platform method, the platform is rigidly attached as well as electrically bonded to the helicopter with the line worker (which will have the same potential as the line) positioned in the platform facing the transmission line to perform the necessary tasks. Whereas in the sling method, as the line worker approach the line, an electrical arc will be generated as the line worker is charged in which the line worker needs to immediately bond to the line to prevent additional arcing by using method such as conducting wand to be at the same potential so that the line worker can perform the live line work safely [8][9].

Fig. 4. Live line maintenance using helicopter platform

Fig. 5. Live line maintenance using helicopter sling

*E. Robotic Technologies*

Robotic technologies have come into play in order to reduce the risks the line worker may encounter and increase the reliably of live line work on energized equipment [7]. Such contribution and efforts have been devoted in robotic field in regard to live line working and some of the robotic technologies currently in play are:

*1) Ground Based Robots*

In this technology, robotic arm that can be remotely controlled is being deployed to meet the requirement of electrical industry and to handle some special tasks on energized conductors of different voltages such as relocation or moving. The development of this technology was also intended to address some live line working needs such as replacing rotten poles with the utilization of the existing hole, reframing/reinsulating structures, ...etc. [7].

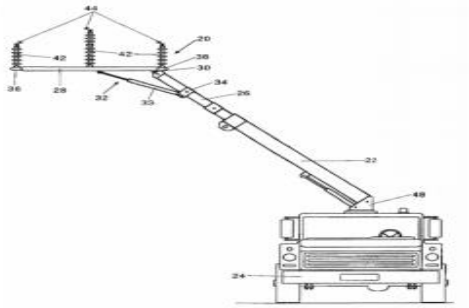

Fig. 6. Live line maintenance using ground based robots

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*2) Robots Suspended from the Line*

Hydro Québec TE research institute (IREQ) has devoted extensive efforts in the development of suspended robots for live line working [7]. The LineRover shown in Fig.7 is first developed in 2006 for de-icing in live line work [3]. Subsequently, the LineScout has been introduced to operate on up to 6 conductor bundles and can cross line obstacles up to 0.76 m in diameter in addition to its capability of visual inspection of the line using four operator cameras, applying sensors to the line for specific measurements, and temporary repair of certain components [1]. Further to IREQ contributions, Hibot corporation has come into play in 2009 to introduce the Explainer. A suspended robot that has the capabilities to visually inspect the line by cameras and detect corrosion. Furthermore, many later contributions/development up to this day have been devoted in this field [7].

Fig. 7. LineRover robot

Fig. 8. LineScout robot

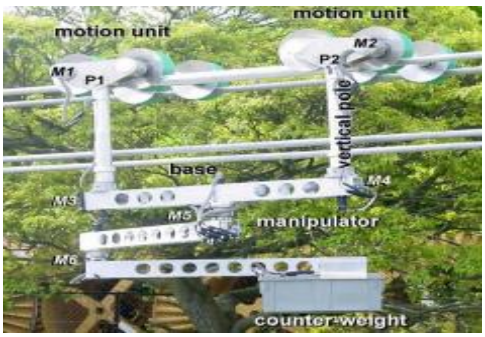


Fig. 9. Explainer robot

*3) Aerial Based Robots*

The development of unmanned helicopter to perform the inspection task in energized transmission lines is first carried out by Chugoku Electric Power Co., in Japan [7]. The helicopter is equipped with cameras, GBS, and image transmission equipment and fly in predefined routes along the transmission network to perform the inspection task. The robot wirelessly transmits its own position as well as taken images to the observer during the inspection process [29].

Fig. 10. Aerial based robot

## III. SAFETY CONSIDERATIONS

A golden rule in hot line operations is “no guarantee for safety when life is at stake”. In high voltage lines, records proved that maintenance work is actually safer to take place when the line is energized rather that de-energized which could possibly be energized while the work is being performed. Line worker awareness of the danger involved in energized equipment will lead to work more cautiously and keep required distances [18].

- It should be kept in mind that the line worker should keep a safe distance from the earth point as well as other phases of the line to prevent hazards [17] [23] [26].
- Perform the hot line work using safety equipment such as hot stick, insulating gloves, …etc.
- Always test the tools before initiating the work and never use a tool that you are not familiar with and never perform the work using damper tool [18].
- Manufacturer’s ratings of hot line tools should not be exceeded and the line worker should be aware of the conductor span weight and tension with the parts dealing with [27].
- Check regularly for indication if the tools have been mechanically or electrically overstressed so that careful inspection and testing is encountered before returning them to service [27].
- The live line tools should not be placed on ground, they should be kept on the tool container when they are not in use [18].
- Manual inspection should be performed for all live line tools and testing for electrical strength should be implemented at the site [18].
- Depending on voltage class, Insulators in the string shall all be in a healthy condition except one or two [18].
- For electrical clearance calculations, altitude correction factor should be deployed [26] [28].
- Distance for the accidental movement of the line worker to the energized equipment shall be considered and in which this depends on the line worker experience as well as the work procedure [17] [18] [23] [26].

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- Line worker shall obey to the safety code on energized equipment work in him\her respective country.

## IV. FUTURE VISION

Since 1980, contributions in the robotic technologies field for live line maintenance have been carried out and many have come into the practical use to perform special live line work such as the discussed ground based, suspended, and aerial robots [7] [30].

According to energy experts, future live line work will be monitoring date remotely online, intelligent maintenance technologies, precise evaluation and reliability analysis systems. There is a need for the development of high voltage automated tools and their life cycle estimation to prevent any hazards the line worker may experience and ensure continuous utilization [18].

- Renovation and modernization of power generation sector
- National grid development
- Strengthened the involvement of renewable energy in the sector
- Utilization of modern technologies for power conservation (DSM)
- Employing cogeneration principal
- Energy audit institution
- Use of innovative business models

## V. CONCLUSION

This paper presents a review in the transmission line maintenance when the line is energized. The methods and techniques used are hot stick, insulating glove or rubber clove, bare hand, helicopter, and robotic technologies including ground based, suspended, and aerial robots. This paper states the safety considerations when live work is being carried out and how performing the line maintenance is safer when the line is energized due to the line worker being aware of the danger involved which will lead to more cautious work than de-energized which could possibly be energized.

The future vision in live line maintenance includes the adoption of automated tools to prevent any danger for humanity and increase efficiency.

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