THE INFLUENCE OF HIGH VOLTAGE CABLE ACCESSORIES & METALLIC SCREEN CONNECTIONS

on the reliability of offshore wind farm cable systems.

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BACKGROUND

High-voltage cable accessories have the task of re-building the different layers of a high-voltage power cable, while simultaneously providing the connection to other electrical components. The outer part of the power cable — the metallic sheath — is covered by a connection arrangement. This connection device has to be adopted on each screen design in order to allow an optimum screen current flow. This poster describes the physical characteristics of the screen connections and highlights the most important parameters to consider to ensure reliable operation. These include contact resistance, ampacity and installation. In addition, testing of the connection technology on Smooth Welded Aluminium Sheath (SWAS) cables was carried out and the results are compared with simulation results.

SUBSEA POWER CABLES WITH SMOOTH WELDED ALUMINIUM SHEATH (SWAS)

Smooth welded aluminum is the environmentally-friendly alternative to lead sheath and combines two critical functions, by providing:

- Electrical earth screen
- Radial water barrier

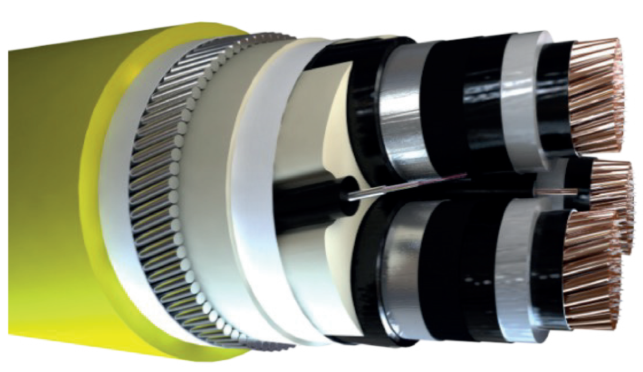


Figure 1

The increasing currents on the screen made further developments necessary to increase overall reliability. The traditional methods that are widely used to connect the SWAS to grounding in medium-voltage systems are typically not robust enough. Additionally, certain older techniques, such as welding of the screen (as used in extra high voltage applications) are not acceptable anymore, as they are dangerous and time-consuming in the limited space inside wind turbines. In addition, when designing cable terminations for offshore wind farm applications, installation sites with limited resources is an important factor to be considered.

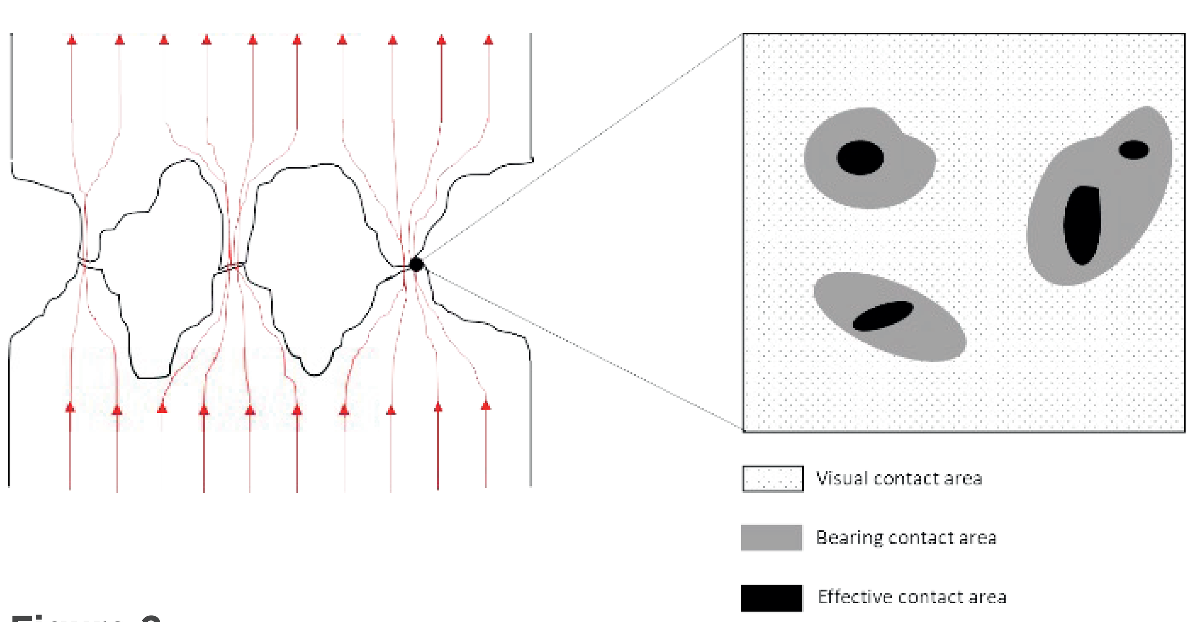


Figure 2

In order to create a proper connection between the smooth welded aluminum sheath and the cable accessory, a suitable physical connection must be established. The quality of this connection is typically determined by the effective contact area. Note, this effective contact area is not to be confused with the surface area where two materials are touching each other. Rather, the effective area is much smaller - only visible on a microscopic scale - and is normally < 5% of the contact area (see Figure 2).

Apart from the nominal current flow on the cable sheath, other current flow conditions have to be considered. These include nominal current flow, short circuit current flow, intermittent current flow and other load situations. The sheath connection must withstand these different kinds of ampacity situations. This is especially true for connections with aluminum-sheathed cables because this conductor material shows lower value of certain key performance characteristics, compared to copper materials.

DESIGN OF SCREEN CONNECTION FOR SWAS CABLE

he SWAS cable is composed of a core cable covered with aluminum tape (applied lengthwise) that has been shaped around the core and welded. Historically, this type of cable had the screen connected by means of an earthing lead, fixed with clamps and specific metallic ties, fastened directly at the cut of the aluminum sheath.

Clamping systems need special attention as a high force onto the cable construction may lead to deformation and subsequent failure of the electrical insulation. However, clamping forces that are too low do not provide a reliable electrical contact, which may result in long-term contact stability issues. Another major factor in the selection of the most appropriate cable is the ease of installation of the screen connection, as this typically determines the ultimate quality of the screen connection. Consequently, the existing specific metallic tie method has been chosen, as this presents the optimum method for achieving the required balance between mechanical force (to ensure a reliable, solid electrical contact) and the need to reduce the risk of installation errors, which can have even greater consequences in offshore applications.

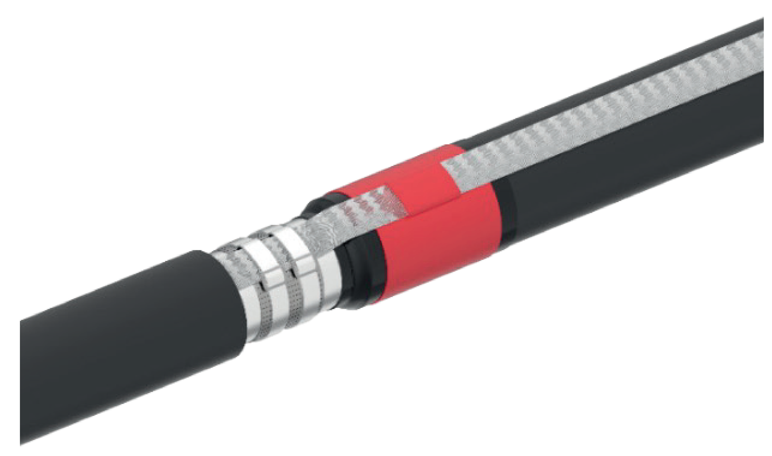
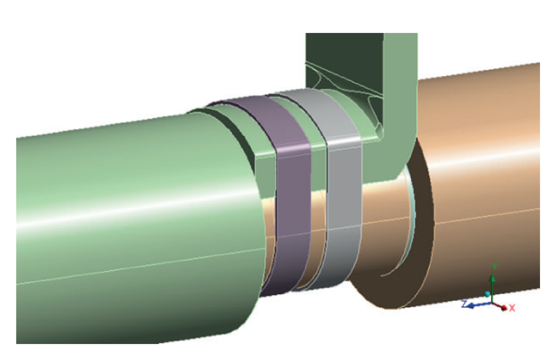


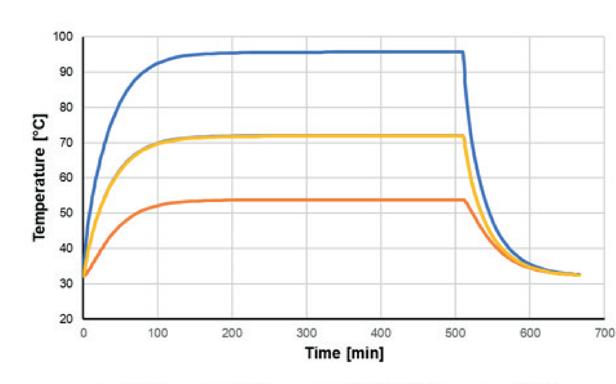
Figure 3

However, in order to optimize this screen connection for the higher requirements of offshore applications – where they may experience frequently fluctuating load conditions in terms of the current flow on the metallic screen – special attention was given to the dynamic behavior of the electrical contact. This dynamic load creates a displacement of the whole screen system both in radial and longitudinal direction, and must be taken into consideration as this is the major parameter for long-term stability of the entire system. For this reason, special design elements were implemented in the construction of the whole screen connection, as well as the electrical contact system.

During a thermal-electric simulation, the core conductor was loaded with a current of 627 A and the aluminum sheath was loaded with a current of 122 A. The screen face and conductor face were chosen as input for currents. An ambient temperature of 32°C was assumed. The resistance of 200 µΩ was provided as input between the braided copper wire and the aluminum sheath. The cycle time for simulation was considered as follows:

1. 627 A in the core and 122 A in the screen for 30 minutes
2. Continuous current for next 480 minutes
3. Cooling time was 120 minutes





TESTING OF THE SCREEN CONNECTION FOR SWAS CABLE

Figure 4 **Figure 5**

To verify the simulation and also the performance in situ, an appropriate test loop was created. For this, several configurations (see Figure 6) were installed and connected in series, and testing was carried out based on the CIGRE recommendation. The distance between the connection points was more than 1.2 m, in order to avoid a temperature influence from one connection point to the other. Each cable was connected with special cable lugs which avoid an influence of the cable connection on the measurement.

To verify the simulation, an original thermal profile based on the IEC 61442 standard was recorded (see Figure 7).

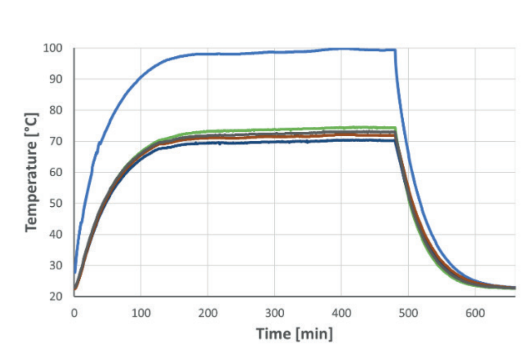
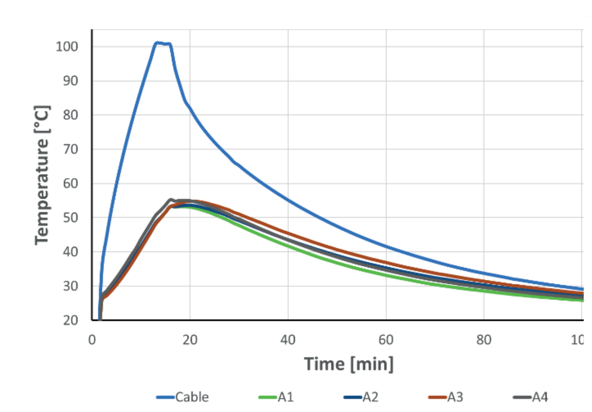


Figure 6 **Figure 7**

The first aging step comprised 150 cycles. Then, to check the ability of the connection to handle short-circuits episodes, a short-circuit test was applied on the screen while the conductor was cold. This represents the worst-case scenario that such a cable would have to withstand in the field.

The short-circuit test was carried out with 2 shots of 6.5 kA for 1 sec, equivalent to an adiabatic Joule integral of 42.9 (kA)² sec. This theoretical value is determined to raise the temperature of the screen from 25 °C to 250 °C.



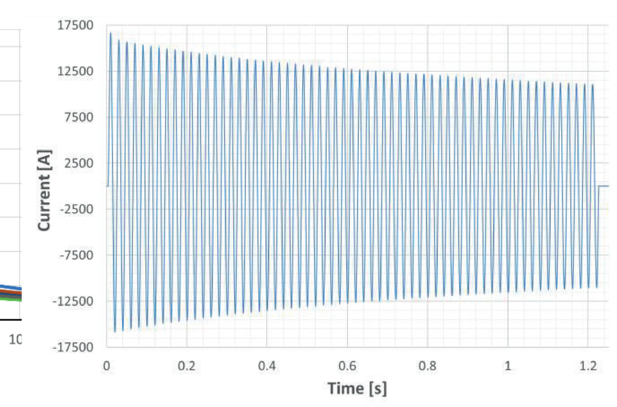


Figure 8 **Figure 9**

The second aging step was carried out by applying 100 additional cycles to stabilize the connection resistance, followed by 2 shots of 10 kA for 1 sec, equivalent to an adiabatic Joule integral of 100 (kA)² sec.

This increased value was applied to evaluate the ability of the connection to handle an abnormal short-circuit current (see Figure 9).

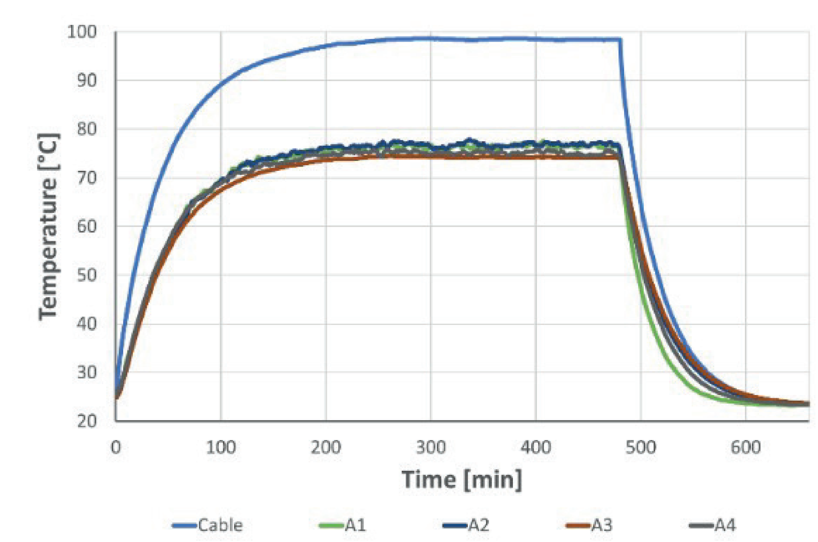


Figure 10

CONCLUSION

A screen connection was developed for use on 72 kV power cables with a smooth welded aluminium sheath (SWAS). This type of power cable has become widely used, especially in offshore applications, but more attention must be given to the selection of the most appropriate screen connection, given the use of aluminum as the sheath material. On the one hand, aluminum provides a more cost-effective solution and a complete radial moisture barrier compared to other widely used materials. However, on the other hand, certain physical properties of aluminum are below those of copper, the other commonly used material. Therefore, a special screen connection was developed that was specifically designed to meet these requirements. The development was based on the existing knowledge base about contact theory for electrical contacts, and was then augmented by simulating the new design's performance using 3D modeling software. The goal was to obtain optimum contact performance, especially over the estimated design lifetime of 40 years, under the challenging operating conditions that exist in offshore wind farms. This screen connection was tested in respect to aging, nominal load and short circuit and did not show any degradation. As a result, this type of screen connection for power cables with SWAS represents the latest innovation for offshore windfarm applications and should be implemented as a standard for this combination of power cable and related cable accessory.

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