New Approaches for Live Wire Maintenance of Transmission Lines

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ABSTRACT

In electrical engineering, live-line working is the maintenance of electrical equipment, often operating at high voltage, while the equipment is energized. Electricity utilities wish to avoid loss of supply, for which they receive customer complaints or are financially penalized. At the same time they are obligated to maintain and replace their electrical equipment on a regular basis. Due to the hazard of high voltage, it is normally necessary for equipment to be isolated from the supply before being worked upon, termed a planned outage. The first techniques for live-line working were developed in the early years of the 20th century, and both equipment and work methods were later refined to deal with increasingly higher voltages. In the 1960s, methods were developed in the laboratory to to come into direct contact with high voltage lines. Such methods can be applied to enable safe work at the highest transmission voltages.

I. INTRODUCTION

The maintenance of line conductors, line insulators, structural, parts etc. without de-energizing the line and with live line is called live line maintenance. The activities in live-line maintenance include:

- Repair of conductor of overhead line or overhead bus bars, overhead earthing wire, while circuit is live.
- Inspection from close distance while circuit live.
- Inspection/repairs/replacements of Insulators, with circuit live.
- Live line washing of insulators.

These terms associated with the state of the circuits are:

Live: Connected to the voltage source.
Dead: Disconnected and earthed.
Disconnected: Disconnected, not earthed.

Condition dead is safest, but under circumstances live line maintenance is essential. Person working in the vicinity of a live conductor is subjected to electric field stress. If the person is insulated earth, he will be charged by the alternating electric field. The charging will depend upon the position of the person in the field and the field strength. If the person is touching the grounded part, current will flow through his body to the earth[1].

1. Tools for live-line maintenance—Insulating ladder, usually laminate depoxy resin bounded wood section or fiber-glass resin insulated section.
- Insulated tongs
- Clip-on-instruments
- Rods for installing earth connection clamps
- Sky-lifts(platform and cage which can be raised, lowered, rotated held in position from ground control)
- Telescopic insulating platform
- Insulating gloves, shoes, mats, supports
- Temporary guards
- Special dress with embedded wire-mesh which can be earthed to the cage.

II. TRANSMISSION LINE

A transmission line is the material medium or structure that forms all or part of a path from one place to another for directing the transmission of energy, such as electromagnetic wave or acoustic waves, as well as electric power transmission [2].
Types of transmission line include wires, coaxial cables, dielectric slabs, strip lines, optical fiber, electric power line, and waveguides.

III. OVERHEAD POWER LINE

Overhead power transmission lines are classified in the electrical power industry by the range of voltages:

Low voltage – less than 1000 volts, used for connection between a residential or small commercial customer and the utility.

Medium Voltage (Distribution) – between 1000 volts (1 kV) and to about 33 kV, used for distribution in urban and rural areas.

High Voltage (Subtransmission if 33-115kV and transmission if 115kV+) – between 33 kV and about 230 kV, used for subtransmission and transmission of bulk quantities of electric power and connection to very large consumers.

Extra High Voltage (Transmission) – over 230 kV, up to about 800 kV, used for long distance, very high power transmission.

Ultra High Voltage – higher than 800 kV.

IV. ELECTRIC POWER TRANSMISSION

“High voltage electric transmission” is the bulk transfer of electrical energy, from generating plants (historically hydroelectric, nuclear, natural gas, or coal fired but now also wind, solar, geothermal and other forms of renewable energy) to substations located near to population centers. This is distinct from the local wiring between high voltage substations and customers, which is typically referred to as electricity distribution. [3]

V. METHODOLOGY OF LIVE LINE MAINTENANCE

There are two basic Live Line methodologies for High Voltage (HV) work, which in industry terminology are called ‘Hot-stick’ and ‘Bare-hand’ methods:

Using hot-stick methods, direct human contact with live components is avoided. Line workers use tools fastened to insulated fibre glass poles to carry out the work, and always keep themselves at a safe distance from the live components.

VI. METHODS

There thus can be an economic advantage to live-line working, but this comes with considerable hazards unless the proper precautions are strictly followed to ensure workers’ safety.

In general, there are three methods of live-line working.

A. Hot Stick

The work is carried out with insulated tools, such as long insulating poles.

B. Hot Glove

The worker is protected by thick rubber gloves, often extending all the way up his arms, and sometimes wears a rubber apron as well.

C. Hot Hand

The worker is transferred to an isolated platform, such as a heavily insulated cherry picker or suspended from a helicopter, and brought into contact with the equipment.

D. What is Hot Stick?

Hot-stick working appeared in the second decade of the twentieth century, when insulating poles made from baked wood were used for tasks such as replacing fuses, swapping out post insulators, and transferring lines onto temporary supports. The sticks enabled the linemen to carry out the work without infringing minimum clearance distances from live equipment. As experience with the techniques developed, and then the operating voltages at which the work was performed increased. With the advent of fiberglass poles in the late 1950s, which neither split nor soaked up rainwater, utilities were prepared to carry out hot-stick working to their highest operating voltages, perhaps 765 kV [4].

E. What is Hot Gloves?

For medium or low voltages, work can be carried out if a worker wears insulating gloves of an adequate standard. The gloves often extend all the way to the shoulder to protect the worker’s arms. Additional protection can be provided by a rubberized apron. To reduce the length of exposed conductor, insulating blankets and hoses can be draped over the equipment not being worked upon. An additional layer of protection can be
provided by the use of insulated tools such as pliers. Linemen often work from an insulated platform or non-conducting ladder, however the primary protection is deemed to come from the gloves. This provides an ultimate limit on voltage for hot-glove working, perhaps 60 KV [5].

F. What is Hot Hand?
Hot-hand (also known as bare-hand, or contact) working involves placing the worker in direct electrical contact with an energized overhead line. He might work alongside the lines, from a platform that is suspended from them, or even sit or stand directly on the line itself. In all cases, the worker’s body is maintained at exactly the same voltage as the line. It is imperative that no earthed equipment is brought within range, else a flashover would occur [6].

G. Line Maintenance Reaches New Heights
Electricity de France develops airborne techniques to maintain and repair transmission lines. Electricity de France (EDF) has always looked for new solutions to improve, inspect and maintain high-voltage and extra-high-voltage transmission lines. More than 50 years ago, EDF engineers thought that helicopters could decrease overhead maintenance and repair problems. Experimental applications and development work progressed, and in 1989, the Services Travaux Héliportés (STH) Operational Division was created. STH now plays a major role in the reinforcement, inspection and maintenance of the French power transmission network [7].

Fig. 4: Classic hot stick technique

Therefore preventive maintenance, deploying live line maintenance techniques, proves the best solution.

A. Conductor Joins (Sleeves)
Since the line break in early 2009, Transpower has commenced live line work (bare hand – from helicopters) to test all conductor joins (sleeves) using the “ohm stick” technique. There are thousands of sleeves to be tested of which around 6,000 have been tested to date (from discussion with Ray Basher on May 26, 2009). As part of the testing on circuits into Auckland, it was more efficient to test multiple lines (up to three separate transmission lines) simultaneously. This was achieved with helicopter leap-frogging men between and along lines 2 [8].

Fig. 5: conductor sleeve/joint replacement from insulated bucket trucks

Bare hand method for the maintenance of transmission line

VII. HOTLINE MAINTENANCE
It is obvious that a constant supply of electricity is required by consumers and for this an almost un-interrupted stable availability of transmission lines is required. Providing redundancy in transmission lines could be a solution, which, however is a costly option.

Fig. 3: Hot line washing

Hotline Washing/Maintenance:
This process entails cleaning of Insulators and Switchyards under live line conditions.

Fig. 5: Conductor sleeve/joint replacement from insulated bucket trucks

Bare hand method for the maintenance of transmission line
Many of Quanta’s operating units such as Danford Technologies Inc. (Oliver, British Columbia) and PAR Electrical (Kansas City, Missouri) have pioneered the techniques and proprietary equipment used in barehand work. When the barehanders find a better tool or technique that will add value and safety to a project, they often work with manufacturers and the industry to make it happen [9].

A good example of this was the LineMaster Robotic Arm developed by a Quanta subsidiary. The LineMaster is a hydraulically powered, boom-mounted, rotating and telescoping robotic arm that can be used for maintaining transmission and distribution facilities live.

C. Unions take a Stand

The utilities' enthusiasm for barehand methods has been damped in some states, such as California, Washington, Oregon, and Pennsylvania, that have barred barehand work altogether.

Some union locals have been a key force in urging states to maintain the ban, contending that adequate safety procedures and training—and appropriate penalties for workplace negligence—should be in place before utilities may do barehand work.

D. Insulated Arms

Although barehand work is the most dramatic live-line technique, the other widely used way to work energized transmission lines employs what are called hot sticks: insulated poles that work a little like the grabbers with which grocery store clerks pull otherwise inaccessible packages from the top shelves. The hot stick’s business end can be fitted with the various tools—a prong, for instance—used to replace or repair a line component, such as a cotter pin. For the lineman, however, the stick can sometimes prove an awkward prosthesis. Changing a pin with a pole of 12 or more feet in length atop an 80-foot tower can be, at best, frustrating. “With sticks, if you’re trying to do something delicate and it’s just not working, you get upset easily,” said Claude Tessier, a line foreman with Sask Power, in Regina, Sask., Canada. That negative view of hot sticks is not necessarily shared by the unions [10].

I. Insulator Washing

This is achieved by hovering a helicopter (an MD500) close to the power lines, and spraying a high pressure jet of water onto the insulators. The helicopter is equipped with a water tank and pump, and an electrical linesman sitting in the back of the helicopter directs the water jet by means of a 5 metre long hollow “boom.” Over time the insulators become coated with dirt, pollution and salt, and this can cause a “leakage” of current and possibly cause power blackouts. Using the helicopter to clean the insulators will result in cost savings for the power companies and a more reliable power supply for the consumer [11].
Due to the inaccessible location of most of the power pylons and poles in Hong Kong, washing the insulators by helicopter will be more efficient and safer than having them washed by crews climbing the towers and doing them by hand.

Bird nests and excrement, corrosive coastal salts and chemical compounds from industrial areas on powerline insulators will often lead to line trips or outages. AIR2 offers airborne power line washing to efficiently remove debris and contamination. An AIR2 helicopter equipped with a water reservoir and washing boom delivers a powerful spray directly to the insulator strings, cleaning away debris and contamination.

VIII. CONCLUSION

A. Economic Benefits
Circuit availability has a positive impact on a utility’s balance sheet, because the availability index is an integral part of the remuneration formula applicable to transmission companies. In the event a network’s availability is above the fixed value, the utility receives a bonus over and above the standard remuneration. Live-line working is one of the maintenance activities where innovation and improvements are continually developed. This often leads to the creation of applied research projects, and the cost of this research and development can attract tax relief, depending on the prevailing national policies.

B. Social Benefits
A key external social benefit of using live-line working techniques for routine maintenance and construction work is that energy is supplied without interruption. This effectively increases system availability, reducing planned outages and thereby satisfying society’s demand for improved service quality.

Another external social benefit affects the use of helicopters for public services. Transmission circuits are often routed over roads and reservoirs, the same locations commonly used by helicopters for public service responsibilities. The transmission lines are highly visible and serve as beacons in adequate numbers, size and colour, which are installed using live-line working procedures.

C. Environmental Benefits
The reduction of losses by an increased availability leads to savings in generation and lower emissions of polluting gases in the atmosphere. Also, live-line working procedures and methods are specially designed to address environmental issues, such as the installation of bird flight diverters and the replacement of insulators, spacers and other accessories that generate noise.

REFERENCES

[8] Silcock, R. Live maintenance of high voltage transmission lines Safety is paramount.