

# CRITICAL COMPONENT—CABLES

Choosing the right cable for specific turbine applications is essential for wind farm success.

By Uwe Schenk



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## FROM THE ROTOR TIP TO THE TOWER BASE,

cables are located throughout the wind turbine keeping these renewable energy power generators operating at peak efficiency. From power cables, torsion cables, fiber optic conductors, and cables for monitoring and communications to medium-voltage and fiber-optic cables for connecting into the local power grid, cables are a critical component in the success of a wind farm.

The cable framework in a wind turbine generator system (WTGS) depends on various factors, which are predetermined by the tower structure and the customer. There are various types of towers and these can be classified into five categories: steel-tube towers, concrete-

tube towers, wood towers, pylon towers and hybrid towers. The hybrid towers are made of steel-reinforced concrete and steel elements and can currently be constructed up to 460 ft (140 m) in height. Depending on the construction of the tower the design of the cable framework can then be suggested to support the turbine's power generation capacity. A wind turbine produces between 1.0 and 7.6 MW, and that power needs to be brought down from the nacelle.

## COPPER OR ALUMINUM? HOW ABOUT BOTH.

The turbine's power cables can be made of copper or aluminum. Each conductor material has its own group



of supporters. Those that prefer copper cable feel this material has been tested over time and has proven to be safe and reliable. Aluminum is preferred by others because it focuses on the commercial aspect of the project, i.e. aluminum is cheaper than copper.

Aluminum makes you relatively independent of the price trend, whereas copper is much more volatile. When the copper price changes the project's management team might have to re-think their entire material calculations to stay on budget. With aluminum, they do not have to recalculate to such a large extent. In a nutshell, one can speak of cost savings of up to 40 percent for the electrical power cabling when flexible aluminum power cables

are used as compared with flexible copper cables. These savings are inclusive of the fact that more aluminum is needed to match the power levels of copper cable (i.e. a larger gauge size is needed for the aluminum cable).

Cable selection should be a collaboration between the cable manufacturer and the turbine developer. These discussions should take place with the engineers during the planning phase. The ideal power cable network should come from the four different types of existing designs. Those are Class 2 copper, Class 5 copper, Class 2 aluminum, and Class 5 aluminum. In Class 2, both copper and aluminum are rigid and inflexible. The Class 5 strand structure is the flexible version.

### COPPER FOR THE LOOP

Every manufacturer of electric cables and wires has their own philosophy on selecting the correct insulation and conductor material. There are suppliers that recommend aluminum for the torsion application in the WTGS cable loop. However, many cable manufacturers test their cables for up to 10,000 cycles only. Experience tells us that testing for 15,000 to 18,000 cycles gives a more accurate, long-term test result.

Results from tests run in our turbine test tower and from past experience shows that the aluminum application doesn't work effectively in the loop. With WTGS service lives of approximately 20 years, demands of up to 15,000 torsion cycles will be placed on the wires in this application. This part of the power cable network, from the generator through the freely suspended loop and through the tower interior wall represents genuine stress for the wires. That is why cable specialists use exclusively Class 5 copper cabling, which has a much better ability to cope with load. The ongoing movement of the torsion cables requires a non-stick surface that allows the cables to glide easily. Therefore, special, highly abrasion-proof materials are used as the insulation material for the conductor insulation and jacketing.

In addition, through our extensive tests we have discovered that torsion cables with a braided shield, so called C-shield, is not optimal for loop cables. We have seen damages on these types of cables after 1,000 torsion cycles. These tests further showed that a D-shield is best for high endurance under consistent twisting and un-twisting conditions.

The loop cable is one of the trickiest points in the power cable network of a wind turbine and can be the Achilles heel, if the correct cable is not selected.

### ALUMINUM FOR THE TOWER

The conventional construction method of the wind turbine is the steel tower with three to four segments. This is where the opportunity exists for the tower constructor to pre-install the power cables. During on-site assembly, the individual cables can then be connected to each other through compressed joints using approved crimping technology. During the cable connection process, up to 80 compressed joints evolve that have to be well-executed



Figure 1: A view of the tower and loop cables of a wind turbine.



Figure 2: All aluminum and copper/aluminum cable lugs for aluminum power cables with crimp tool.

and well-insulated to guarantee long-lasting, permanent function. Connecting the wires in an entire plant in such a fashion takes two to three days and is very costly. This critical part of the power cable network has to function correctly throughout the entire lifetime of the WTGS.

If you consider that a crane deployment when assembling wind tower carries the cost of about \$66,000 per day, the installation time needs to be kept as short as possible. For plant constructors who want to reduce this expenditure to the minimum, some manufacturers provide a cabling solution where the cables after the loop can be installed in the tower ready to plug-and-play in as little as five to six hours. A Class 5 aluminum design can be flexibly pulled into the tower structure and routed in conduits through the foundation to connect to external transformers.

### CONNECTORS FOR ALUMINUM CABLES

The electro-technical aspects, however, are of the utmost importance, since a cable is only as good as the connectors that secure it at each end. Cable and connection technology should be matched and tested as one system. The conductor fill factor in the cable lug or compression connector is an important aspect. Additionally, the slight vibrations in a WTGS should also not be neglected. Previously, only a mechanical pull-out test on the cables and connection was sufficient. For a manufacturer to provide a firm statement around product reliability, the mechanical tests need to be supplemented by an electrical test. The cable manufacturer's philosophy is to not interrupt the power cable network if at all possible. So an uninterrupted installation into the tower up to the inverter



Figure 3: A view at the HELUKABEL wind cable test tower. Up to 20 cables can be tested at once under conditions found in wind turbines located throughout the world.

in the tower base is preferred. In practical application, that means a prefabricated aluminum line with aluminum/copper compression joints to the loop and an aluminum/copper pressure cable lug to the inverter. In keeping with the spirit of plug-and-play, the wire can be installed through the tower and up to the inverter in one piece.

### SPECIAL CRIMPING TECHNOLOGY ENSURES CONDUCTIVITY

Standard crimp or screw technology is not recommended with a finely-stranded aluminum cable designs due to the surface of the conductor, which oxidizes more. With conventional crimping technology, the electrical values in large cross-sections would be relatively high and insufficient. That causes excessive heating of the cable lug under load. Due to the higher temperature on the wire, the temperature of the insulation material also rises. This higher stress accelerates the aging process of the line, since contacting aluminum demands the greatest attention.

To work around this problem, cable manufacturers have developed special connection technology for finely-stranded aluminum cables. The crimp contour makes the aluminum flow, mechanically rupturing the surface of the wire and making it conductive. This means the contour penetrates deep into the stranded bundle, facilitating ideal contact between all strands even in the bundled conductors. Another connection option is a screw technology with shear bolts. Performance reliability is extremely important. To ensure that components are in compliance, it's important for customers to make sure the connecting equipment meet certain regulations such as IEC – DIN EN 61238-1 Class A.

### OIL AND HIGH TEMPERATURES

The gearbox up in the nacelle requires aggressive oils and grease that can damage the cables if exposed for long periods of time. In this part of the wind turbine it is therefore important to choose cables with high oil resistance. In addition, the temperatures inside the gearbox can reach 70°C (158°F). In other words, cables that can endure higher



Figure 4: Wind cable performance can be reduced in part by exposure to extreme temperatures, oils and other lubricants, and mechanical stress. It's important to select cables that can withstand these and other challenges within the turbine for long-lasting cable performance.

temperatures (in Helukabel's case up to 145°C (293°F) are suitable for applications in the nacelle.

### INTERNATIONAL REGULATIONS AND APPROVALS

Every country has its own regulations and that is something wind turbine manufacturers should consider when choosing a cable supplier. Cables with multiple international approvals (e.g. UL, CSA, FT4, CE, VDE, TC, and WTTC) can be used in wind towers no matter where in the world they are constructed.

### HALOGEN-FREE FOR THE AMERICAN AND CANADIAN REGIONS

The customer can be rest assured that both conductor materials are being protected by

jacket materials that do not use halogen. The use of halogen-free cables has been a staple in the European market as the regulating body would like to prevent harmful toxins from being release in the event of a fire. However, the trend for using halogen-free cables within turbines is ever increasing in the U.S. and Canada. While UL/CSA places high importance on not allowing any fire to arise in the first place, if one does breakout regulators would also like to prevent halogen's harmful components, such as fluorine, chlorine and iodine, from being released. Additionally, halogen further contaminates the turbine when it combines with moisture, creating hydrocyanic acid. ⚡



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