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Working hot: life at 765 kV

Specially trained utility workers, clad in conductive suits to equalize voltage over their bodies, repair live lines 'barehanded,' sometimes perched below a helicopter cockpit

SPECIAL REPORT

POWER/ENERGY

In March of 1987, a vandal with a high-powered rifle shot up three conductor bundles on a 500-kilovolt transmission link over a swamp between Miami and Fort Lauderdale, Fla. When Florida Power & Light Co. officials arrived to inspect the damage, some of the conductors, or uninsulated power lines, appeared ready to break and fall.

The situation could have turned into something far worse than a simple line outage. Because of maintenance on other parts of the transmission grid, those lines were for the time being the main source of power to Miami. Turning them off to make the repair could have meant a blackout at least in part, possibly throughout all, of the city.

The only way to avert such a disaster was to make the repairs without deenergizing the lines, working while the lines were hot. To get to the damaged spot, workers from the Miami-based utility had to truck in landfill and create a makeshift road through the swamp that would carry a bucket truck with an insulated boom. Lifted from the ground, a lineman clad in a steel-mesh suit touched the live line with a wand, a three-foot-long implement that looks like a car antenna. With his body energized to the line voltage, he could splice the conductors safely.

Utilities have practiced these so-called barehand techniques for maintaining high-voltage transmission lines in the United States and Canada for almost 30 years; more recently, other countries have also adopted the practice. The term barehand is actually misleading. When working above 150 kV, the lineman's entire body, including the hands, is covered with a conductive stainless steel suit, hood, and gloves to equalize voltage across the surface of the body. Only the worker's face is uncovered.

Barehand methods may be on the rise, according to some industry officials, as utilities build lines at higher voltages and sell more power to other utilities, making it highly inconvenient to take the lines out of service. New technology is also helping; for example, helicopters and crews, again energized at hundreds of thousands of volts, can complete large jobs quickly and service isolated power lines. One such helicopter company that specializes in barehand work helped Florida Power & Light Co. in the March 1987 incident.

Use of these techniques is growing among the relatively small number of utilities that operate at the highest transmission voltages, 230 kV and up. But some unions view the barehand work with less than enthusiasm. Although the principles involved are well understood, touching lines energized at hundreds of thousands of volts demands flawless equipment and rigid work procedures followed to the letter.

Barehand work puts to practical use a phenomenon that protects any bird that perches on a power line: as long as a lineman in contact with a live transmission conductor is isolated from ground and from any other conductor at a different voltage, no life-threatening current will flow.

Gary Stix Associate Editor

In contacting a live conductor, however, workers do not just flap down like pigeons. After elaborate preparations—such as testing a bucket truck to ensure that its insulating properties are in order—the truck lifts the lineman to within a few feet of the line. The lineman connects, or bonds, to the line with the wand and can perform maintenance work ranging from replacing insulators to actually splicing a damaged line. No formal records appear to exist of the number of utilities doing barehand work, but Pacific Gas & Electric Co. (PG&E), San Francisco, did an informal survey last year in preparation for a California state regulatory hearing. The company found that some 40 states permit barehand work and that at least 30 utilities in the United States and Canada engage in such work, said Floyd Bucholz, a Danville, Calif., consultant.

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.

Although a proposal for such regulation does exist, there are in effect no formal Federal rules governing the technique. There is, however, Subpart V of the U.S. Occupational Safety and Health Administration (OSHA) regulations—covering power transmission and distribution—which includes some provisions for barehand work. The regulations deal only with construction of transmission and distribution lines, not line maintenance, but they are generally adhered to for line work as well.

OSHA has yet to decide on a proposed standard, "Operation and Maintenance of Electric Utility Production, Transmission/Distribution Facilities," which would include provisions for barehand work. The standard would most likely be based on a joint proposal from the International Brotherhood of Electrical Wor-

Defining Terms:

Bonding: the process of making contact with an energized line to eliminate the difference in potential between a lineman and the line itself.

Conductor: an uninsulated high-voltage transmission line.

Conductive suit: a suit made of steel and synthetic fibers worn by a lineman to shield his body from the strong electric field.

Flashover: electric arcing between adjacent conductors or between a conductor and another object, such as a tower, conductor, or person.

Hot sticks: insulated poles with attachments for tools for servicing high-voltage lines.

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Rick Diaz

Seated on the edge of a rigid platform attached to a helicopter's struts, a lineman with Haverfield Helicopter, Miami, Fla., "unbonds," drawing away from a center conductor carrying 765 kV. The lineman has just replaced a spacer, used to separate two subconductors in the bundle. The job, done for Appalachian Power Co., Roanoake, Va., is completed while lineman, helicopter, and pilot are all energized. The short rod, or wand, is used to draw the arc that occurs because of the relatively slight difference in voltage between the conductor bundle and the lineman, whose body and conductive suit is substantially energized as he enters the electric field around the conductors.

Georgia Power

A lineman, wearing a conductive metal suit to equalize voltage across his body, is about to change an insulator string. The rectangle of insulated rods, called a cradle, is attached to a boom, which, in turn, hangs from the tower (boom and tower not shown). The insulator string is lowered to the ground, where a new string is installed, lifted and connected to the conductor.

kers (IBEW) and the Edison Electric Institute, a Washington, D.C., industry group. The IBEW, also based in Washington, points to studies that suggest possible adverse effects on health from the strong electromagnetic fields that surround energized high-voltage lines ["Power-line fields and human health," *IEEE Spectrum*, February 1985, p. 62].

Some utilities ardently defend barehand techniques, pointing out that if maintenance and repairs were not done on hot lines the company might have to purchase power from neighboring utilities or generate its own more expensive power from gas turbines. An unscheduled outage can cost a utility as much as $500 000 a day, said Keith E. Lindsey, chief executive officer of Lindsey Manufacturing Co., Azusa, Calif., and chairman of the IEEE's Transmission and Distribution Committee's Engineering in the Safety, Maintenance and Operation of Lines (ESMOL) subcommittee, which formulates procedures for barehand work.

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. James Dushaw, IBEW international representative for the utility department, asserts that an experienced hot-stick crew can work as agilely as barehand workers bonded to the live line at even the highest voltages, up to 765 kV.

Careless work on energized lines could indeed spell disaster. Although no formal tracking of barehand safety exists, officials report few fatalities. One of the worst barehand accidents hap-

pened in 1980, when a Florida Power worker in training died after oil leaking from a hydraulic line in the insulated boom created a partial vacuum that caused ionization and a flashover between conductor and truck. The resulting explosion sent parts of the boom flying and the man died when he was thrown off and fell 75 feet; another worker was paralyzed. According to Bill Cole, who recently retired from his position as Florida Power's manager of system transmission operations, an OSHA investigation turned up no negligence. "It was a design discrepancy with the vehicle," Cole said. Claims for damages were settled out of court.

Dushaw contends that the Florida accident points up the need to track and regulate barehand work. It was known that a similar accident had occurred in France, and measures should have been taken to prevent the Florida incident, he said. (Today, bucket-truck manufacturers have improved hydraulic systems, putting in valves that ensure a vacuum cannot occur.)

A lineman straddling an epoxy-glass ladder is about to unfasten the insulators on these 500-kilovolt conductors so that line workers on the tower can use a swivel boom pole, shown next to the insulator string, to ease the string away from the conductor, lower it to the ground and replace it with new insulators, an operation that usually takes four workers three hours. This scene shows a training exercise, hence the crowd.

A delicate touch

Live-line workers approach their jobs with the care accorded lion training and skydiving. (While most people would shy at the prospect of touching a 500-kV line, there will be an opportunity to do so for anyone at the next ESMOL conference on live-line work, to be held in Toronto in June 1990.)

Because a significant electrostatic field surrounds a live line for several tens of meters and increases in strength the nearer to the line, a lineman's body is energized well before he touches the conductor. Within a meter or so, the field may be 20-30 kV less than the conductor's voltage. Despite that difference, a human body has a relatively small mass, and a current of no more than a few microamperes is induced in the body when the lineman contacts the line with his wand—a level an IEEE guidebook on live-line work calls "almost imperceptible."

Because of that difference in voltage, however, an arc will leap between conductor and wand as the conductor is approached. Although not strong enough to be fatal, such sparks can cause a brief loss of sensation in the hand. Joseph Van Name, superintendent of transmission for Philadelphia Electric Co. and a pioneer of barehand line techniques, recalls placing an uncovered hand on a 230-kV line some 30 years ago. The only ill effect, he said, was a slight numbness in his hand lasting about 10 minutes.

The lineman's wand and steel-mesh suit prevent the spark from touching his body: the arc jumps from line to wand rather than to a gloved hand or finger, and the suit equalizes the charge across its surface, working on the principle of a Faraday cage. (Michael Faraday, the English scientist, discovered that everything within a metal cage—in this case the steel suit—in an electric field is shielded from the field, so little current will flow.) After the lineman is bonded, contact is maintained through a short tie, called a bonding lead, from suit to conductor.

The suit, required at voltages above 150 kV, protects against current as well as against the corona effect, the ionization of the air around a person's body that results in a prickly sensation on such protruding body parts as the ears, and a distinct buzzing sound. "It's like having a bunch of bees buzzing around your head," said Bill Croker, transmission staff engineer with Georgia Power Co. in Atlanta.

The suit is not necessarily all that protects a lineman. A bucket truck's boom, which can reach higher than 200 feet, is often made of an insulating material such as fiberglass. Another method is to attach an insulating polypropylene rope to a pulley, both of which are suspended from a boom above the tower and controlled by an electric winch. (Winch and pulley can also be suspended from the tower itself.) The lineman sits in a chair on the rope and is eased down to the conductor. He may also descend to the conductors on an insulated ladder attached to the tower.

In China, Van Name said, a similar technique uses a line made of silk, which is highly insulating. A weighted silk line is twirled like a lasso and thrown over a conductor; the lineman, frequently a woman, is hauled up by hand. Standing on one of the two or three lines in a bundle—the cluster of lines that carries one phase in a three-phase transmission—the lineman gains support by holding on to the other two. In the West, other techniques include seating the lineman either in a cart pulled along the line from the ground, or in a motorized vehicle that "drives" along, hanging from the line.

Whirlybirds do it hot, too

The latest techniques employ helicopters, useful where transmission lines traverse inaccessible terrain or where a bucket truck would damage crops. Haverfield Helicopters, Miami, Fla., the most prominent supplier of this service in the United States, began in 1983 by installing "bird discouragers" on Florida Power & Light's towers—metal spikes in places where birds, whose droppings contaminate insulators, might perch. Haverfield has its lineman sit on a platform clamped to the helicopter struts. As the helicopter approaches the line, the lineman bonds on, and since the helicopter becomes energized as well, lineman and pilot alike must wear conductive suits. The IBEW's Dushaw expresses strong reservations about using helicopters until there are regulations to protect workers.

Still another approach employs a robot arm at the end of insulated booms developed by the Electric Power Research Institute, Palo Alto, Calif.; a prototype now being tested has yet to reach commercial production. It may be that such a system would be prohibitively expensive, but a robot can operate during a lightning storm, or when snow or rain makes it dangerous to work.

The benefits of barehand work—saving in cost from doing the work faster and without taking a line out of service—have made more and more utilities pose the question: why not do it hot?

To probe further

Although there are no formal rules for live-line work, there are many procedures. The IEEE's Transmission and Distribution Committee set up its Engineering in the Safety, Maintenance and Operation of Lines (ESMOL) subcommittee to deal with live-line issues. Through ESMOL, the IEEE has published guidelines and guidebooks on all aspects of live-line maintenance.

In addition, the American National Standards Institute, New York City, has various standards on live-line work and equipment safety specifications. The American Society for Testing and Materials, Philadelphia, has established the F-18 Committee on Electrical Protective Equipment for Workers, which has developed specifications for manufacture and testing of live-line equipment like hot sticks. The International Electrotechnical Commission (IEC), Geneva, Switzerland, also has a number of standards for such live-line equipment as voltage detectors, insulated hand tools, grounding, hot sticks, and conductive suits. •