Return to Session

ALUMINIUM CONDUCTORS IN ANTI-ROBBERY CABLES

Luiz Henrique ROSA, Nexans Brasil SA, (Brasil), luiz.rosa@nexans.com.br
João de PAULA, Nexans Brasil SA, (Brasil), joao.paula@nexans.com.br
Sidnei UEDA, Nexans Brasil SA, (Brasil), sidnei.ueda@nexans.com.br

ABSTRACT

This paper discusses the development and use of anti-robbery cables with aluminium conductor, a cable design with a high potential to replace both low voltage bundled copper cables and copper anti-robbery cables, used at the electrical service entrances of low voltage consumer units. The anti-robbery cable construction is described in details as well as the accessories developed for its connection to the power distribution network. The replacement of copper by aluminium demands a series of accessories adaptations in order to minimize connections deterioration due to corrosion, a phenomenon that is closely related to galvanic currents that appear in different metal junctions.

KEYWORDS

Anti-Robbery Cables, Aluminium Conductors, Cable Accessories.

INTRODUCTION

The end of the state monopoly in the Brazilian electric sector introduced a competitive environment, forcing the power utility companies to look for a way of increasing their profits without modifying the value of the tariffs, since the tariffs are regulated by the State. In this context, the power utility companies aim to be more efficient, reducing the commercial and technical losses in order to maximize the available energy for commercialization.

The technical losses are those that occur in the system due to physical characteristics of the electrical conductors. The commercial losses are directly related to the energy robbery and insolvency.

The electricity robbery issue is one of the main concerns of the Brazilian electrical sector agents; according to the Electric Energy National Agency - ANEEL, the damage is estimated R$3.5 billion (US$ 1.7 billion). To illustrate this problem, two Brazilian power utility are given as examples: Light, in Rio de Janeiro, attending 3,8 million consumers units, has losses of R$720 million (US$360 million) per year, what represents around 16% of its market; in São Paulo, the commercial losses of the AES Eletropaulo reach almost 7% and it is around R$500 million per year [1].

The most common way of energy robbery is using metallic claws, biting the phase and the neutral conductors, allowing the use of electricity without passing through the energy meter (figure 1). However, some years ago, a new cable begun to be used in order to avoid the electricity robbery. This product, called anti-robbery cable, is so constructed that the use of the claws is not possible anymore. Its neutral conductor surrounding the phase like a wire armouring does not allow any contact with the central phase conductor without touching this concentric neutral conductor. That is the reason why, each time more, low voltage bundled copper cables used in service entrances have been replaced by anti-robbery cables.

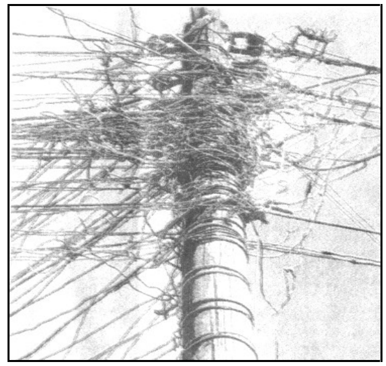

Figure 1: energy robbery

ANTI-ROBBERY CABLE

Constructive aspects

The anti-robbery cables are constructed in such a way that the central conductor and its insulation are involved by a copper wire layer, helically applied around the core, forming the neutral conductor. When a metallic claw is used to reach the conductor phase, a short circuit with the neutral conductor occurs, avoiding the energy robbery.

Figure 2 shows a cross section of an anti-robbery cable used in single-phase installations. Although, there are cables with two and three conductors, all of then involved by a concentric neutral conductor, formed by copper wires helically applied.

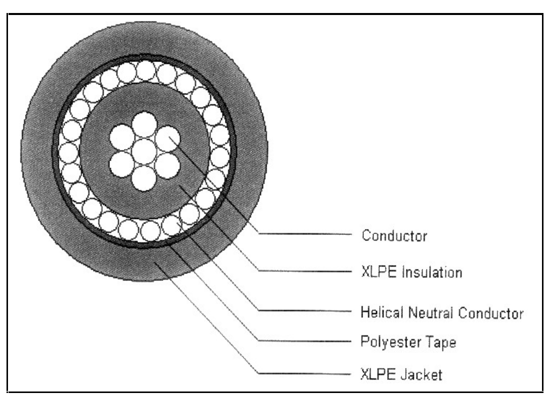

Figure 2: anti-robbery cable

The phase conductor is made of plain copper wires, soft annealed, class 2 stranding, XLPE insulated. The neutral conductor is formed by a plain copper wire layer, soft annealed, helically applied around the cable core(s). The jacket is, also, XLPE compound.

Application

As described above, the constructive characteristics of the anti-robbery cable impose a difficulty to the clandestine linking. However, the use of these cables, replacing the low voltage bundled copper cables in service entrances, will be effective if the following steps are accomplished:

- Low voltage distribution network using insulated aerial bundled cables, so the conductor shall not be easily accessed.
- All the connections that can be reached by consumers must be sealed.

Facing it, in the localities where the energy robbery frequency is bigger, the power utility companies adopt a system of energy distribution where nobody can access the energy conducting metallic parts. The distribution line use insulated cables and the ramifications are made in distribution boxes, from where they go directly to the energy meters at the consumers. Figure 3 shows an example of “anti-robbery solution”, where distribution box and anti-robbery cables are used.

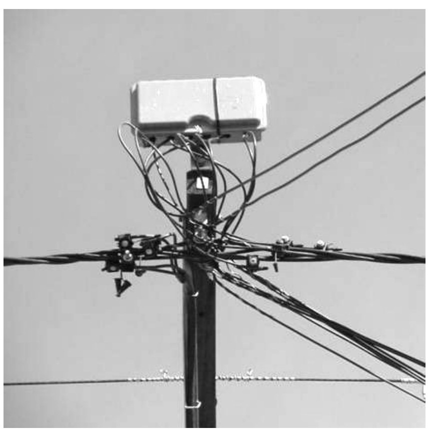

Figure 3: anti-robbery solution

Figure 3 shows the distribution box, its interconnections with the insulated cable of the distribution line, piercing connectors and the anti-robbery cables that leave the distribution box in direction to the residences. It is noticed that the cost of this installation tends to be more expensive than the common configuration (non anti-robbery) because of the presence of the mentioned accessories. Moreover, the anti-robbery cable has a higher cost because of its complex construction and because of the high cost of its main raw material, the copper.

COPPER X ALUMINIUM

Copper and aluminium are the most common materials used in electrical conductors manufacturing.

Although the copper has more interesting electrical characteristics than aluminium, as higher conductivity, allowing using smaller electric sections, the aluminium gained its space for being a lighter material, a very important requirement for the transmission and distribution power systems. However, the border between cable applications using these two conductors continues indefinite, varying in accordance to the preference of the user and price of the raw material.

Figure 4 shows the US$/ton variation of copper and aluminium in the international market, defined in the London Metal Exchange (LME).

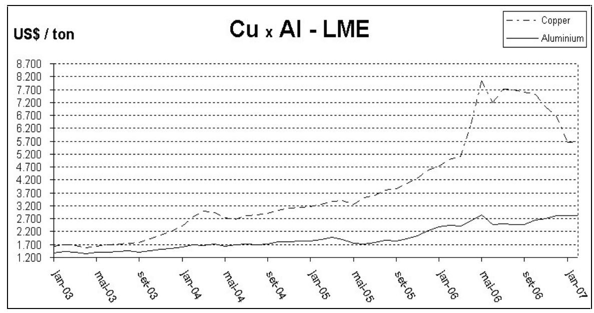

Figure 4: Cu x Al – LME monthly average prices

The graph of figure 4 shows a great deviation between copper and aluminium curves after 2004. In May of 2006, the month where the copper reaches its maximum quotation, the value US$/ton of aluminium is only a third part of the US$/ton of copper. This price difference encouraged researches for applications where aluminium cables could substitute the copper cables.

In this context, Nexans Brasil SA, one of the main manufacturers of copper anti-robbery cable in Brazil, aiming the increase of its market share and the satisfaction of its customers, start the development of an aluminium anti-robbery cable with significant reduction in raw material costs, comparing to the copper anti-robbery cable. However, the challenge would be to find a solution for the difficulties of the new cable application, since it would replace copper cables that have very different characteristics such as electric resistance, mechanic resistance and corrosion resistance.

ALUMINIUM ANTI-ROBBERY CABLE

The constructive aspects of aluminium anti-robbery cables and copper anti-robbery cables are very similar. However, the exchange for a conducting material with lesser conductivity modifies the current rating capacity of the cable. So, in the applications where it is used copper cables with 6mm^2 and 10mm^2 nominal cross sections, it is required aluminium cables with 10mm^2 and 16mm^2 nominal cross sections, respectively. The table below shows the current rating of the most common cables.

	Copper		Aluminium	
Cross Section	1 x 6 + 6 mm2	1 x 10 + 10 mm2	1 x 10 + 10 mm2	1 x 16 + 16 mm2
Current	51 A	71 A	55 A	73 A

As mentioned before, the aluminium anti-robbery cables are less expensive and lighter than the copper cables. However, some characteristics of aluminium are not compatible with the copper anti-robbery cables applications. The main problems are listed below:

- Mechanic resistance requirement for the tiny wires that form the concentric neutral conductor.
- Presence of galvanic currents in the connection between the energy meter copper terminals and the aluminium conductors.

The first problem is related to the mechanical characteristics required by the concentric neutral wires, since that, during the installation of the anti-robbery cable, the installer strongly handle the neutral wires in order to remove the wires (which involve the phase conductor) and locate them in a way that allows the connection.

This problem was solved, after local tests, using aluminium wires with mechanical properties, such as elongation and tensile strength, compatible with the application.

The second problem is related to one of the most serious types of corrosion, the galvanic corrosion, an electrochemical deterioration of the electropositive metal when two or more different metals are in contact in the presence of an electrolyte. For the aluminium anti-robbery cable, the aluminum conductor will be affected by galvanic corrosion when in direct contact with the copper terminals of the energy meter.

The solution for this problem was to find connectors for aluminium anti-robbery cables that could minimize the galvanic currents that would exist in the aluminium/copper interface. The characteristics of these cable connectors are presented below.

CONNECTORS FOR COPPER/ALUMINIUM JUNCTION

In addition to the accessories that are used in copper anti-robery cables, a connector with apropriated characterístics suitable for aluminium/copper interface became necessary for aluminium anti-robbery cables installation.

This connector was developed by Tyco Electronics' Energy Division and is part of AMP COPALUM product line, which comprises terminals and splices that are designed especially for solving the inherent problems of terminating aluminium conductors.

Each connector body is constructed of tin-plated copper and houses a nickel-plated brass insert and funnel. The funnel is designed to prevent wire strands from hanging up when inserted into the wire barrel. The perforated insert enhances reliability for the terminal and splice when crimped to the aluminium or copper conductors.

During the crimping operation, the relatively soft conductor material extrudes through the insert holes, causing the brittle oxide to be sheared, and clean conductor metal to be brought into intimate contact with the inner surfaces of the body and insert. These areas of extrusion form an air- and moisture-tight seal, minimizing oxidation and corrosion.

Stranded-wire crimping also produces "cold welding" or solid-phase bonding between each wire strand. During the crimping process, deformation pressure is applied from several planes, causing sufficient plastic flow of the conductor material. This fractures the oxide film on each wire strand and induces different rates of extrusion. The resulting wiping action under pressure produces interstrand bonding, yielding many contact surfaces and a substantial increase in the contact area. Excellent electrical characteristics are thus achieved.

The increase in contact area also decreases the chances of electrical failure due to creep, differences in thermal expansion, and corrosion. Also, the insert grips the conductor securely, providing a good mechanical connection.

APPLICATIONS TESTS

In order to evaluate the aluminium anti-robbery cable performance when working connected to a distribution box and tinned copper connectors, a specific test was carried out as the following description.

Two anti-robbery cables, 10mm^2 cross sectional area (1x10+10mm^2), were connected to a distribution box through the COPALUM connector. The cables were connected in such a way that one end of each cable was connected to the distribution box (figure 5) and the other end was short-circuited.

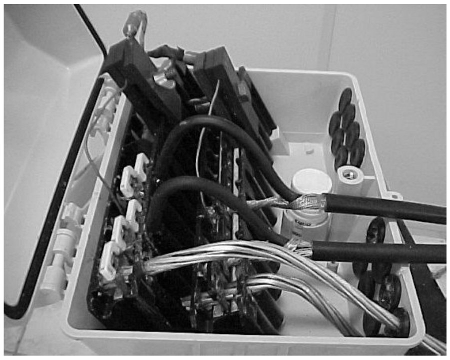

Figure 5: test arrangement

A current source was used to impose different current rates to the testing cables, while temperature meters were placed inside the distribution box and in the middle part of the cables to inform the temperature inside the distribution box and the temperature of the cable conductors.

The following table shows the testing results, presenting the temperature inside the distribution box and the temperatures of each conductor cable when the currents 25, 35, 50 and 65 amperes are applied in each cable. In each test the current was maintained for two hours so the temperature could be established for the measurement.

Current	25 A	35 A	50 A	65 A
	Temperature (ºC)			
Cable 1	34,8	44,3	56,7	63,6
Cable 2	35,4	46,1	60,2	71,2
Box	34,5	44,3	57,5	82,1

Return to Session

In any installation, the connection between cable and distribution box should not be the weak point or the highest resistance point of the circuit. The temperature inside the box is a way to evaluate the contact resistance through out COPALUM connector, since the current losses are responsible for internal box warming.

The testing results were satisfactory because in most cases the box temperature were close to the cable temperature, except for the last case when an overloaded current were applied.

CONCLUSIONS

The electricity robbery issue is one of the main concerns of the Brazilian power utilities companies and the use of anti-robbery cable is one of the main actions related to the combat of energy robbery.

The high cost of copper conductors, comparing with aluminium conductors, motivated the development of aluminium anti-robbery cable, despite the problems related to the galvanic corrosion in copper/aluminium interfaces.

In order to solve these problems and allow the replacement of copper anti-robbery cables by aluminium anti-robbery cables, a special connector was developed, comprising the requirements for an excellent electrical and mechanical connection.

The accomplished tests showed the good performance of the aluminium anti-robbery cable and its connections. Therefore, this cable design can be used to replace both low voltage bundled copper cables and copper anti-robbery cables in electrical service entrances of low voltage consumer units.

REFERENCES

[1] R. Vidnich, 2005, “Furto de Energia e Conseqüências”, VII Encontro Nacional de Conselhos de Consumidores de Energia Elétrica, São Paulo, Brasil.

[2] M.L.Tavares, 2004, “Análise e evolução da tarifa de energia social no Brasil”. Dissertação (Mestrado), Escola Superior de Agricultura Luiz de Queiroz, Piracicaba.

[3] ABNT – Associação Brasileira de Normas Técnicas, Projeto 03:020.03-034, 2003, “Cabos Concêntricos para ramais de consumidores e para tensões até 0,6/1 kV, com isolação externa de PE ou XLPE – Requisitos de desempenho”

GLOSSARY

ANEEL: Brazilian Electric Energy National Agency
XLPE: Crosslinked Polyethylene compound
LME: London Metal Exchange