Furukawa Electric, VISCAS, Inoue Manufacturing, Asahi Electric Works,
Furukawa Electric Industrial Cable

Underground Power Cable, Distribution Cable, Overhead Transmission Line, Industrial Cable and Their Accessories

*by Shinji Umeda *1, Noboru Ishii *1, Noriaki Horiguchi *1, Makoto Maeda *1, Takumi Yamaguchi *2, Hideo Tanaka *3, Hiroshi Niinobe *3, Takehiko Mizuno *3, Satoru Maruyama *3, Kunio Iwasaki *4, Hiroyuki Majima *5, Shigekazu Amanuma *6, Hideki Kamiyama *7, Masaji Tokita *8, Shingo Oya *9, Hiromichi Shigeta *10 and Hiroji Akasaka *10*

ABSTRACT In the area of electric energy, recent years have seen expanding deregulation of electric utilities, heightened consciousness about secured supply, the global warming problem and the like, which lead to significant changes in the environment surrounding the electric power industries. Thus, Furukawa Electric has been promoting technological developments on the premise that safety and security is the first priority, concentrating on preservation of the global environment and supply of new products that are lean, compact and economical. In this report, technological achievements of the Furukawa Electric Group comprising Furukawa Electric, VISCAS, Inoue Manufacturing, Asahi Electric Works and Furukawa Electric Industrial Cable are presented on a categorized basis.

1. EXTRA-HIGH VOLTAGE POWER CABLES

Extra-high voltage cables over 66-kV rating may be categorized into OF (Oil Filled), POF (Pipe Oil Filled) and CV (Cross-Linked Polyethylene Insulated PVC Sheathed, i.e., XLPE) cables, and we took the worldwide initiative in developing these cables of 500-kV rating which corresponds to the world's highest voltage. Among these, XLPE cable has made a remarkable progress since its first application 50 years ago, with respect to the material, structure, manufacturing technology and quality control technology. As illustrated in Figure 1, the cable has been downsized by means of insulation thickness reduction (i.e., increase in electrical stress), thereby putting 500-kV long-length XLPE cable and large-sized, long-length CVT (Cross-Linked Polyethylene Insulated PVC Sheathed Triplex, i.e., Triplex-type XLPE) cable into practical application.

*1 Power Cable Engineering Dept., VISCAS
*2 Installation Engineering Dept., VISCAS
*3 R&D Dept., Technological Administration Div., VISCAS
*4 Distribution Cable Dept., VISCAS
*5 Power Equipment Dept., Inoue Manufacturing
*6 Overhead Power Transmission Line Research & Development Dept., Technological Administration Div., VISCAS
*7 Overhead Power Transmission Engineering Dep., Power Transmission Div., VISCAS
*8 Engineering Dept., Asahi Electric Works
*9 Engineering Dept., Furukawa Electric Industrial Cable
*10 Engineering Dept., Energy Div., Energy & Industrial Products Co., Furukawa Electric

1.1 500-kV XLPE Cable

500-kV XLPE cables have been adopted in long-distance underground power transmission lines such as for Tokyo Electric Power Company's Shin-Keiyo-Toyosu Line (approx. 39.8 km x 2 circuit, total number of intermediate

Voltage	History of the insulation thickness
500 kV	35→32→27 mm
275 kV	27→23 mm
220 kV	23→20 mm
154 kV	23→19→17 mm
77 kV	17→15→13→11 mm
66 kV	15→13→11→ 9 mm

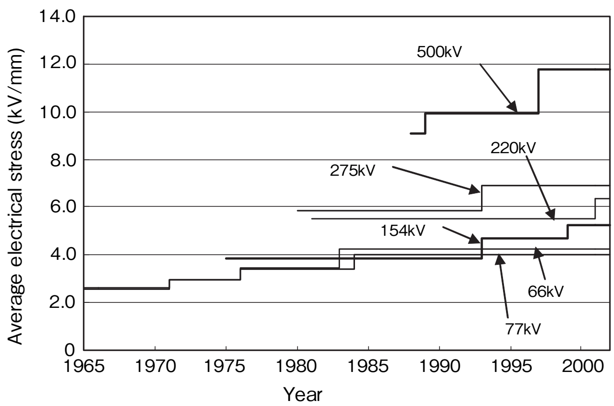


Figure 1 Trends in voltage upgrading and electrical stress increase.

joint: 240 phase, maximum span: 1,800 m), as well as in outgoing lines from power plants. Figure 2 shows a scene of cable installation for the Kan'nagawa Hydraulic Power Plant of Tokyo Electric Power Company in 2003. Because the cable was so long in unit length as to reach 1,800 m, ordinary methods were unable to deal with its transportation. Accordingly, the cable was transported from the manufacturing plant to Hitachi Port by sea, and from where to the power plant by land using a special-purpose vehicle under a restriction of nighttime-only traveling, spending an unprecedentedly long transportation time of seven days.

With respect to connection with the power equipment, an inverted type of gas-immersed termination joint was needed, so that we developed a new joint after reviewing its inner structure, having succeeded in delivery ahead of other manufacturers.

We have accumulated several track records of 500-kV XLPE cables domestically since then, and having gained a foothold in overseas market through our recent delivery to China, we plant to receive more orders from overseas.

1.2 Cable Downsizing and Capacity Increase

We have developed jointly with Tokyo Electric Power Company the Triplex-type XLPE cable having a sectored cross-section shown in Figure 3, and have applied the cable to many practical transmission lines since 1998. It was intended that the new cable design would be applied to increase the transmission capacity (i.e., increasing the conductor size) while making efficient use of existing cable conduits, because the costs related with civil engineering work to construct new cable conduits were very expensive. This development has made it possible to apply 500-mm^2 sized cables to those transmission lines where the maximum cable size was limited to 325 mm^2 due to the duct size restriction, thereby achieving a capacity increase.

Figure 2 Installation of a long-length cable using a special-purpose vehicle.

Figure 3 Appearance of sectored Triplex-type XLPE cable.

1.3 Large-Sized Triplex-type XLPE Cable

Although the largest conductor size of Triplex-type XLPE cables was conventionally limited to 600 mm^2 due to manufacturing difficulties, we have overcome these problems and subsequently investigated the characteristic thermal behavior of large-sized segmented conductor cables at the time of stranding. As a result, taking into account these results in installation design, we were able to expand the size of 66-kV and 154-kV Triplex-type XLPE cables up to 1,000 mm^2. The specification based on these results has been adopted since 2005 as a standard for practical lines, resulting in a number of improvements such as reducing the space for cable accommodation, efficiency increase in cable laying (i.e., enabling laying of three phases in a shorter period of time), reducing the line construction costs and downsizing of manholes due to elimination of cable offset.

1.4 DC XLPE Cable

There is much need for DC transmission cables for its higher power transmission efficiency with no AC losses. Until recently, AC power transmission was preferred to DC transmission due to the fact that AC-DC power converters to be installed at either end of the cable line are expensive thus causing an increase in total construction cost. As the cost of power converter decreases, however, application of DC power transmission is expected to expand.

But, in developing DC XLPE cables, it was found that the AC insulation material (i.e., cross-linked polyethylene) was not directly applicable to DC cables due to the problem of space charge accumulation within the insulation material. Accordingly, we have developed a DC insulation material which can control space charge accumulation, and have confirmed that the prototyped DC 250-kV and 500-kV XLPE cables are provided with superior electrical properties including long-term characteristics.

Figure 4 Large-sized Triplex-type XLPE cable and its installation.

Moreover, taking advantage of the DC cable technology mentioned above, we have recently embarked on the development of coaxially-integrated return conductor DC XLPE cables (i.e., DC coaxial cables), in which the main DC cable and the return cable are integrated into a single cable, and the development has advanced to the stage of the 250-kV class.

1.5 Submarine Cable

There are firm demands for submarine cables both at home and abroad.

In 2004, we have delivered to the Matsushima-Narao Line of Kyusyu Electric Power Company connecting the Matsushima Substation on the Kyushu mainland side and the Narao Substation on the Goto side a large volume of 66-kV optical fiber-composite submarine power cable in lump-sum, totaling approximately 2,670 ton in mass and 54 km in length, which equals the world-class length as an AC triplex XLPE submarine cable. The Line comprised two cable lines, and the cable laying work was carried out, under the direction of Kyusyu Electric Power Company, by a joint venture consisted of four companies headed by Furukawa Electric.

Although the cable structure had a proven track record, the unexperienced length of the cable made it indispensable to factory joint the power cable and the optical fiber unit. Accordingly, in addition to the conventional inspection items specified in the CIGRE recommendations, we have reviewed the history of procedures that the cable is anticipated to undergo ranging from manufacturing at the plant to final installation at the site, and, after designing the cable taking these results into consideration, we confirmed the validity of the design by verification.

In this cable laying work done by the four-company joint venture, a cable laying ship built by using pure domestic technologies and provided with the dynamic positioning system (DPS) "Tenzan" played an active role (see Figure 8). The ship traveled, in a complete DPS scheme without using anchor at all, the whole 54-km route to lay and bury the cable at a pace of one line in ten days (day and night).

High-accuracy cable laying with an accuracy of not more than ±5 m for straight sections and not more than ±10 m for curved sections has been achieved. The cable burial depth was set at 1.5 m to avoid damages due to anchoring. In terms of burial method, the simultaneous laying and burying method was applied where a cable paid out from a laying ship is immediately buried by a burying machine that is tugged by the laying ship (see Figure 9).

It is expected that, as a result of this achievement,

Figure 7 Appearance of typical submarine cable.

Figure 8 Cable laying ship "Tenzan" with DPS function, built by using pure domestic technologies.

Figure 5 500-kV DC XLPE cable.

Figure 6 ±250-kV DC coaxial submarine power cable.

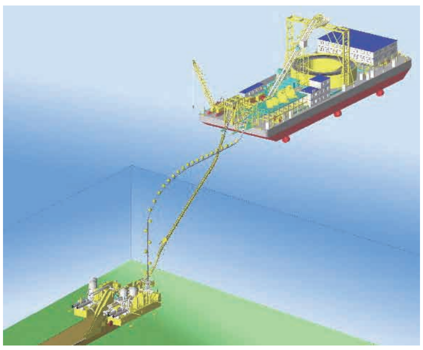


Figure 9 Conceptual image of simultaneous laying and burying using a cable laying ship with DPS function.

demand for isolated island connection cables over long distances will grow in future.

2. JOINT FOR HIGH-VOLTAGE XLPE CABLES

Because XLPE cable is characterized by its ease of maintenance, the cable rapidly proliferated domestically in the 1960s when its application began, currently constituting the majority of domestic power cables having voltage ratings of 66-kV and higher. During this period, we have developed the sealing end and the extrusion molded joint for XLPE cable joints, achieving significant improvements in terms of performance, ease of installation, reduction of joint size and so forth.

As the cable rating was upgraded from the 66-kV class to the 154-kV, 275-kV and further to the 500-kV class, we carried out development concentrating on the reliability and work management of joints, thereby achieving an extremely low rate of dielectric breakdown across the world. Moreover, since the late 1990s when 500-kV XLPE cables have been put into actual use, studies have been made focusing on simplifying the installation process for joints as well as reducing their sizes, and new joints that utilize new structures and materials have been developed for practical application.

A rubber block-based intermediate joint named cold shrinkable joint (CSJ) is one of these developments, which is aimed at simplifying the installation process. The structure of CSJ is such that a rubber block insulator (see Figure 10) that is molded at the factory in advance is used as a reinforcing insulator to fit to the cable joint. The CSJ has achieved, due to its simple structure, a significant reduction in installation time and simplification of work management when compared with taped joints where an insulating tape is wound at the work site, or with field molded joints where cross-linked polyethylene is used to integrally mold the cable at high pressure and high temperature. Currently the CSJ is practically applied to the 154-kV class domestically as well as to the 220-kV class overseas, and the one for 400 kV has already been developed, so that its application area is growing. Moreover, aiming at simplification of installation work, we are presently developing a simplified termination which applies rubber block insulator and oil to a termination, whereby the 110-kV class has already been put into practical application, while the 220-kV class is under development.

As for termination using new materials, on the other hand, a composite-type termination has been developed, which is based on composite insulator that consists of FRP insulator and silicone rubber sheds instead of porcelain insulator. Because the composite insulator is lighter than porcelain insulator, it is considerably advantageous in that the assembly work can be carried out safely in a shorter period of time without using heavy machinery. With respect to electrical characteristics, it has been confirmed that the composite insulator is comparable to or better than porcelain insulator due to the water-shedding property of silicone rubber. While the composite insulator has been applied to the 154-kV class presently, it is expected that the application will grow to higher-voltage regions in the future.

In addition, an insulation oil-free, 77-kV class dry composite type termination (see Figure 11) has been developed, which utilizes silicone rubber for the outer jacket molded on an epoxy insulator. The termination is advantageous in that free-angle installation is allowed for; no oil leak occurs making it environment friendly; and jointing work of cable takes only a short time because compact versions of the CSJ mentioned above are used. Introduction of dry composite type terminations to higher voltage ratings has just begun, so that the application is expected to expand in the future.

Furthermore, we have two kinds of compact joints, namely: compact transition joint for different types of cables such as the XLPE and OF cables; and compact Y-branch joint (see Figure 12) for three XLPE or OF cables. These achievements have been realized by accumulating design technologies, whereby the structural dimensions

Figure 10 Rubber block insulator for 220-kV rating.

Figure 11 Dry composite type termination for 77-kV rating.

were reviewed for size reduction based on the new design parameters obtained by improving the material and work management.

3. DISTRIBUTION ELECTRIC WIRES AND CABLES

3.1 Underground Distribution Cable

Underground distribution cables range from 6.6 kV to 33 kV in voltage rating, and XLPE cables that employ cross-linked polyethylene as insulator are generally used. It may be said that the history of XLPE cable is the history of countermeasures against water tree, a process of insulation deterioration due to water absorption. Water tree is a phenomenon in which water penetrates into insulation under the influence of electric fields forming a dendritic (tree-like) array of voids filled with water, thereby degrading the insulation performance. Countermeasures against this include: minimizing the foreign matters and voids contained in the insulation, reducing the protrusions on the interface of the insulation and relaxing the local concentration of electric fields. These can be realized by dry cross-linking where cables are manufactured without using water vapor pressure, by composing a layered cable insulation where the inner and outer semiconducting layers are structured by semiconductive plastics replacing conductive tapes, and by extruding the resultant semiconducting layers simultaneously with the insulation to carry out triple-layer extrusion. These countermeasures were implemented sequentially in the 1980s, significantly reducing the occurrence of water tree deterioration since that time.

Moreover, water-impervious XLPE cables were developed and applied in the late 1980s centering on the 22-kV and 33-kV XLPE cables, with the aim of improving the reliability further by completely preventing entry of water into the cables. The water-impervious tape consisted of a laminated lead tape which is laminated with a lead foil and plastics to improve the extensibility, making it possible for the tape to follow the thermal expansion and contraction of the cable. This laminated lead layer was bonded on the inside of the cable sheath, constituting a water-impervious cable. In the 2000s, we eliminated lead from water-impervious cables ahead of others intending to make an environment-conscious cable. To this end, we replaced lead on the water-impervious layer with aluminum to complete an aluminum water-impervious cable, and we are promoting substitution of this cable for lead water-impervious cables (see Figure 13).

3.2 Submarine Cable

High reliability is required for submarine cables, because repair is difficult once they are laid. Although steel rods 6 to 8 mm in diameter are wound around the cable for armoring purpose to prevent external damage, these steel armor rods are often damaged in long-term service by electric corrosion and the like due to ocean current and earth magnetism. To improve this disadvantage, application of corrosion-free FRP rod was investigated. As the result, a composite steel and FRP armored submarine cable was developed which combines the strength of steel rods and the corrosion resistance of FRP rods, and the cable was laid between the main island and Izenajima island in Okinawa in 2002 (see Figure 14). From the standpoint of natural environment preservation, an arch

Figure 12 154-kV compact Y-branch joint, measuring 300 mm x 600 mm x 1,500 mm.

Figure 13 Aluminum water-impervious cable.

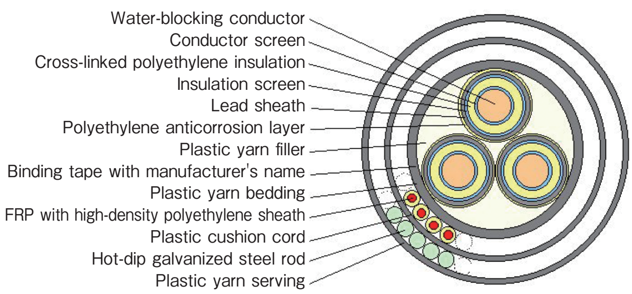


Figure 14 Cross section of composite armored submarine cable.

horizontal boring method was adopted to protect the coral reef at the both sides of foreshore, as the first application for domestic submarine cable.

3.3 Reduced Wind Drag Insulated Wire

Strength of supporting structures for electric wire facilities such as electric poles is designed based on the loads under the influence of wind pressure. With the aim of reducing the construction cost by decreasing the design load on supporting structures, studies on wind drag reduction have been conducted. Whereas the studies have been conducted mainly for overhead transmission lines conventionally, recent years have seen an expansion to overhead distribution lines such as the OC (Outdoor Cross-linked PE insulated) and OE (Outdoor PE insulated) wires, and the cross-sectional shapes of insulated wire with reduced wind drug have been established resulting in practical applications.

Drag on a cylinder placed in a flow is generated as a difference between the windward pressure and the reduced pressure called wake flow at the leeward, so that the principle of reducing the wind drag on wires consists in reducing the wake flow, as shown in Figure 15. The reduction of wake flow can be achieved by introducing irregularities on the cylinder surface thereby displacing the separation point of the boundary layer from the cylinder to the leeward as far as possible. Accordingly, reduction of wind drag on wires resides in finding out a surface shape that offers efficient wind drag reduction. Our wire shapes for reduced wind drag come in two types of grooved cylinder and regular polyhedron, and an optimized reduced wind drag design is available depending on the type of wire and the applicable range of wind speed.

(1) Groove type

Figure 16 shows the shape with 30 grooves. This is targeted at smaller wires, and has come into use in practical applications in the range of 10 to 25 mm in diameter.

(2) Polyhedron type

Figure 17 shows the shape with a 19 to 20 faceted polyhedron. This has come into practical applications for wires having a diameter of 18 mm or above.

Figure 18 shows typical wind drag reduction. Compared with conventional cylinder wires, wind drag can be reduced by 30 to 50 %.

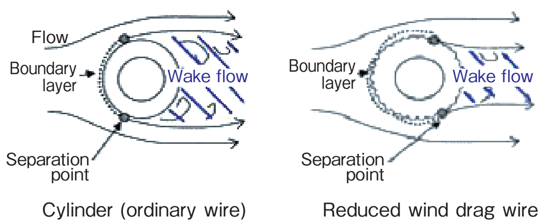


Figure 15 Mechanism of wind drag reduction.

3.4 Recycling of Wire Sheath Materials

A recycling system is established for electric wire stocks, in which copper used as conductor is recovered and reused in electric wires, and application of recycled aluminum to electric wires and the like is also making progress thereby achieving a recycling percentage of nearly 100 %. Moreover, we are developing jointly with Tokyo Electric Power Company a recycling program of electric wire sheathing material, which is targeted at a recycling percentage of 100% for electric wire. Main sheathing materials for electric wires to be recycled include polyvinylchloride (PVC), polyethylene (PE) and cross-linked polyethylene (XLPE).

(1) Recycling of PVC

PVC materials recovered from the removed OW (Outdoor Weatherproof PVC insulated), IV (PVC insulated), DV (PVC insulated Drop service) and SV (Service entrance PVC sheathed cable) wires have varied characteristics in their roughened extruded surface, insulation resistance

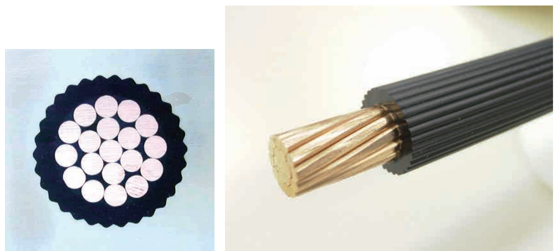


Figure 16 Reduced wind drag wire with 30 grooves.

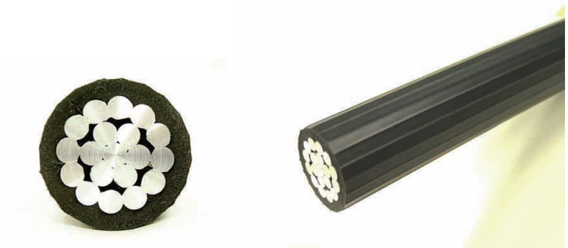


Figure 17 Reduced wind drag wire with 20-faceted polyhedron.

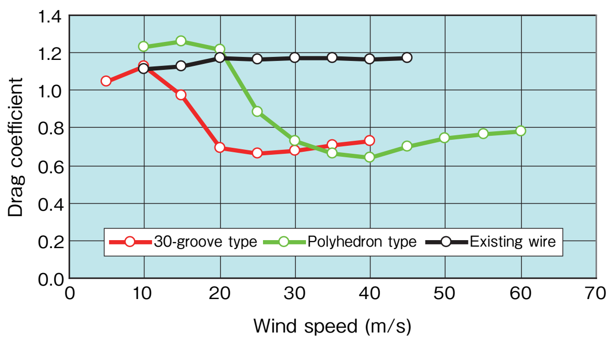


Figure 18 Comparison of wind drag reduction characteristics.

and degraded brittleness, so that it is necessary to take proper measures before applying them to electric wires again. Even though the recovered PVC materials are kneaded after adding stabilizer and plasticizer so as to improve their characteristics, the recycled materials are still inferior to new materials such that it is difficult to apply some specified color markings on their surface. Accordingly, in application to wire sheathing, a two-layered structure is adopted: recycled material for the inner layer and new material for the outer layer. The use of new material on the outer layer makes it possible to distinguish phases by coloring, and the appearance becomes comparable to that of conventional wires. Thus, we have achieved the reuse of recovered PVC material to electric wire sheathing by means of material property management, improvement of recycling kneading techniques and the adoption of two-layered structure. The recycling of PVC is currently applied to the IV, DV and SV wires.

(2) Recycling of PE

As for the recycling of PE, recovered PE from OE wire is pelletized into recycled PE to be used in sheathing of OE wire again. PE sheathing recovered from Tokyo Electric Power Company ---colored in black by its nature containing weather resistant carbon--- was found to be rather stabilized in the quality, so that it was concluded that application to wire sheathing would pose no problems if the quality of recovered lots are properly managed. The characteristics of prototyped OE wires fully satisfied the wire specifications despite their somewhat roughened surface. The recycled OE wire has acquired Tokyo Electric Power Company's type certification leading to continued delivery. Also, the recycled PE material is being applied to plastic drums for wires, expanding its applications.

(3) Recycling of XLPE

XLPE is a cross-linked polyethylene with improved heat resistance. Cross-linked structure results in low fluidity above the melting temperature of a material, capable of sustaining the original shape. This made it difficult to reprocess the recovered XLPE using extrusion and the like, so that conventionally recovered materials were disposed of as fuel by thermal recycling or as industrial waste. We have developed a melt & shear kneading method, in which suitable amounts of heat and shear are applied to XLPE to break down the cross-linked structure thereby reducing the molecular weight. In this way the recovered XLPE can be reprocessed using ordinary extrusion forming. Because the recovered XLPE is forcibly reduced in the molecular weight, its mechanical characteristics like elongation are significantly lowered. Accordingly, in applications to wire sheathing, the material was mixed with virgin PE to improve the deteriorated characteristics, and it was found that if the mixing ratio of the recovered material is not more than 25%, the resultant material is comparable to virgin materials. This recycled material can be cross linked by either the water vapor or silane cross-linking processes, and is applicable to OC wire using regular manufacturing processes. This recycled OC wire also acquired a type certification from Tokyo Electric Power Company, and was delivered to the same company (see Figure 19).

4. CABLE ACCESSORIES FOR UNDERGROUND DISTRIBUTION

4.1 Joint for 6.6-kV XLPE Cable

Joints for underground distribution cables have ever undergone changes to adapt themselves to the cable structures of the times. Specifically after 1970, as XLPE cables have evolved to become established, solder jointing of conductors has been replaced by compression jointing using neither torch nor heat reducing jointer errors, together with prefabricated joints which need no tape wrapping for insulation. As for 6.6-kV cables, such joints have come into practical applications and are widely used including slip-on type straight-through joints, slip-on type terminations and porcelain bushing type terminations.

Since around 2000, cold shrinkable terminations have been used, with which, as shown in Figures 20 and 21, the main body of a joint is expanded beforehand at the factory over a supporting core, which is removed after cable conductor jointing and insulation shaping to make the main body fit on the cable. The main body uses silicone rubber having superior contamination resistance and mechanical as well as electrical characteristics, with an aim to improve reliability and workability.

Intermediate joints such as straight-through joint and Y-branch joint also use silicone rubber, and cold-shrinkable joints have come into practical applications in order to reduce the number of parts and to improve workability.

The structure of Y-branch joint is such that a spacer with a built-in electric stress relief function is mounted on each core conductor, on which an insulation housing is cold-shrunk. A waterproof spacer is mounted on the ends of two branches to waterproof them in block using a waterproof tape, aiming at workability improvement and downsizing of the joint.

The Y-branch joint is practically applied in the field as a component of the so-called "soft" underground distribution cabling system. Conventionally underground installation of distribution cables required that a tower for circuit breakers be installed on the ground for branching, thus necessitating a certain width for the sidewalk. Application

Figure 19 OC wire using recycled material.

of Y-branches, in contrast, allows for branching without installing equipment on the sidewalk (see Figure 22).

In the beginning of the 1980s, cable connectors for XLPE cables to circuit breakers and transformers began to have a prefabricated structure, in which a premolded insulation housing made of EP rubber is inserted into equipment-side bushings molded with epoxy and the like, taking advantage of rubber elasticity to maintain insulation performance. In the first half of the 1980s, separable connectors for multi on-load switch and separable connectors for mold-dyscon were specified by Tokyo Electric Power Company, and they became widespread nationwide. In the last half of the 1980s, as the gaseous circuit breakers became popular, cable connectors were required to be small in size, so that T-type cable connectors were specified by the four electric power companies headed by Chubu Electric Power Company, and these cable connectors were extensively adopted.

4.2 Joint for 22-kV XLPE Cable

As for the 22-kV ratings, slip-on type straight-through joint using molded rubber insulation housing plus spacer (i.e., stress relief cone) came into use in the 1980s, and the conductor connection method changed into compression connection. Thus the so-called prefabricated joints have been extensively used for their stabilized performance until today.

In an effort to reduce the distribution equipment costs by upgrading facility efficiencies, Tokyo Electric Power Company has been promoting the expansion of the 22-kV power supply system since the first half of the 1990s. New cables and joints were required aimed at maintaining reliable power supply and cost suppression, and in response to this requirement, cables using aluminum laminate tapes for water-impervious layer were developed together with joints suitable for these cables. The cable outer semiconductive layer end treatment method on the joint was elaborated to reduce the insulation thickness, resulting in a reduction in the thickness from 7 mm to 4.5 mm (including the inner semiconductive layer). Thus a cold-shrinkable straight-through joint with improved workability on site has come into practical applications.

The new water-impervious structure has adopted a heat-shrinkable tube with a built-in metal foil inside. The metal foil is of aluminum taking environment-friendliness into consideration, and it is sandwiched via adhesive layers between heat-shrinkable polyolefin layers (see Figure 23).

4.3 Overhead Line Protector

We have developed a flame-retardant wire protector for preventing overhead distribution wires from contacting with trees, in which, unlike conventional ones, both ends are colored in gray.

It has been reported that overhead distribution wires

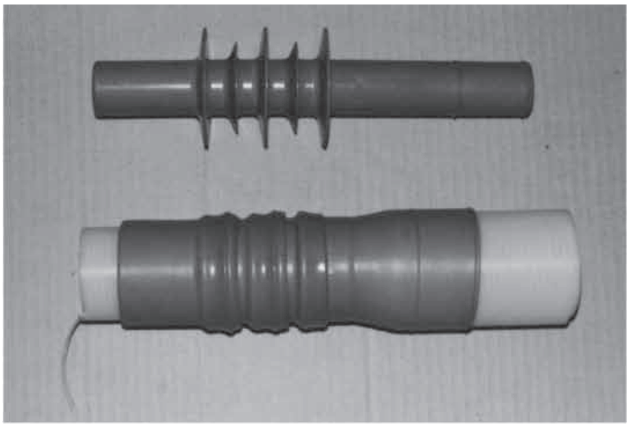


Figure 20 6.6-kV cold shrinkable outdoor termination (main body).

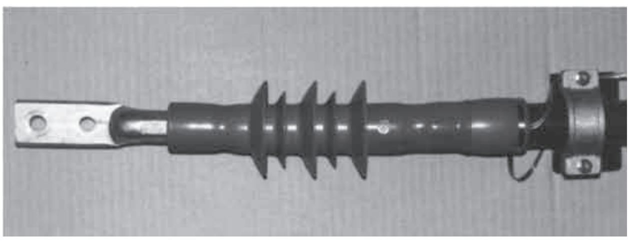


Figure 21 6.6-kV cold shrinkable outdoor termination.

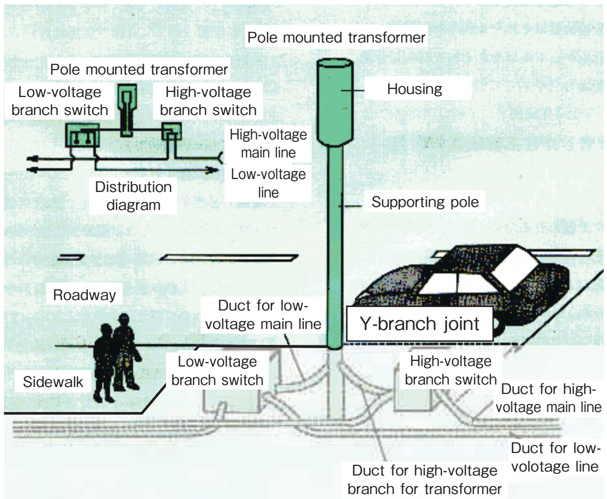
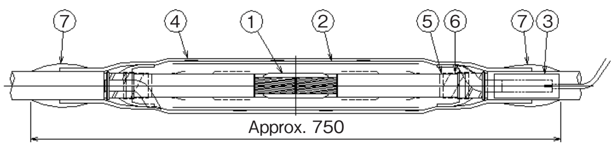


Figure 22 Conceptual image for installation of Y-branch joint.



①	Conductor connecting sleeve	⑤	Semiconductive paint
②	Insulation housing	⑥	ACP tape
③	Grounding plate	⑦	Waterproof tape
④	Water-impervious heat-shrinkable tube		

Figure 23 Cold-shrinkable straight joint with water-impervious layer.

can catch fire when they contact with trees, and accordingly, the Technical Standards for Electric Facilities specifies the use of double-layer structured wire protectors or abrasion-proof insulated wires. Because no flame-retardant specifications were applied to the prototyped wire protectors, it was occasionally found that they catch fire. To settle this problem, development of flame-retardant wire protectors was intended.

Flame-retardant polyethylene materials were investigated to achieve ample fire-resistance, and both ends were colored in gray to make the protector distinguished from conventional ones easy (see Figure 24). Before the adoption of gray-colored covers, 2,000 hours of Sunshine Weatherometer tests were carried out together with accelerated weathering tests equivalent to 4,000 hours using a Super UV Tester, thereby having confirmed the long-term performance (see Figures 25 and 26).

As a result, it was determined that the characteristics hardly changed even after 2,000 hours had passed, and the product was released into the marketplace. Tokyo Electric Power Company is introducing this product increasingly.

Figure 24 Overhead line protector.

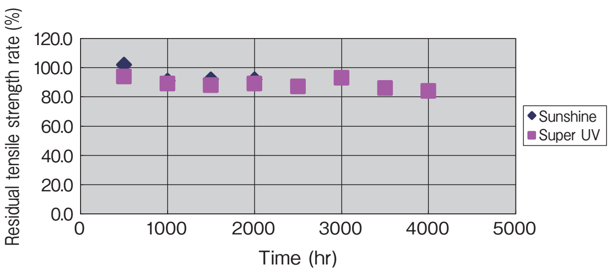


Figure 25 Results of weather resistance test.

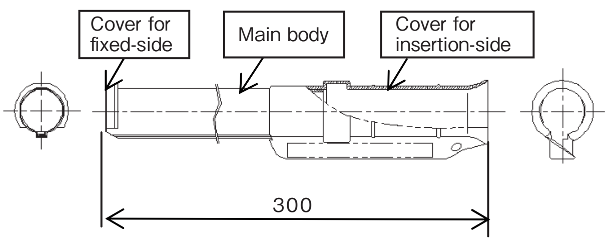


Figure 26 Cover for overhead line protector.

4.4 Recycling of Removed Accessories from Distribution Lines

In addition to the recycling of wire sheathing materials described in Section 3.1 above, we are also studying recycling of accessories removed from overhead distribution lines.

Disposing of accessories removed from overhead distribution lines results in an enormous amount of costs. We began recovery of removed accessories aiming at reducing these costs and developing practical uses of recycled materials. Removed accessories at installation companies come in a wide range: porcelain products, metal products, insulation products and packaging materials, so that we asked the companies to sort the removed items according to the list shown in Table 1 for our recovery.

Large-sized bags called FleCon (flexible container) are distributed among branch offices of installation companies, and they are collected when filled up. But removed accessories of large size are collected in the form as they stand. Collection efficiency can be improved by visiting plural sites at a time (see Figure 27 and Table 2).

Table 1 Materials of removed accessories for recycling.

Classification	Material
Insulation cover	Normal polyethylene
	Flame-retardant polyethylene
	Polyvinylchloride
	Rubber
Wire protector	Normal polyethylene
Supporting wire protector	Normal polyethylene
Cable sheath	Polyvinylchloride
Binding wire waste	Copper
	Aluminum

Figure 27 Removed overhead line protector.

Table 2 Effectiveness of recycling.

Company	Effectiveness of recycling
Installation company	Full awareness of sorting at sites
	Enhanced sorting awareness of removed accessories
Furukawa Electric	Improvement in R&D technology for recycled products
	Product development using recycled materials

Removed accessories collected in this manner are properly sorted and pulverized for further applications including reuse as a distribution line component, for which prototyping is underway. This program is attaining good results in many fields and accordingly, we are studying its feasibility as a business. There are concerns, however, that removal, sorting and productization can be costly for recycling the removed accessories, so that a comprehensive study that takes these factors into account is needed.

5. OVERHEAD TRANSMISSION LINE

5.1 Aluminum Conductor

In the beginning, aluminum conductors for overhead transmission lines were manufactured from pure aluminum (ECAL), using wire rods made by the hot-rolling and extrusion methods. Later on, in response to the increased demand for aluminum conductors, continuous casting-and-rolling methods such as the Propelti method were developed to improve productivity. During the 1960s and 1970s, various aluminum alloys for electrical conductors have been developed that are characterized by strength, heat-resistance and electrical conductivity, respectively. In particular, a heat-resistant aluminum alloy conductor (TAL) with an enhanced power transmission capacity has been developed in order to meet the rapidly increased power demand at the time of high economic growth in the 1960s, and the conductor has been used in abundance up to the present date. This was followed by the development of a extra thermo-resistant aluminum alloy conductor (XTAL) with much improved heat resistance, and a 60% heat conductivity super thermo-resistant alloy conductor (ZTAL) which realized improvements in both electrical conductivity and heat resistance; and both of them have come to practical use. An electric power conductor is configured using these aluminum alloy conductors suitably selected depending on applications, which are arranged around the central steel or aluminum-clad steel wires to constitute a corrosion-resistant stranded wire. Table 3 shows the properties of various heat-resistant, high-strength aluminum alloy conductors.

Table 3 Properties of various heat-resistant, high-strength aluminum alloy conductors.

Type	Tensile strength (MPa)	Electrical conductivity (% IACS)	Working temperature (°C)		
			Continuous	Short time	Instantaneous
HAL	157~196	61	90	120	180
TAL	157~196	60	150	180	260
KAL	225~255	58	90	120	180
KTAL	225~255	55	150	180	260
UTAL	157~196	57	200	230	260
ZTAL	157~196	60	210	240	280
XTAL	157~196	58	230	310	360

5.2 OPGW

Optical ground wire (OPGW) is an overhead grounding wire to effect grounding of overhead transmission lines, in which optical fibers are integrated to provide communication functions. OPGWs enable long-distance, high-quality data transmission as well as video transmission without being affected by electromagnetic fields in any way, so that it is utilized as a transmission line for remote control of unattended power plants and substations in addition to communications between power plants. Aluminum-clad steel wires used in OPGWs are manufactured using conform extrusion. Conform extrusion technology allows for arbitrarily changing the thickness of the aluminum layer of aluminum-clad steel wires, thereby having the wires with varied electrical conductivities. We manufacture and supply OPGWs of various specifications that are tailored to the diversified customers' needs.

5.3 Trolley Wire

We manufacture power distribution wires (i.e., trolley wires) and feeders to supply electricity to electric railcars. Trolley wires, commonly known as overhead wires for electric railcars, are used to supply electricity to electric railcars and the like, whereby electric railcars and electric locomotives take electricity in by bringing their pantographs in contact with the trolley wire. Common electric railroads use grooved trolley wires to hang them by grappling for installation. Requirements for trolley wires include high tensile strength and superior abrasion resistance as well as good electrical conductivity, and abrasion resistance is quite important for railway sections of heavy traffic, and accordingly we are also studying the improvement of abrasion resistance. Trolley wires made of silver-containing copper with superior heat resistance are widely used for high-capacity applications.

Supplying electricity by means of trolley wire only can result in usage of trolley wires too large in diameter, so that separate electric wires having large current capacity are installed in parallel, which are suitably connected to the trolley wire to supply electricity. This electric wire, called feeder, used stranded wires of hard copper conventionally, but recently aluminum stranded wires are widely used.

5.4 Overhead Transmission Line

Overhead transmission lines have undergone distance and capacity upgrading, and 500-kV lines have already been installed in succession, which has been followed by 1000-kV lines. For this market, we manufacture various aluminum conductors such as steel wire core aluminum stranded conductor (ACSR) and steel core heat-resistant aluminum stranded conductor (TACSR). Figure 28 shows a large stranding machine used for manufacturing.

To ensure reliability of these high-capacity overhead transmission lines, it is essential that mechanical characteristics of multi-conductor lines be clarified such as galloping oscillation and subspan oscillation, and we have made a significant contribution through experimentation to the optimization of conductor and spacer spacing and to the validation and practical application of large-sized accessories.

In terms of environmental harmonization, we are studying to reduce wind noise on conductors, mechanism of which is that a conductor exposed to wind generates Karman vortices, which cause noise when they separate from the conductor. We have developed a reduced wind noise conductor, which has protrusions on the surface to disturb the vortices thereby suppressing the wind noise, and we have brought this conductor into practical use. This reduced wind noise conductor tends to generate corona discharge, when it is used in high-voltage transmission lines, due to water droplets adhering to the protrusions in rainy weather. Accordingly we have also developed a corona suppression technology, in which together with enhancement of hydrophilicity of the conductor surface, improvement of the shape of protrusion lines provided at the outermost layer for wind noise suppression efficiently reduced the corona noise.

We manufacture anti-snow conductors that prevent accretion of ice and snow, by mounting resin rings at regular intervals at the time of conductor manufacturing. This anti-snow conductor has the advantage of laborsaving at the time of installation compared with the anti-snow ring which is manually installed on the existing lines using a midair carriage, and moreover, the conductor is indispensable for small-capacity lines where midair carriages are unusable because of the small-sized conductor. Figure 29 shows the SL (snow-less) conductor and its manufacturing facilities.

To make newly installed conductors which are very shiny less conspicuous against the environmental background, low-reflectivity conductors with reduced luster have been developed using the sand blasting process, together with low-brightness conductors having a surface brightness matched to the background along the overhead line's passage, and these conductors are used in the national parks and the like.

As the line capacity is increased, the allowable temperature for usage of aluminum conductors is raised, resulting in an increase in the span dip of the conductor. To suppress this increase in the span dip, super-thermo resistant aluminum alloy conductors, galvanized invar reinforced (ZTACIR) having invar wires of small linear expansion coefficient at the core of its steel central members has come into practical use, along with extra-thermo resistant aluminum alloy conductors, aluminum clad invar reinforced (XTACIR). These conductors contribute to the downsizing of the facilities because their use can avoid bank raising and reinforcing of supporting towers.

In terms of construction method, prefabricated conductor stringing has been extensively implemented aiming at laborsaving, whereby the length of a conductor is precisely measured at the factory beforehand, with a precision of 1/10,000 and taking the specified span dip into account, and the resultant length is marked to enable dead-end clamp compression work of conductor at the drum site. In recent years, complete prefabricated conductor stringing has come into practical use, in which cable drums provided with an accommodation space for the clamped portion of a conductor are used. This method allows for clamp compressing the conductor before shipping, and accommodating the compressed conductor in a drum for delivery, thereby enabling shortening of conductor extension time at the site.

5.5 Overseas Construction Project

With respect to the turn-key projects for construction of new overhead transmission lines and the projects for live-line OPGW installation on existing overhead transmission lines overseas, we are promoting marketing, bidding, sales activities as well as execution of projects. Marketing and project execution for the turn-key projects for construction of new overhead transmission lines worldwide is targeted mainly at extra-high voltage transmission lines over 500-kV rating.

Live-line OPGW installation refers to replacement of existing overhead grounding wires by OPGW without power shut-down. Conventional replacement work was to be carried out under conditions of either single-circuit power shut-down in case of a double-circuit transmission line or full-circuit power shut-down in case of a single-circuit transmission line. However, in some electric power companies and government agencies overseas where power grids are insufficiently established, it is very difficult

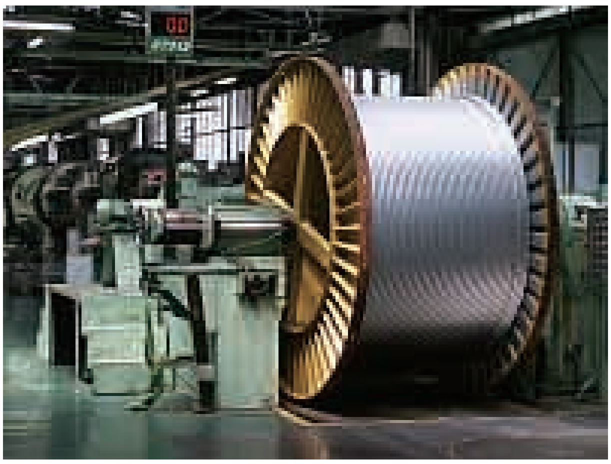


Figure 28 Large stranding machine.

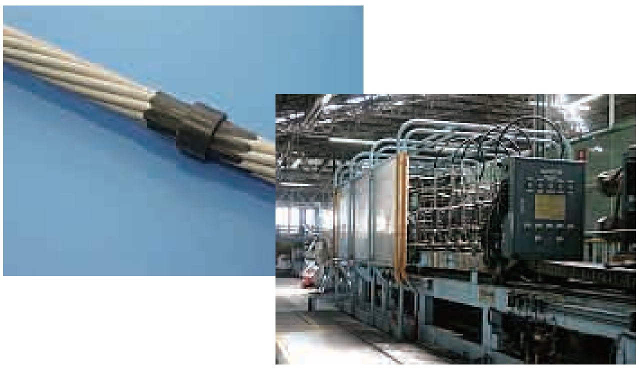


Figure 29 SL conductor and its manufacturing facilities.

to interrupt power transmission, or even when permitted, to interrupt transmission for a long time, rendering replacement to OPGW not easy.

We possess the installation technology to replace existing overhead grounding wires with OPGW while keeping the overhead transmission line alive without interrupting power transmission. We have carried out a total of 10,400 km of OPGW live-line installation in India, Malaysia, Iran, Philippines, Morocco, etc. Because this live-line OPGW installation method uses hanging pulley blocks for replacement of existing overhead grounding wires resulting in a very low stringing tension of no more than 1,000 N, it becomes possible to avoid using heavy-duty stringing machinery and to transport these machinery by manual transportation. This advantage makes construction of passageways for machinery transportation unnecessary in case there is no access road to the site, leading to realization of installation in a shorter period of time. Table 4 shows the features of the OPGW live-line installation method.

Table 5 shows the overseas projects underway, and Figures 30 and 31 work scenes at previous overseas projects.

The world's first OPGW live-line installation project 1,700 km in total length was planned in 1997 by Indian electric power corporation PGCIL, and the tender specification was based on ground wire-wrapped optical fiber cable (Wrap Cable) and All Dielectric Self-Support Cable (ADSS). We succeeded in adding, through presentation, the brand-new OPGW live-line installation method we had developed to the tender specification, received order in 1999 winning an international competitive bidding, and completed the work in 2002 successfully, thereby acquiring customer's satisfaction and confidence. Since then, we brought to perfection four projects of OPGW live-line installation totaling 7,000 km in length in India as scheduled, and furthermore, based on the bid document prepared by a consulting company KEMA, the same as for the Indian projects, we received jointly with ABB in Switzerland an order for the SCADA project of Philippine NPC which included 1,500 km of OPGW installation in live condition, and brought the work to completion with the customer's satisfaction.

After that time, we have completed two OPGW live-line installation projects totaling 2,000 km in Morocco, and currently, we are undertaking a live-line installation project in Senegal and simultaneously an OPGW installation work in Bangladesh under the condition of single-circuit interruption. As just described, our worldwide market share for OPGW live-line installation accounts for 50%.

In the future, we intend to promote our marketing activities focusing on South Asia, Middle East, East Europe and Africa.

Table 4 Outline of OPGW live-line installation.

Item	Description
Stringing tension	700~1,000 N
Stringing time	2 days/drum (3~5 km)
Applicable transmission line	66~500 kV

Table 5 Overseas projects underway.

Nation	Voltage	Line length	Description
Malaysia	500 kV	150 km	Turn key-base installation of new transmission line
Egypt	500 kV	216 km	Turn key-base installation of new transmission line
South Africa	765 kV	250 km	Turn key-base installation of new transmission line
Bangladesh	220/132 kV	2,500 km	OPGW live-line installation
Sri Lanka	132/ 66 kV	105 km	OPGW live-line installation
Senegal	220/ 90 kV	345 km	OPGW live-line installation

5.6 Research & Development

At our Nikko Development Center, we conduct research and development for products related with overhead transmission lines to meet diversified requirements. This laboratory is engaged in the research of wind noise, wind load, corona discharge, snow accretion, galloping, size

Figure 30 OPGW live-line installation for 220-kV power transmission line in Teheran, Iran.

Figure 31 OPGW live-line installation for 275-kV power transmission line in TNB, Malaysia.

reduction and environmental harmonization, since technologies to control these external environment elements are indispensable for overhead transmission lines.

We have a low-noise wind tunnel for measuring wind noise and wind load on overhead conductors. The wind tunnel was at first constructed for the purpose of wind noise measurement, and was used for the development of reduced wind noise conductors, but after a refurbishment to enable wind load measurement, was converted for the development and productization of reduced wind load conductors. The reduced wind load conductors have a drag coefficient (Cd value) 30% lower than ordinary conductors, thus significantly contributing to the reduction of transmission line construction costs.

In the study of corona discharge countermeasures for overhead transmission lines, corona noise and corona hum noise from low noise conductors and jumper assemblies are investigated using the transformer and the corona cage (see Figure 32), both of which are applicable to UHV ratings. We installed the above mentioned facilities prior to the construction start of UHV transmission lines, making a considerable contribution to the breakthrough and improvements of corona characteristics of UHV products, which led to the adoption of a number of our new technologies and products in the UHV transmission lines.

When overhead conductors have snow and ice accretion under high winds, self oscillation with low frequency and large amplitude (i.e., galloping) can occur, causing interphase short circuits and considerable damage to supporting structures. As a countermeasure for this, we have developed a light and flexible polymer interphase spacer (SR interphase spacer) consisting of FPR rods covered with silicone rubber molding, and the product has been used in 66- to 500-kV overhead transmission lines, proving its effectiveness.

Loose spacer is another countermeasure product. The loose spacer is designed to give differing torsional rigidity among multi-conductors so as to make the shape of snow and ice accretion nonuniform, thereby intentionally randomizing the lift forces acting on the windward and leeward in order to suppress galloping. Its structure is virtually the same as that of conventional bolt-less spacer,

Figure 32 UHV corona cage.

making it possible to suppress galloping simply by replacing conventional spacers with a loose spacer. We are also developing simulation technologies to predict the effectiveness of such countermeasure products. At the Oku-Nikko UHV Test Line, we are making observations of galloping oscillation of overhead transmission lines to improve the accuracy of the simulation software through comparison with observation data, as well as to validate the effectiveness of the countermeasure products.

Moreover, we have released a lightning protector called “SR Horn” for overhead transmission lines, an application of our silicone rubber molding technology. Using direct silicone rubber molding on zinc oxide elements, the products is lightweight and compact, and is applicable to 33- to 500-kV ratings. It is necessary that lightning protectors for overhead transmission lines satisfy the requirements of growing demand and increasing voltage and therefore, we are promoting research and development activities under obligation to offer stabilized power supply.

Snow accretion to overhead conductors is an important problem affecting the strength of supporting structures, short circuiting, earth faulting and sudden dropping of accreted snow, and accordingly, we have long been studying the problem. As a result, we have released two effective countermeasures of “anti-snow ring” and “anti-twist damper”, which are currently in wide use for their ease of use and effectiveness. Indicator ring to prevent the collision of wild birds on the overhead conductors is one of the application products of ring, improvement of which is underway through effectiveness validation tests.

We are also studying snow melting wires as a countermeasure against sudden snow dropping, in which an Fe-Ni alloy wire is closely wound around an overhead conductor to prevent snow accretion and sudden snow dropping by means of the heat generated by the conductor current. To make the products effective even in the harsh conditions in winter seasons, the magnetic material has been improved to develop a high heat generation type. The amount of wire winding depends on the current and ambient air conditions, but usually results in a mass increase of approximately 1 kg/m, so that partial application over the span or countermeasures against the increased loads are implemented in some cases. We plan to develop new lightweight products for snow melting.

Electric power companies are addressing the investigation of deterioration of aluminum conductors as a part of facilities maintenance program, and accordingly, we provide engineering services to analyze and evaluate the degree of deterioration of removed aluminum conductors.

It is said that construction of large-scaled overhead transmission lines will be settled for the time being when currently planned projects are completed in a few years, and efforts will be focused on the maintenance activities of existing facilities, where further laborsaving is required. In response to such needs, we plan to concentrate on the research and develop of new products related with maintenance work.

6. ACCESSORIES FOR OVERHEAD TRANSMISSION LINES

6.1 Oscillation Analysis Technology

We have been carrying out observations of an oscillation phenomenon called galloping ever since we constructed the Mogami Test Line (see Figure 33) in Shonai-machi, Higashi-tagawa-gun, Yamagata prefecture. Galloping is one of the peculiar aerodynamic phenomena seen in winter seasons, where more specifically, overhead conductors with snow or ice accretion oscillate in large amplitudes in the vertical plane when the wind speed and wind velocity meet certain conditions.

Because, if the oscillation amplitude increases, it is possible that the conductors will come into contact with each other thereby causing short circuit accidents, clarifying its mechanism in an effort to prevent accidents is a very important task for appropriate maintenance of electric power facilities. Accordingly we have been addressing this problem since 1979.

The vicinity of Shonai-machi is provided with suitable conditions for occurrence of galloping due to the local wind called "Kiyokawa-dashi" that blows almost throughout the year. Because snow accretion is the absolute condition for occurrence of galloping, we use a "mock accreted snow" (see Figure 34) that can achieve equivalent effects during snowless seasons to forcibly generate galloping.

This test line is characterized by its unattended observation operation using our proprietarily developed system, in which measurement data such as wind direction, wind velocity, conductor tension and conductor displacement are transferred in real time to our laboratory located in Nagai-city. The obtained data are input to simulation software to achieve comparative analysis between the actual measurements and the simulated results, enabling improvement of simulation technologies as well as application to development of countermeasure products. Our "loose spacer damper" that has received a lot of inquiries from electric power companies is one of the representative examples (see Figure 35).

Airflow simulation software has also been introduced since last year, which predicts wind behavior at any location with specific geographical features when the longitude and latitude of that place are given. Combining this software with the one for oscillation analysis will enable improving the accuracy of oscillation analysis as well as simulating wind behavior at an arbitrary spot on a power transmission line. Since these techniques, together with the mechanical deterioration data such as fatigue degree and wear amount that have long been accumulated, make it possible to predict the progression of products deterioration, it is expected that they will lead to creation of a new customer service like making suggestions for replacement life time of products.

Figure 33 Panoramic view of Mogami Test Line.

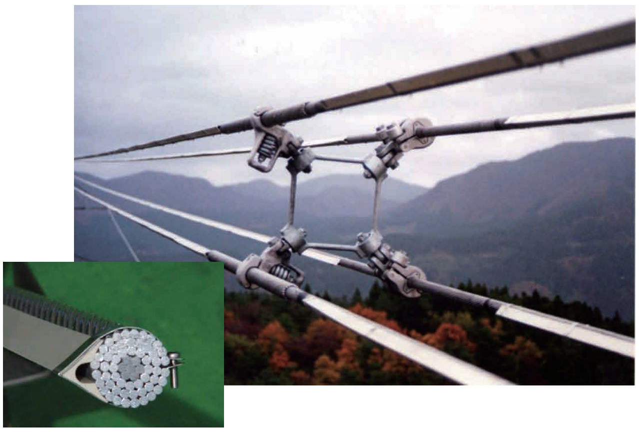


Figure 34 Installed "mock accreted snow" to simulate snow accretion.

6.2 Deterioration Prediction Technology

The causes of deterioration of overhead conductors may be divided into two categories: one is mechanical deterioration which is caused by loads due to oscillation and the like, and the other is electrical deterioration in which electrical resistance increases at electrical connections under application of current. While we are involved with both of

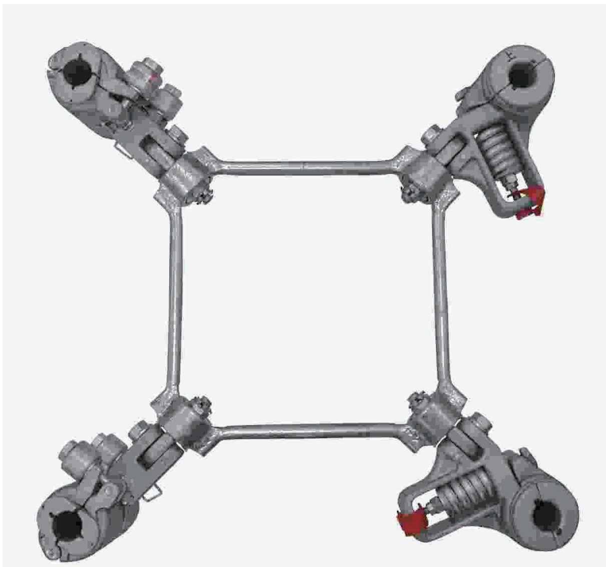


Figure 35 "Loose spacer damper" for four-conductor overhead transmission lines.

these categories, we will present here the prediction technology for electrical deterioration because our activities related with mechanical deterioration overlaps with the description in Section 6.1 above.

Generally speaking, compression joint tubes for aluminum conductor have an intrinsic problem in that their electrical resistance more or less increases by use over time. Increase in electrical resistance is nothing short of impeding current flow, and the jointed portion is heated due to Joule heat. The larger the current, the higher the temperature rises, resulting in melt down in the worst case. For this reason, electric power companies consider inspection of compression joint tubes is a maintenance management job of the utmost importance.

Against this background, we have long been engaged in the study of this technological field. In the preliminary stage of the study, we gathered a maximized number of removed products from every electric power company, making efforts to accumulate fundamental data including the correlation between usage period and electrical resistance. In the medium stage, based on these data, we have set up a hypothesis concerning the electrical deterioration, and succeeded in validating the hypothesis through accelerated deterioration tests and the like.

Currently, we are addressing the joint development of "Deterioration Simulation System" with some electric power companies to integrate our study (see Figure 36). To be more specific, samples are taken from overhead transmission lines, their initial electrical resistances are compared with those at the time of inspection to understand the present degree of deterioration, and thereby simulating, based on the data and knowhow which have been enormously accumulated, what degree of deterioration is anticipated in the future. It is thought that this system contributes, when completed, not only to prevent melt-down accidents but also to reduction of maintenance and inspection costs, because it will help us to reasonably make out a schedule of inspection cycle and refurbishment time.

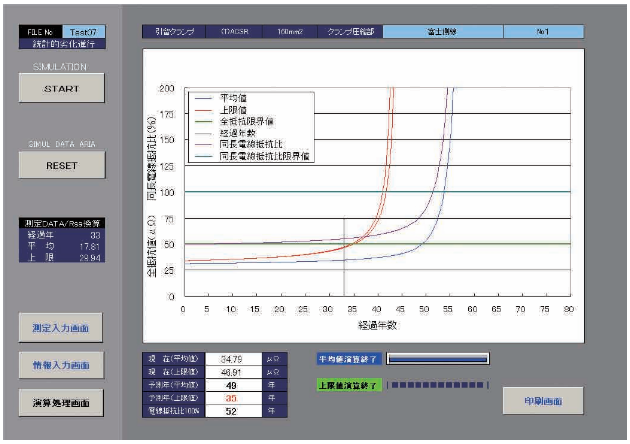


Figure 36 Display in "Deterioration Simulation System" under development.

Furthermore, "Bypass Device" (see Figure 37) and "Fusion Joint" (see Figure 38) that have been developed during the course of this study have been employed by a number of electric power companies. In particular, the Fusion Joint was highly appreciated for its unique idea, and was awarded jointly with an electric power company in 2005 a "Shibusawa Award" which is intended for inventions that have achieved a strong performance in the field of electrical safety.

6.3 Casting Technology

We manufacture some of aluminum castings in-house while enjoying our proprietary casting knowhow solely in the industry. Our casting method is gravity die casting comprising greensand mold casting and metal mold casting. Greensand mold casting is carried out at outside companies headed by our affiliate company, while metal mold casting mostly in-house.

We deal mainly with Al-Mg-based AC7A, Al-Mg-Si-based AC4C-(H) and pure aluminum. Every material has its specific features. For example, AC7A has superior corrosion resistance and mechanical characteristics, while its castability is insufficient. Pure aluminum is not stipulated in the JIS standards for castings, making itself a very special material specific to the industry. Its solidification behavior is quite different from other materials, thus requiring a unique mold design. Material selection is determined depending on the characteristics of the prod-

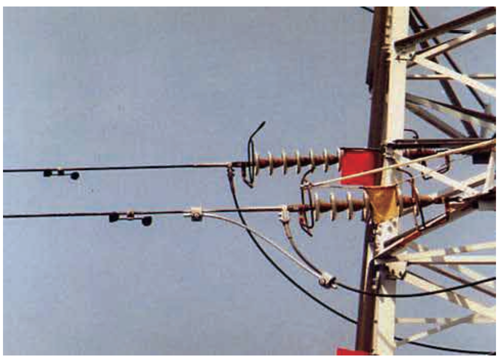


Figure 37 "Bypass Device" for stagnant electric current.

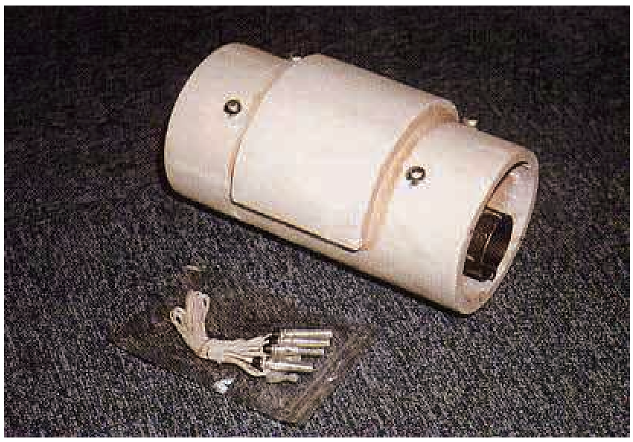


Figure 38 "Fusion Joint", where conductors are welded without forming an electrical connection.

uct to be manufactured. In this context, products manufactured by casting of pure aluminum unexceptionally belong to, as represented by compression dead end clamps (see Figure 39), the family of compression joint tubes aimed at electric current conduction, so that care must be taken in casting such a material of poor castability.

Since this industrial field is the most susceptible to adverse influences of the exodus of the baby-boom generation, there is an urgent need for constructing a new system that combines “high technology” and “experience” for handing down the technology, and accordingly, we are addressing such a problem.

Our casting technology has gained ground not only domestically but also overseas. In 2004, Shanghai-Asahi Electric Works Ltd., our affiliate company in China received an order for aluminum cleats made of AC7A (see Figure 40) for use in 110-kV power cables to be laid along Donghai Bridge in Shanghai, and we provided them with technical assistance. At that time, there was virtually no plant in China that could cast AC7A, the most difficult aluminum alloy to cast, so that the technical assistance covered an extensive area comprising plant layout, selection of facilities, design of molds, casting through machining, assembly, inspection and quality control. Thanks to the sincere attitudes of local workers to follow what they learned, they succeeded in achieving the same product levels as for the domestic counterparts. Today, they still keep a high quality level, and their products are not only delivered in China but also exported to Japan.

Figure 39 Compression dead end clamp, a typical product of pure aluminum.

Figure 40 Aluminum cleat made in China.

7. INDUSTRIAL CABLE

The business fields of industrial cables cover a wide range of applications including industrial plants, buildings, ordinary houses, railway rolling stocks, ships and industrial machinery, so that varieties of electrical wires and cables are developed and supplied in response to the service conditions and required performance. We develop, in addition to wires and cables, cable accessories and special functional products, which have acquired a favorable reputation.

7.1 Electric Wire for Industrial Plants and Building Facilities

To deal with global environmental problems, regulation tightening against hazardous substances is accelerated in the business field of electric wires as well. Whereas conventionally, lead-based stabilizers were generally used for PVC that has been extensively used as an insulating and sheathing material for electric wires and cables, we have eliminated lead not only from the IV (Indoor PVC) and HIV (Heat resistant Indoor PVC) wires for distribution boards and equipment, but also from general purpose cables like XLPE and CVV (Control PVC PVC), thereby proactively promoting the elimination of hazardous substances.

Moreover, Eco-material wires and cables in which PVC is replaced by flame-retardant polyethylene to make them environment-friendly, which emits neither hazardous halogen gases nor large amounts of smoke when combusted, are in widespread use centering on government and other public offices. We develop and supply wires and cables according to specifications best suited for the service conditions and required performance, based on the designs such that a UV-resistant, flexible material is applied to the EM-EEF/F cable substituting for conventional VVF, and also a material of superior mechanical characteristics is used for the EM-CE/F cable for power applications (see Figure 41). Furthermore, in the process of promoting the clean technology for Eco-material wires and cables, we have succeeded in developing a “lower outgas cable c901” for use in clean rooms where liquid crystals and semiconductors are handled, achieving excellent delivery track records. This is a new product that

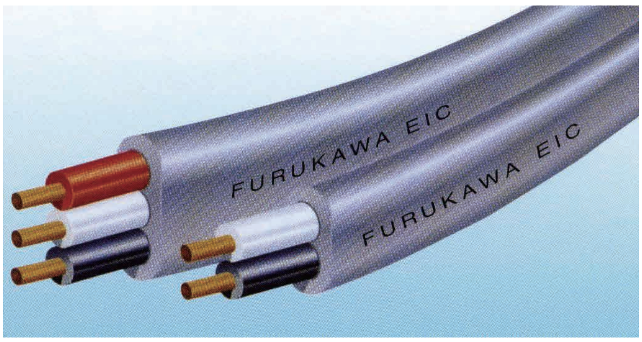


Figure 41 UV-resistant flexible ECO wire “EM-EEF/F”.

has reduced the organic gases (outgases) emitted by the cable to one tenth or lower than the general-purpose ECO cables.

7.2 Electric Wire for Railway Rolling Stocks

The amount of electric wire for in-vehicle use is increasing as computerization in railway rolling stocks advances, accompanied by the requirement for decreasing the size and weight of the wires to reduce the wiring space and weight. We have developed the so-called “compact wire” that has reduced the insulation thickness to less than half the conventional electric wires for railway rolling stocks (WL1 and the like). The wire has, despite their thin insulation, superior mechanical characteristics such as abrasion resistance and cut-through resistance in addition to long-term reliability under varied environmental conditions, thus having been adopted by many customers.

Electric wires for subway vehicles are required, with an aim to ensure safety within a tunnel, to be halogen-free so as to suppress emission of hazardous gases and smoke when combusted. In response to this requirement, we have developed “low-smoke emission, halogen-free, compact wire”, and the demand is growing.

7.3 Cable for Electric Equipment of Ships

As ships advance in capacity, speed and automation to improve the efficiency of marine transportation, cables for ships are required to offer higher performance. Responding to this requirement, we have developed “medium-voltage cable for ships” and “halogen-free, highly flame-retardant cable for ships” provided with high reliability, and the delivery has begun. Recently, we have also developed “compact cable for ships” that has removed metal braid armor from conventional wires aiming at weight reduction, making a contribution to weight reduction and speed increasing for ships.

Against such a background where requirements for cables for ships have attained greater sophistication, IEC standards for cables for ships have been revised, and accordingly, we are actively making provision for revision of JIS standards.

7.4 Cabtire Cable

Mobile cabitire cables for supplying 100-V to 6-kV power sources and controlling various equipment are in widespread use in heavy-duty outdoor material handling machinery installed at harbor piers, raw materials stock yards of steel plants and the like. These cables for mobile use are required to be provided with superior tensile force resistance, bending resistance, twist resistance and so on, because they are subjected to repeated mechanical stresses under the harsh environments at the site. We have developed, by achieving an excellent structure design, a cabtire cable for mobile machinery named “TraCab” (see Figure 42) with outstanding endurance to offer a best-suited cable depending on application, acquiring a favorable reputation from our customers. Recently, besides voltage increases in these cabtire cable lines, “optical fiber-composite TraCabs” are used among many customers, in which optical fibers are integrated for ITV image and data transmission. However, optical connection of fibers in the optical fiber-composite cable to optical transmission equipment mounted onboard poses a problem such that it is impossible in principle to adopt slip rings based on metal cables, and that optical rotary joints known as an optical coupling method cause coupling loss increases and loss variation. In this context, an innovative optical coupling device “SC-BOX” we have developed is based on an optical accumulator method, whereby one end of a multi-fiber optical fiber tape (with six to twelve fiber counts) is fixed to the central fixed axis to be spirally wound, while the other end is rotated as the cable reel rotates. This enables transmission of optical signals in a completely coupled state with the least coupling loss, so that the device has accumulated a number of delivery track records for its high reliability in signal transmission.

7.5 Medium Voltage Rubber Insulated Cable

While most of the electric power circuitry in Japan use XLPE cables when they exceed the 6-kV class rating, demand for medium voltage cables provided with higher flexibility than XLPE cables is growing in order to cope with the application conditions such as cabling in limited spaces and cabling inducing bending and twisting, which is often caused by cabling works for power capacity upgrading in ships, wind-power generation facilities and power supply systems between land and ships. We have developed, taking advantage of the technology and experience we have accumulated for conventional 6-kV class cabtire cables, a series of medium voltage EP rubber-insulated cables in response to the individual requirements. We have established product lineups for both of these cable categories, and the delivery is expanding. As for medium voltage EP rubber-insulated power cables together with their accessories, we are promoting research and development. Specifically, specifications for their termination joint materials have been studied aiming at weight reduction and a completely dry system, and the final evaluation is underway to finalize the development.

Figure 42 Cabtire cables.

7.6 TV Camera Cable System

In the broadcasting industry, contents upgrading aimed at high-definition images is advancing. Because it is impossible to transmit these contents using coaxial cables, conventional systems are rapidly being replaced by transmission systems using optical fibers. We have developed an optical fiber-composite TV camera cable system of high strength and flexibility together with optical connector assemblies that combines ease of use with high endurance and high reliability that are indispensable for operations at broadcasting fields. This cable system has acquired a high reputation not only from domestic but also overseas customers, making a significant contribution to digitization and high definition imaging in the broadcasting industry. Highly flame-retardant cables and low smoke emission cables in compliance with the Japanese, European or U.S. standards have also been developed, in response to the individual customers' requirements (see Figure 43).

Figure 43 Optical fiber-composite TV camera cable system.

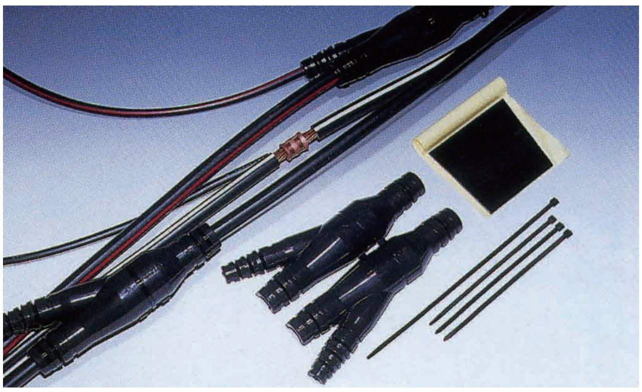


Figure 44 EfTouch Cover.

7.7 Joint Materials for Low-Voltage Cables

Because the tape winding method conventionally used for branching and jointing cables at the construction sites necessitated good skills and experience as well as considerable work time, there is an increasing requirement for a method that offers simplicity and assuredness. Our "EfTouch Cover" (see Figure 44) has been developed to satisfy such a requirement while offering a short-time, assured jointing work necessitating no skill. With this jointing kit, the jointing work can be completed simply by; after jointing the conductor, one layer of self-bonding insulation putty sheet is wound around the conductor to form an insulation layer in a manner such as for clay work; a protection cover cut into half is placed to cover the putty work on the joint; and the cover is fixed using an attached belt. Because the kit can shorten the work time significantly, it has acquired a good reputation among the customers, achieving satisfactory results year by year.

Moreover, all-purpose jointing materials kit "CellPack" (Figure 45) is also available to offer high water-tightness and mechanical strength independent of the installation environments. CellPack is a resin injection-based jointing kit, featuring the use of a binary liquid mixture of low curing temperature and low contractility, and can be used in various cable jointing works including the low-voltage power, control, instrumentation, telecommunication, fire-resistant and flame-retardant cables. While only a resin injection method using a funnel was available conventionally, "CellPack CC" with which the resin can be directly injected to the inlet on a closure recently joined the product lineup. CellPack has been extensively used in various countries across the world for its ease of use and high reliability, achieving a track record of more than four million kits in total sum.

Figure 45 CellPack.

7.8 Special Function Products

We offer to the marketplace various products featuring special functions as well as cables.

"DryKeeper" (see Figure 46) is a new type of absorbent compound material provided with a humidity controlling function, consisting of a high-performance water-absorbing polymer and a rubber of our proprietary blending. Thanks to its reversibility such that it absorbs humidity in humid environments, while emitting humidity in dry environments, DryKeeper can maintain a constant humidity controlling function for a long time. In electric facilities like switch board installed outdoors, electric trouble and rusting due to dew condensation occurs from time to time, thereby causing a maintenance problem. But DryKeeper can suppress dew condensation for a long time taking advantage of its humidity controlling function. DryKeeper preserves its function for several years, more than ten times longer than the conventional drying agents such as calcium chloride and silica gel, thus contributing a great deal to make electric power facilities maintenance-free.

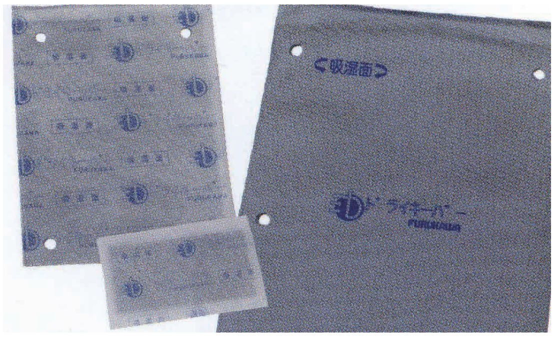


Figure 46 DryKeeper.

"Joint unit for street light wiring" (see Figure 47) is a unit-type wiring system developed as a wiring equipment to be installed in street light poles. With its structure filled with molded resin, the joint unit protects the breaker and the wired portion from humidity and dew condensation as well as enables jointing of the power source with equipment outside the lighting pole, thereby achieving substantial laborsaving. Thus the joint unit is an innovative wiring system that has solved the long-standing improvement target of dew condensation prevention and work performance improvement simultaneously, and its delivery is expanding.

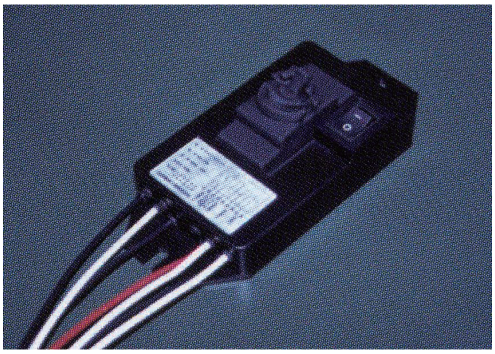


Figure 47 Joint unit for street light wiring.

8. CONCLUSION

We have long been developing the technologies for electric wires and cables together with their accessories in the electric power industry. It is anticipated that there will be a growing need for safety, environment preservation and low price in the future. Accordingly, we think it is our responsibility to promote developing innovative technologies, thereby contributing to society.