Low Wind-Pressure Aluminum Conductors Insulated Wire with Grooved Surface

Shunsuke YAMADA* and Naoya YAMASAKI

Copper conductors cross-linked polyethylene insulated wires are widely used for overhead distribution lines in Japan. On the other hand, a trend can be seen in the shift from copper conductors to aluminum conductors because aluminum is light and moderately priced. For the replacement, however, the increased diameter of insulated wires is inevitable due to the difference of conductivity between aluminum and copper. This causes an increase in wind pressure on wires, occasionally requiring rebuilding supporting structures (for example poles). Under such a circumstance, we have developed a low wind-pressure aluminum insulated wire with an original grooved surface. This helps reduce the wind pressure at a wind velocity of both 28 m/s and 40 m/s. Featuring competent electrical performance and workability for connection and other wiring work, the wire has been applied to actual distribution lines.

Keywords: low-wind-pressure insulated wire, aluminum conductor

1. Introduction

Overhead distribution lines supported on utility poles are used to supply electricity to consumers. They are insulated wires made of copper or aluminum conductors provided with insulation such as cross-linked polyethylene. Figure 1 provides diagrammatic illustrations of overhead distribution lines and an insulated wire used to construct them.

One recent trend is to consider replacing copper conductor wires conventionally used to construct distribution lines with aluminum conductor wires. The reasons for this trend include the factors that aluminum is significantly lighter than copper (30% of copper in specific gravity), and the market price of aluminum ingots is relatively low and stable.

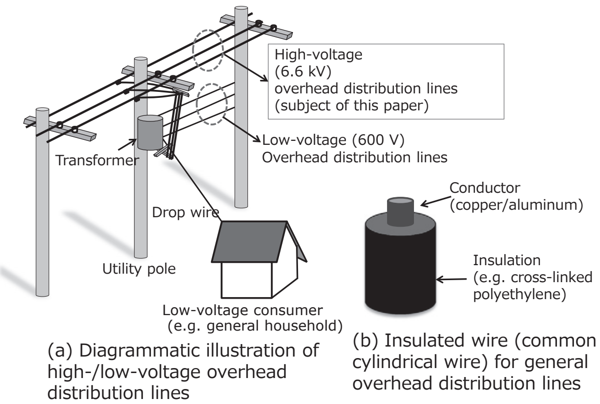


Fig. 1. Overhead distribution lines and insulated wire used to construct them

However, aluminum is lower in conductivity than copper by 37%. Consequently, it is necessary to construct conductors with a larger cross-sectional area for aluminum to be used at a similar level of current carrying capacity to copper conductor wires. Take as an example a wire manufactured by covering an 80 mm^2 copper conductor with cross-linked polyethylene [outdoor cross-linked polyethylene insulated wire (OC wire*[1])] used to construct 6.6 kV lines. The outside diameter of this wire is approximately 16 mm. To replace this wire with an OC wire made of an aluminum conductor, the cross-sectional area of the conductor needs to increase to 120 mm^2, with the outside diameter of the wire reaching 19 mm.

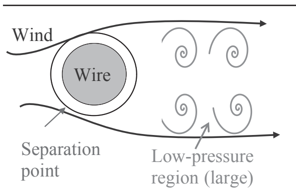
One challenge associated with an enlarged wire diameter is increasing wind pressure resulting from an enlarged area of wind exposure. The Commentary on Technical Standards for Electric Installations ("Denki Setsubi no Gijutsu Kijun no Kaishaku" in Japanese) set forth by the Japanese Ministry of Economy, Trade and Industry requires that utility poles and other support structures be designed on the assumption that wires are subject to gravity and vertical wind pressure caused by 28 m/s winds as experienced in an urban area or 40 m/s winds as experienced in a typhoon, depending on the use environment. Accordingly, replacement with aluminum wires involving an increasing wind pressure may require major capital investment, such as replacement of utility poles.

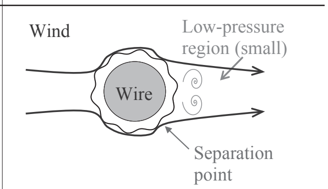
Against this backdrop, development of a low-wind-pressure wire has been under way by arranging the wire form to reduce the wind pressure. However, conventional technology was limited in that it was effective only at specific wind velocities, making it necessary to select them wisely according to the installation location. Sumitomo Electric Industries, Ltd. developed a low-wind-pressure OC wire with reduced wind pressure at both 28 m/s and 40 m/s, by forming its original grooves in the wire insulation. This paper reports on the newly developed low-wind-pressure insulated wire.

2. Principle and Method Used to Reduce Wind Pressure [1,2]

First, this paper describes the wind pressure generation mechanism. A common cylindrical wire in the wind produces air streams as shown in Table 1 (a). The wind separates from the wire surface at a relatively frontal part of the wire, producing a whirl region behind the wire. The pressure in the whirl region is low. The differential pressure between the front and rear of the wire results in a load such that the wind presses the wire.

Table 1. Wind pressure on wire





(a) Common cylindrical wire	(b) Low-wind-pressure wire
Separation points occur in the frontal part. Large wake flow region High wind pressure (differential pressure between front and rear)	Separation point shifting toward rear to reduce the occurrence of wake flows Low wind pressure

While a common electric wire is cylindrical, imparting projections and depressions on its surface allows the separation point to shift toward a more rearward part, diminishing the low-pressure region where whirls occur, as shown in Table 1 (b). The result is a reduced differential pressure between the wire front and rear, with the wire benefitting from the reduced wind pressure.

A familiar example of the application of this effect is the golf ball. Golf balls have dimples on their surface to extend the carry distance by reducing the wind pressure. For overhead power transmission lines used to transmit power over a long distance with bare conductors supported on power towers, various methods were explored around 2000, including spiral elliptic wires and grooved wires.

Sumitomo Electric explored irregular shapes for the insulation of low-wind-pressure OC wires to achieve a low-wind-pressure effect while providing the required level of electrical insulation.

3. Characteristics of Sumitomo Electric's Grooved Low-Wind-Pressure Wire

Sumitomo Electric developed and launched a low-wind-pressure OC wire with a grooved surface. This section details the appearance, wind-pressure characteristics, and electrical characteristics of the low-wind-pressure OC wire for 6.6 kV lines, made of the most common 120 mm^2 aluminum conductor (internally designated as 6.6 kV ACSR/AC*2-OC-L*3 120 mm^2).

3-1 Appearance

Photo 1 shows the appearance. The insulation is formed with longitudinal grooves. Various candidate shapes were explored, including tiny spherical pits and projections on the surface, as described later. The groove style was selected from the perspectives of low-wind-pressure characteristics, electrical characteristics, and ease of manufacturing. The number, depth, and width of the grooves were optimized. Electric wires manufactured by Sumitomo Electric bear letters in relief to indicate information such as voltage, product name, manufacturer name, and year of manufacture to meet the need for maintenance of lines. The wire structure was selected with visibility of the indication in mind.

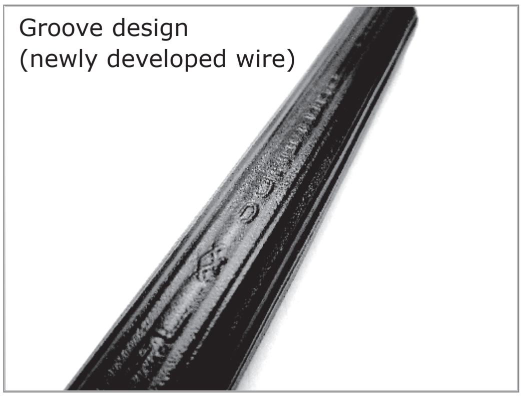


Photo 1. Grooved low-wind-pressure wire (new technology)

3-2 Wind-pressure characteristics

The wind-pressure characteristics of the low-wind-pressure wire were evaluated by supporting the wire in a wind tunnel and measuring wind pressure at different wind velocities.

Table 2 presents wind pressures measured with four types of OC wires [1] to [4] rated at comparable capacities (approximately 300 A), including the newly developed grooved low-wind-pressure wire. Table 2 reveals that the wind pressure on the newly developed grooved low-wind-pressure wire made of a 120 mm^2 aluminum conductor [1] is lower than that on the simple cylindrical wire of the same diameter [2]. Furthermore, compared with the conventional 80 mm^2 cylindrical wire made of a copper conductor with a smaller outside diameter [3], which was

Table 2. Wind pressure on wire

Wire type	Conductor type	Cross sectional area of conductor [mm^2]	Surface shape	Wire Outside diameter [mm]	Permissible current [A] (approximate)	Wind pressure [N/m]	
						28 m/s	40 m/s
[1] Newly developed	Aluminum	120	New, Grooved (Photo 1)	18.6	300	6.8 ~ 7.6	14.0 ~ 15.2
[2]	Aluminum	120	Common, cylindrical	18.6	300	9.1	18.2
[3]	Copper	80	Common, cylindrical	15.6	300	7.6	15.2
[4]	Aluminum	120	Tiny pits and projections (Photo 2)	18.6	300	8.6	13.6

rated at a similar permissible current, the wind pressure on conductor [1] was equal to or lower at the two wind velocities of 28 m/s and 40 m/s. This implies that by using the structure of conductor [1], it becomes feasible to replace lines consisting of conventional wires made of copper conductors [3] with aluminum conductor wires without the need to replace utility poles.

Wire [4] is an example of, and represents evaluation results for, conventional technology. Its surface had tiny semispherical pits and projections instead of grooves (see Photo 2 for the appearance). Compared with the newly developed technology of wire [1], wire [4] received a higher or lower wind pressure at 28 m/s or 40 m/s, respectively. Compared with copper conductor wire of comparable current carrying capacity [3], the wind-pressure reduction effect of wire [4] was sufficient at 40 m/s while insufficient at 28 m/s. Thus, wind-pressure reduction effects of surface irregularities and other features have been known to depend on wind velocity.(2) It is generally difficult to realize a wire that exhibits sufficient wind-pressure reduction effects at both 28 m/s and 40 m/s. Meanwhile, Sumitomo Electric's low-wind-pressure wire exhibits wind-pressure reduction effects at both wind velocities owing to the optimized surface shape.

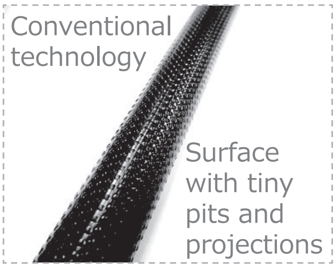


Photo 2. Wire with tiny pits and projections (conventional technology)

3-3 Electrical characteristics

Regarding electrical characteristics, tests were conducted to examine properties such as dielectric strength, insulation resistance, and tracking resistance in accordance with standards covering specifications for implements principally used by power companies. The newly developed wire was proven to exhibit sufficient electrical performance withstanding use on lines in the field even with insulation surface irregularities.

3-4 Verification of suitability for use with connection components and ease of work

The newly developed wire was also checked for compatibility with connectors and other connection components and ease of installation work. It has already been selected for use on many lines in actual applications.

4. Conclusion

This paper reported on Sumitomo Electric's grooved low-wind-pressure insulated wire that exhibits low-wind-pressure effects at wind velocities of 28 m/s and 40 m/s. While this paper focused on the characteristics of the most common 6.6 kV class wires of conductor size of 120 mm^2, deployment of the newly developed technology to larger diameter and smaller diameter wires as well as to 22/33 kV wires that need to meet higher dielectric strength requirements is under way, representing the Company’s efforts to expand the product lineup.

The wind-pressure reduction technology used with this wire is not limited to serve as a solution to increased wind-pressure arising from the use of larger-diameter wires due to replacement of copper conductors with aluminum conductors described in the introduction of this paper. It also has the potential to fulfill various demands such as the development of wires with increased diameters for increased current carrying capacity of the grid and reduced loading on utility poles. Accordingly, the technology is anticipated to play a major role in the construction of power distribution networks in Japan.

Technical Terms

*1 Outdoor cross-linked polyethylene insulated (OC) wire: OC wires made of copper or aluminum conductors are widely used for overhead distribution wires with the rating ranging from 600 V to 33 kV.

*2 Aluminum conductor steel reinforced/aluminum clad (ACSR/AC): An aluminum conductor that has aluminum-clad steel wires at the core for strength reinforcement.

*3 Low-wind-pressure (-L): Denotes that the wire is a low-wind-pressure wire.

References

(1) Mijika na densen no hanashi, Japan electric cable technology center, ed. Ohm-sha, pp. 42-47 (2011)

(2) T. Yukino, H. Okada, Y. Eguchi, T. Nishihara, H. Ito, N. Iwama, and N. Kikuchi, “Development of low wind pressure conductor for overhead transmission line,” Wind Engineers, No. 98, pp. 37-44 (2003)

Contributors The lead author is indicated by an asterisk (*).

S. YAMADA*
• Assistant Manager, Power Cable Division

N. YAMASAKI
• Group Manager, Power Cable Division