# Development of Tower Cable and Accessories for Wind Turbine

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*In recent years, as an alternative energy source to fossil fuels such as oil, wind power generation, which is a renewable energy source, is attracting increased attention and lots of wind power farms are being built within the country and overseas. We started development of cable and accessories for wind power generation from around 2000, and have already supplied them to many wind power plants. Here, we give you an introduction to the wind power plant equipment and distribution systems we have developed.*

## 1. Introduction

The Ministry of Economy, Trade and Industry set an introductory goal of generating, by 2030, 10 million kW of electricity by wind power, to which lots of attention is being paid as a renewable source of energy. At present, lots of wind power plants are being constructed across the country.

As shown in Fig. 1, until now, our cables and accessories have been supplied to more than 50 sites, including Koriyama Nunobiki Kogen wind farm and Rokkasho Village wind farm in Japan and overseas wind power plants in the U.S. and China.

## 2. Distribution systems for wind power plant

### *2.1 Wind power generation system*

Figure 2 is an electric power system schematic of a wind power generation system. Electric power generated by wind turbines is sent from cables suspended from towers and through underground cables, overhead cables, grid connection transformers, and a transmission network to ordinary households. In many cases, wind turbines are installed in suburban areas, owing to noise problem, etc., and there are concerns about capacity shortage of power transmission lines in grid vulnerable regions. Therefore, strengthening of the grid is desired.

### *2.2 Cables and accessories in the nacelle and tower*

There are various pieces of equipment in a wind turbine nacelle and tower, and cables and cable accessories that connect these pieces of equipment have also been developed. As an example, Fig. 3 shows our cables and cable accessories used for a wind turbine with step-up transformer in a 2 MW class nacelle. Our products include torsion-resistant and bend-resistant cables are used in the wind turbine tower, separable connectors for switches and transformers, separable surge arresters, which are highly demanded for lightning protection, cable harnesses for control, and optical cable harnesses. Here, torsion-bend resistant cable and separable connectors are described as follows.

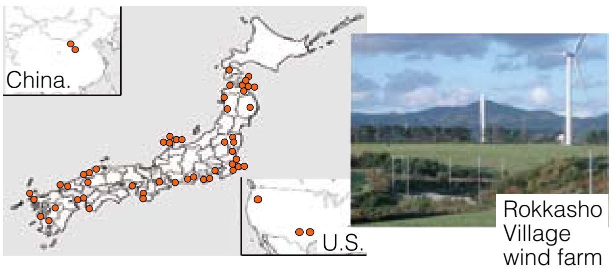


**Fig. 1. The construction map of our equipment.**

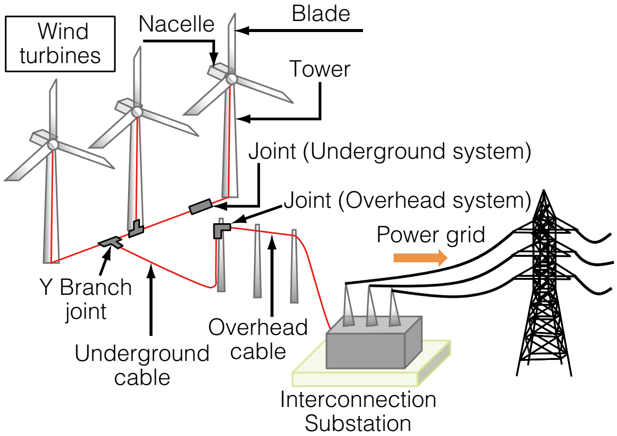


**Fig. 2. Electric power system schematic of a wind power generation system**

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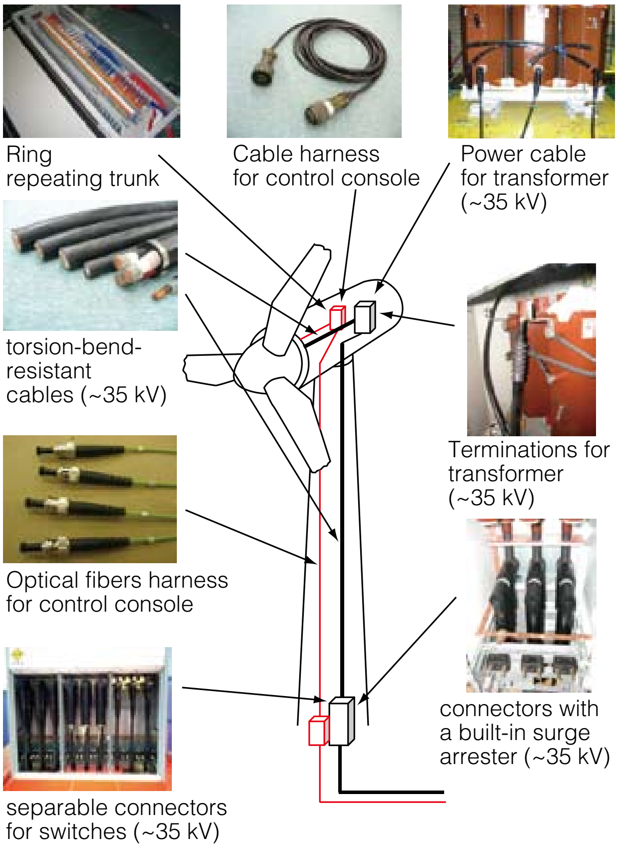


**Fig. 3. Our equipment used in the Wind turbine**

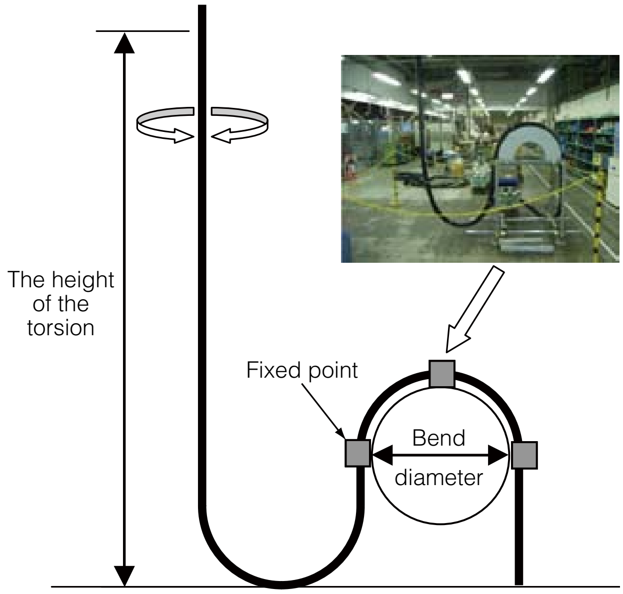


**Fig. 4. Schematic diagram of torsion test equipment**

## 3. Cable and accessories for wind power generation

### *3.1 Tower cable*

Since a wind turbine generates electric power by rotating blades (a propeller) attached to a nacelle, the blades and nacelle must be turned toward the direction in which wind blows so that wind may be caught efficiently. Since the nacelle turns in relation to the tower, the tower cable that connects the tower to the nacelle must have high durability to torsion. Additional requirements include low-temperature torsional properties taking into account climate condition of the installation site, and flame-retardant properties for the event of fire in the tower.

We utilized our know-how about the structural design and pliable material of torsion-resistant cable (cabtyre cable) which we have cultivated for years, and developed a product that can withstand severe uses, exhibiting torsion-resistant and flame-retardant properties.

#### *3.1.1 Torsion qualites evaluation*

Using a torsion testing machine shown in Fig. 4, which simulates torsion in the tower, we confirmed that there are no abnormalities in electric performance of the cable (Table 1). The results of low-temperature

**Table 1. Test result of torsion test**

| testing requirement | Condition | | Test result |
|---|---|---|---|
| Torsion test | After ±360° × 10000 cycles<br>±540° × 40 cycles<br>Sheath, shielding layer, and conductor No particular | | Good |
| Conductor resistance | Max conductor resistance 0.795 Ω/km | before the test | 0.690 |
| | | after the test | 0.682 |
| Shielding resistance | Only advisory (mΩ) | before the test | 87.4 |
| | | after the test | 86.6 |
| Partial discharge | 10 pC (at35 kV) | | Free (at40 kV) |
| AC withstand voltage | 90.9 kV (5 min.) | | Good |

**Table 2. Test result of low-temperature torsion test**

| testing requirement | Condition | Test result |
|---|---|---|
| Torsion test | −40°C<br>±180° × 10000 cycles<br>(Equivalent to ±540°)<br>Sheath, shielding layer, and conductor No particular | Good |

**Fig. 5. Picture of shield wire and conductor after low-temperature torsion test**

torsion test are shown in Table 2 and Fig. 5. A twisting test at low temperature was carried out at −40°C, and the results of cable demolition investigation following the test confirmed that there were no abnormalities in the conductor and braided wire.

### *3.1.2 Flame retardancy evaluation*

A 60° incline flame test (JIS C 3005) and a vertical wire flame test (UL-1581 VW-1) were carried out, and confirmed that no ignition occurred. The test results of the vertical wire flame test are shown in Table 3, and the sample status after test is shown in Fig. 6.

**Table 3. Test result of flame test**

| testing requirement | Condition | Test result |
|---|---|---|
| VW-1 Vertical Flame Test | Test sample: One cable length457 mm<br><br>Test process<br>(1) The sample attached to an indicator is fixed in a vertical position (see diagram right).<br>(2) The laboratory burner is set at a 20 angle, & its flame is applied directly for 15 seconds & then taken away for 15 seconds. This process is repeated 5 times.<br><br>Judging standards<br>(1)The remaining flame burns out after 60 seconds.<br>(2) The indicator does not suffer fire damage of 25% or<br>(3) The surgical cotton under the sample is not burned by falling insulation. | Good |

**Fig. 6. Picture of sheath after flame test UL-1581 VW-1**

### *3.2 Separable connectors*

Since wind power generation earlier came in wide use in Europe, most wind turbines and equipment which are introduced into Japan adopt Europe products (DIN standards). Therefore, we have developed a lineup of connectors for 22kV power cables connectable with the equipment for European wind turbines (Table 4). As shown in Fig. 7, the equipment installed in a narrow space in a wind turbine is small; miniaturization is also required for the connector. Therefore, fitting interface design is improved to have a compact structure enabling storage in the control panel of equipment. In addition, from early times we have also developed several kinds of connectors for power cables of 35 kV or less (in conformity with IEEE 386 standards) for U.S. equipment, to prepare a lineup for various pieces of equipment used for wind power generation.

An important problem is that a wind turbine is vulnerable to damage caused by lightning due to the installation environment. Therefore, a surge arrester is generally used for protection of the transformer and switch. The surge arrester has a role of protecting electric power equipment by controlling abnormal voltage caused by lightning. However, since a common surge arrester adopts an air insulation system, an

**Table 4. Separable connectors for 22kV**

| | |
|---|---|
| Rated voltage | 22 kV |
| Continuous | 250 A/400 A/630 A (three types) |
| Applicable cable insulation | Cable insulation diameter: $\phi$ 17.2 mm − 47.6 mm<br>Insulation: XLPE, EMDM etc. |
| Conductor size | 25 mm$^2$ ~ 400 mm$^2$ |
| compliance standards | IEC 60502-4 |
| Bushing interface | DIN 47 636 |

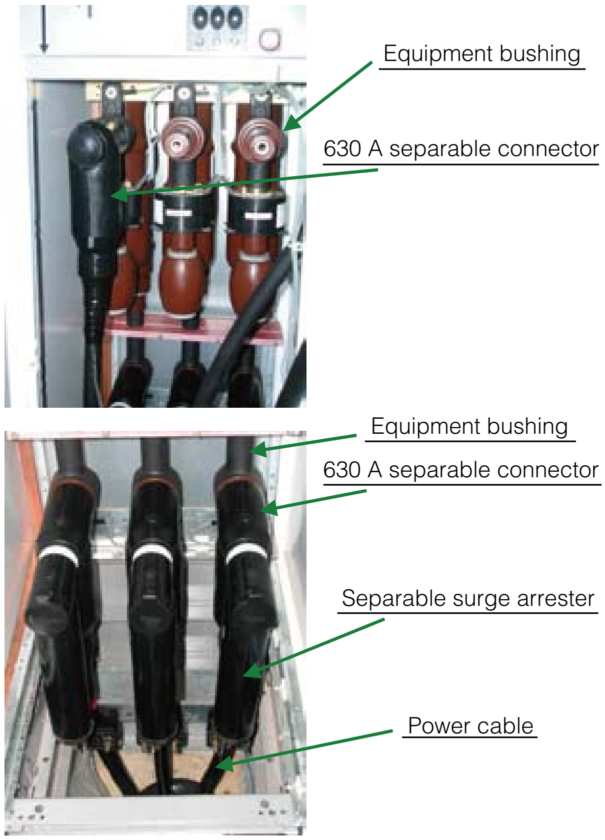


**Fig. 7. Connection status of the separable connectors for 630 A (cases)**

insulated offset distance must be secured, which causes a problem of equipment becoming large. We developed a compact separable surge arrester (built-in surge arrester) that combines a zinc oxide element and a connector. The specifications of separable surge arrester are shown in Table 5, and the appearance is shown in Fig. 8.

## 4. Conclusion

TIn recent years, wind power generation has accomplished rapid growth as renewable energy. In the future also, many wind farms are planned to be constructed at home and abroad. Especially, offshore wind power generation, which can supply large-scale electric power using the long coastline, is expected to be introduced, and demonstration and verification of safety, reliability, and economy continues to be promoted. Although wind power generation is energy whose output becomes unstable by change of the weather, it is considered to play a role of energy supply in combination with a smart grid or other decentralized energy sources.

**Table. 5 Specifications of separable surge arrester**

| | |
|---|---|
| Rated voltage | 27 kV |
| MCOV (Maximum continuous operating voltage) | 22 kV |
| Lightning impulse classifying current | 10 kV(8/20 μs) |
| compliance standards | IEEE C62.11 |
| Bushing interface | DIN 47636, EN 50180, EN 50181 (36 kV-630 A) |

**Fig. 8. Picture of separable surge arrester**