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DECEMBER 2010

TRANSMISSION & DISTRIBUTION WORLD™

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A PENTON MEDIA PUBLICATION

Raising Solar

Cutting Out Copper Theft

ComEd works to discourage the increasing problem of pole ground thefts.

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According to an Electrical Safety Foundation International baseline survey about copper theft in the United States, utilities annually see more than $60 million in losses and 450,000 minutes of outage time due to theft. Additionally, every year 35 to 50 deaths or injuries are associated with copper theft.

ComEd, a utility serving about 3.8 million customers across northern Illinois, knew it had a problem with copper theft when stolen wire and cable became regular occurrences in its daily operating reports. For instance, a material yard would be broken into and a reel of conductor would be missing. A coil of wire would be missing from a line truck. A substation fence would be cut by vandals in search of copper. Something had to be done about copper theft.

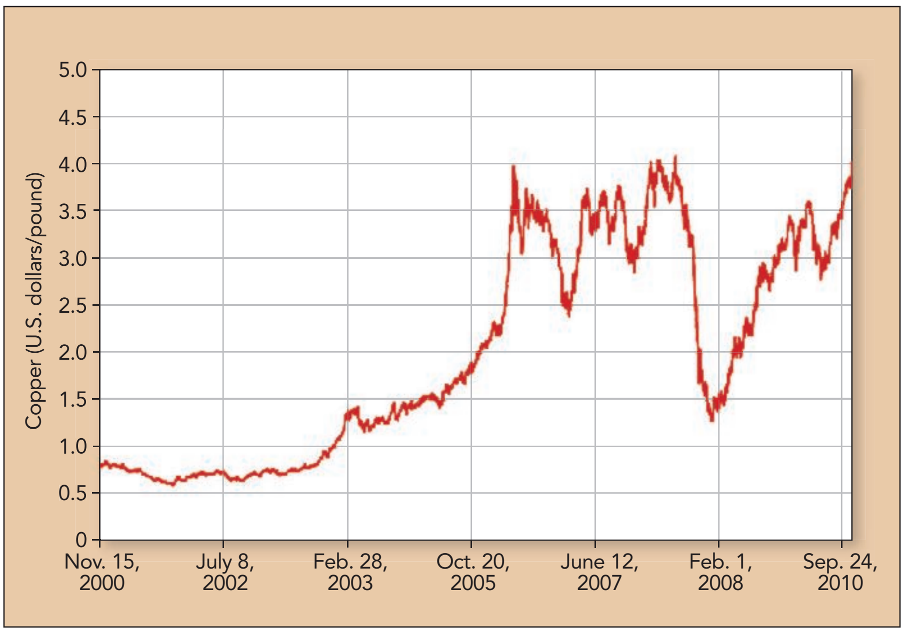
Financial Motivation

Stealing wire and cable is not a new occurrence; however, the rising copper prices have given thieves more financial incentive for the same amount of risk just a few years ago. The recent rise in copper prices has made solid-copper pole grounds a valuable target for thieves. Copper has gone from a high of $4/lb ($8.82/kg) in mid-2008 to a low of $1.45/lb ($3.20/kg) in January 2009, and then back up to $4.00/lb ($8.82/kg) in November 2010.

Comparing these prices to copper priced under $1/lb ($2.21/kg) less than 10 years ago, one can see the increased value to thieves. The volatility of copper prices has been affected by global demand, copper mine strikes and commodity speculators. This volatility means it is difficult to know when to buy copper. It is likely a utility will have to buy replacement copper when prices are elevated, as this is when thieves get more for their deeds.

Distribution Pole Ground Theft

Engineers in ComEd's distribution standards group also were well aware that distribution pole ground wires have long been a target of copper thieves, particularly in inner-city areas. Pole grounds in transmission rights-of-way are vulnerable because few people are around to witness and report a theft. However, as odd as it may seem, roadside pole grounds also are frequently stolen. Copper thieves steal copper ground wire where it is most accessible, from the ground rod to about 6 ft (1.8 m) above the ground. The thousands of pole ground wires that are virtually unguarded become easy targets for any vandal with a set of bolt cutters.



The rising price of copper has made solid-copper pole grounds a valuable target for thieves. Courtesy of www.infomine.com.

ComEd shared its copper theft information with the distribution standards engineers at its sister utility, PECO Energy, which serves 1.5 million electric customers in Pennsylvania. In these discussions, PECO also confirmed it had a problem with ground wire theft. The magnitude of the copper theft problem at ComEd was so broad that the utility's engineers wanted to investigate a solution that focused on the theft of distribution pole ground wires through enhancements to construction standards and possibly using theft-deterrent wire.

Code Requirements

ComEd engineers knew grounding the electric distribution system was important for the safety and protection of personnel and equipment. The National Electrical Safety Code (NESC) requires multi-grounded systems to have at least four grounds per mile. Another concern of the engineers was the impact of the missing pole grounds on system reliability. The reliability of the system could be comprised if ground wires are missing. ComEd is working to solve the issue.

ComEd installs surge arresters to protect equipment from voltage transients such as lightning. Surge arresters are installed to prevent insulator flashovers and equipment damage. The concept involves bleeding off the excess energy from a lightning strike to ground before it can damage system equipment. Ideally, surge arresters work as shorting switches, closing in the presence of an overvoltage and opening the instant the overvoltage has passed. However, to function as designed, the surge arrester requires an intact ground.

Problem Magnitude

For years, ComEd had an optional theft-resistant pole ground U-Guard that an engineer could specify in areas where theft or vandalism was known to be a problem. Not only was the solution optional, it was expensive and the installation time-consuming. Essentially, a steel U-Guard was fastened to the pole over the existing ground wire and molding with tamper-proof screws. In spite of this, if thieves were persistent, a crowbar could be used to pry the steel U-Guard off the wood pole, exposing the copper ground wire.

Pole grounds in transmission rights-of-way are vulnerable because few people are around to witness and report a theft. A theft-resistant pole ground molding is specified in areas where theft or vandalism is known to be a problem. Essentially, a steel U-Guard fastened to the pole with tamper-proof screws was placed over an existing ground wire and molding.

Distribution pole ground wires have long been a target of copper thieves who steal copper ground wire where it is most accessible. From left to right, ground rod cut from about 6 ft above the ground, distribution pole ground wire cut about 6 ft above the ground, and distribution pole ground wire cut at the ground line just above the ground rod.

Prior to October 2008, there was no formal mechanism to quantify the magnitude of stolen pole ground wires. Since then, ComEd has developed an overhead-circuit inspection program that inspects every circuit on a regular cycle using a detailed checklist on a handheld or notebook computer. Items requiring repair are prioritized within the checklist and electronically transferred to ComEd's work management system.

In October 2008, the overhead-circuit inspection program added a new inspection category to the checklist: stolen grounds. For the two-year period of October 2008 to September 2010, approximately 5,400 stolen pole grounds were identified through the inspection program. Since ComEd performs routine overhead-circuit inspections on a four-year cycle, this may potentially represent only half of the actual amount.

In addition to learning the magnitude of the problem, ComEd also confirmed the problem was spread across its 11,400-sq mile (29,526-sq km) service territory and was not limited to the city of Chicago. Excluding the cost of replacement materials, an estimate of the labor cost to replace the identified stolen ground wires (based on an industry-average hourly lineman's rate) was in excess of $1.5 million.

Theft-Deterrent Ground Wire Options

Before ComEd could determine the suitability of using theft-deterrent wire on its system, the utility needed to become familiar with commercially available options. One option uses a composite wire with multiple galvanized-steel outer strands and a smaller number of tinned-copper inner strands. The wire looks like guy strand wire.

A second type of theft-deterrent wire uses tinned outer and center strands to distinguish it from other bare copper. The core strand contains a series of traceable identification codes etched on the product, which law-enforcement agencies can access when they suspect wire is stolen.

A third type of theft-deterrent wire is copper-clad steel, which is composed of two metals, copper and steel, in a single composite conductor. The bimetallic construction makes it more difficult to cut than copper and virtually impossible to recycle. This makes it undesirable to wire thieves and of no value to salvage dealers.

ComEd's final selection criteria for the theft-deterrent wire included cost, availability from multiple suppliers and wire size offerings.

Considering that copper-clad steel ground rods have been used by ComEd for years, it seemed a logical next step to connect the ground rods to similar metal wire material.

Copper-Clad Steel Wire

There are various manufacturing methods for combining copper and steel. Copper-clad steel encompasses the benefits of both copper and steel, giving the product strength and corrosion resistance. The cladding process uses temperature and pressure to achieve a uniformly bonded and tightly adherent copper coat. For copper-clad steel wire, the nominal thickness of copper varies according to wire size.

ComEd sought out bimetallic wire made using a metallurgical bonding process — an oxygen-free, heat and pressure bonding process to minimize porosity — performed by U.S. manufacturers. The better the molecular bond between copper and steel, the lower the porosity. This leads to greater corrosion resistance and longevity in service.

Copper-clad steel wires are available with 30% or 40% conductivity. This is the percentage of conductivity copper-clad steel has compared to the diameter equivalent of copper.

The distinction between continuous current-carrying capability and ground-fault conductivity must be made. If copper-clad steel wire were to be used for a continuous current-carrying condition, then it would not be suitable. However, fault currents are high-current pulses of a higher frequency and travel on the outer diameter of the wire, not through the entire wire cross section, requiring only a percentage of the conductivity of the same-sized copper wire. This is known as the skin effect for carrying high-frequency pulses.

Copper-clad steel has been in use in ground rods, cathodic wire, utility pole staples, resistor leads and, most abundantly, coaxial cable for TV (high-frequency signals) usage.

Fusing Current Considerations

ComEd engineers used the following criteria to select an appropriate wire:

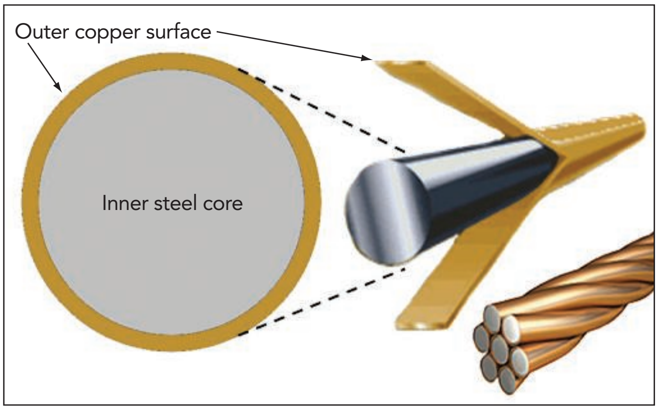
- Size and conductivity equivalent to a #2 stranded copper wire (to meet potential high-fault currents)
- Compatible with standard connectors already in use on the system
- Transparent to the field as much as possible, including packaging, handling and workability
- One wire size for use on all new and replacement 4-, 12- and 34-kV pole grounds
- Primarily considered for installation between the ground rod connector and the system neutral connection.

The wire initially considered was the 7–#9 stranded copper-clad steel wire. It was selected because both the 30% and 40% conductivity wires exceeded the fusing current characteristics of the #2 stranded copper wire, which was presently specified.

Here tamper-proof screws are used on ground wire guards.

Additionally, the nominal diameter of a 7–#9 stranded 40% copper-clad steel wire is 0.343 inches (8.7 mm), larger than the 0.292-inch (7.4-mm) diameter of the #2 stranded copper wire currently used.

Fusing Characteristics of Various Wires					
Time (seconds)	Cycles	7–#10 stranded (30%) copper-clad steel	7–#10 stranded (40%) copper-clad steel	#2 copper	1/0 (7 stranded x 0.1327) AAAC
0.05	3	33,991	38,187	42,148	52,658
0.10	6	24,035	27,002	29,803	37,235
1.00	60	7,601	8,539	9,424	11,774
Comments:		Acceptable substitute, if economics dictate	Recommended size – closest fusing currents and physical characteristics (diameter) compared to #2 copper	Ground wire used for 12 kV and 34 kV	Neutral wire presently in use (Azusa)



Copper-clad steel encompasses the benefits of both copper and steel, giving the product strength and corrosion resistance. The copper cladding is metallurgically bonded to the steel core.

The existing ground wire molding would accommodate the larger-diameter 7–#9 stranded copper-clad steel wire; however, further study revealed the 7–#9 stranded copper-clad steel wire would not fit easily into a standard bar tap on the neutral bushing of an overhead transformer. It was determined a 7–#10 stranded copper-clad steel wire, with a nominal diameter of 0.306 inches (7.8 mm), would fit into a standard bar tap on the neutral bushing of an overhead transformer. The concern, however, was that along with the smaller diameter came a reduction in the fusing current to just slightly below that of the #2 stranded copper wire currently used.

The key criterion for properly selecting replacement ground wire is fusing current. Fusing current is a function of both the physical size and number of strands, along with the conductivity of the wire. Fusing current is the current at which a deformation of the wire is sufficient to prevent it from carrying the current in a subsequent ground fault.

The 7–#10 stranded copper-clad steel wire did not meet the original criteria of maintaining an equivalent to a #2 stranded copper wire in terms of fusing characteristics, so the distribution standards group sought out the support of the utility's relay protection group, the group that performs fault studies for circuits of various voltage systems under worst-case scenarios. Based on its analysis of the ComEd system, the relay protection group recommended that either a 7–#10 stranded 40% or 30% copper-clad steel wire would be acceptable for use.

Final Choice

In addition to a review of ComEd's protection requirements, the following NESC sections were reviewed regarding the use of grounding conductors.

Section 93.C.2 of the 2007 NESC allows the use of grounding conductors for an AC system with grounds at more than one location, exclusive of grounds at individual services, having continuous total ampacities at each location of not less than one-fifth that of the conductors to which they are attached. For bare grounding conductors, the short time ampacity is the current the conductor can carry for the time during which the current flows without melting or affecting the design characteristics of the conductor.

Section 93.C.4 of the 2007 NESC allows the use of arrester grounding conductors of copper-clad or aluminum-clad steel wire having not less than 30% of the conductivity of solid copper or aluminum wire of the same diameter, respectively.

Finally, based on a discussion with ComEd's corrosion group, the 40% copper-clad steel wire was selected for its higher fusing current and better protection against corrosion. TDW

Acknowledgment

The authors are grateful for the active and valuable support from CommScope BiMetals.

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Companies mentioned:
ComEd **www.comed.com**
CommScope **www.commscope.com**
National Electrical Safety Code **standards.ieee.org/nesc**
PECO Energy **www.peco.com**