640 kV extruded HVDC cable system

World´s most powerful extruded cable system

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Summary

In this paper, NKT’s new 640 kV extruded DC cable system is presented as the latest result of our intensive investment in research and development in the field of HVDC transmission technology. This new development has been made in continuation of the 525 kV cable system that was launched in 2014. This new cables system is a further new world record in the field of HVDC transmission technology which affirms NKT’s commitment to this technology.

The new 640 kV DC cable system is capable of transmitting staggering power levels up to at least 3 GW. The complete underground cable system including the cable, prefabricated joints and terminations are qualified with successfully completing prequalification test and type test according to the latest standards and recommendations.

This technical paper provides a brief description of the cable system’s design, qualification and applications.

Keywords: HVDC cable, extruded, 640 kV, 525 kV, non-linear field control

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Demand for higher voltages

Since its introduction in 1998, extruded DC cables systems, together with the voltage source converter (VSC) technology, has provided a major platform for high voltage direct current (HVDC) power transmission. Interconnectors and subsea power transmission, off-shore wind farm export cable applications, power from shore to remote platforms and underground power transmission through populated or sensitive areas, are the main applications of the extruded DC cables technology.

The development and commercial introduction of extruded HVDC cable systems starting at 80 kV level has grown very rapidly to 150 kV followed by 200 kV and 320 kV which is currently the highest voltage level in installed extruded DC cable systems. All these systems are based on the same technological platform and feasibility studies indicated that in order to reach higher voltages a new generation of insulation materials was required.

In line with its strategies for more efficient power transmission and the HVDC grid vision, next steps in the development for higher voltage levels were taken. Intensive research and development in collaboration with an experienced insulation material supplier, led to the development of the new generation of insulation material system. The new material system together with an optimized process, NKT's know how in production and installation of DC cables and advanced field grading technology provided a new platform for reaching far higher voltage levels. In august 2014, this new technology was introduced to the market by launching a complete HVDC cables system for both land and sea applications at 525 kV [1].

In this paper, as the latest development in this product line, we proudly present NKT's new 640 kV extruded DC cables system for underground applications, that builds on the same technology platform as the 525 kV system. This new cables system is a new world record in the field of HVDC transmission technology which reaffirms NKT's commitment to this technology.

The new technological platform

The insulation material as used in the new 640 kV cable is exactly the same as already introduced on the 525 kV level. As a reminder, this robust insulation material system has a low conductivity to eliminate the risk of thermal runaway and electrical failure which is highest during the electrical type tests when 1.85 times the nominal operation voltage is applied.

The prefabricated joints and the terminations use the same materials and are of a very similar design as the earlier announced 525 kV versions.

The fact that the qualified 640 kV system uses the same insulation materials and very similar accessory designs affirms the technical robustness of the system.

The new HVDC cable system product line

The insulation material as used for 525 and 640 kV is a cross-linked polyethylene for DC purpose. This is a major advantage since NKT's vast experience in extruded HVDC and HVAC cables and the existing quality control techniques can be applied. Due this similarity, aside from the optimization of the design and process parameters and applying more advanced quality assurance measures, the production technique is very similar to that of the previous XLPE insulated extruded HVDC cables.

Application of non-linear field grading material (FGM) first introduced for HVDC cable applications, has been used in many projects and proven to be a very reliable and robust method for controlling the electrical stresses in cable accessories. For the new 525 and also 640 kV prefabricated HVDC joints, an optimized design with non-linear resistive field grading and geometric stress grading is utilized.

The termination development is based on existing HVDC bushing technology and the know-how from 800 kV HVDC bushing development has been utilized – just as in the case of 525 kV. The termination of the 640 kV extruded HVDC cable system can be installed indoors or outdoors. The polymeric composite insulator offers maximum safety without the risk of shrapnel from explosions. The 640 kV HVDC termination is filled with dielectric gas (SF_6) that is non-inflammable.

Similar to the prefabricated joint non-linear resistive stress grading technology in combination with a geometrical stress grading is chosen to meet the high requirements of stability during transients, both for DC voltage and transients such as impulses.

Testing and qualification at 640 kV level

The 640 kV extruded HVDC cable system is in line with the qualification process according to international standards and recommendations. The latest document governing the qualification of extruded HVDC cables is the CIGRE Technical Brochure (TB) No. 496 which was issued in April 2012. Mechanical testing and other tests not specific to HVDC cables are based on IEC standards whereas the electrical testing is in TB 496.

NKT has excellent in-house test facilities and equipment for the extensive qualification and type test process for cable systems. Figure 1 shows the type test set-up for the cable system including the two terminations and the land joint.

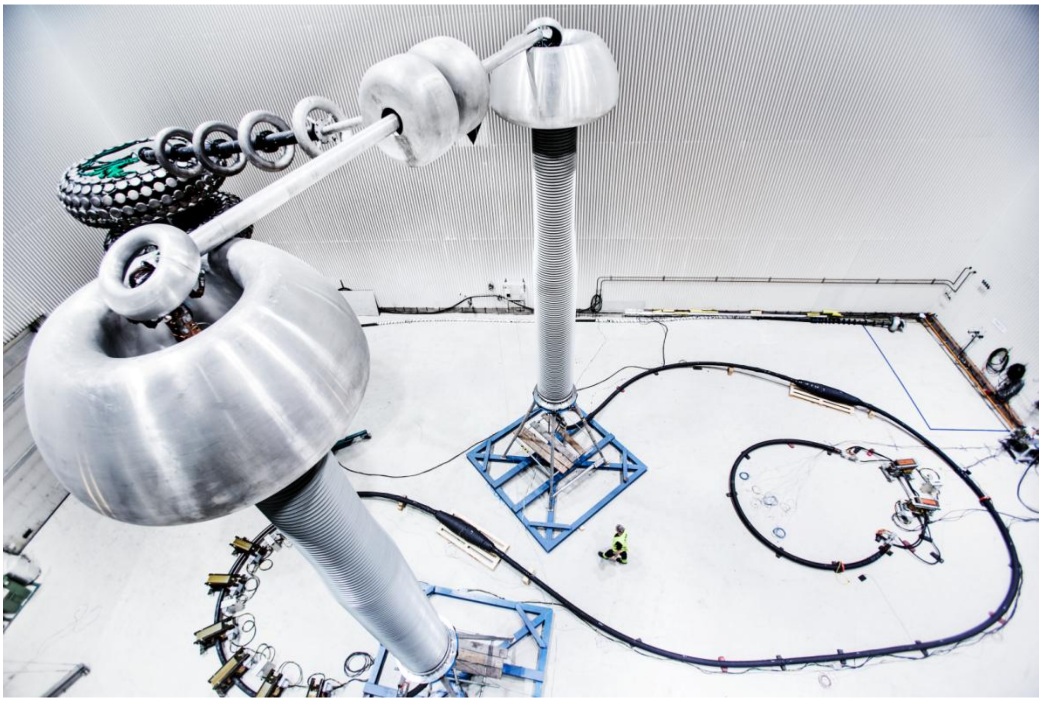

Figure 1. New system means new possibilities

The 640 kV extruded DC cable system can transmit about 20% more power over extreme distances than the previous world record of 525 kV . The technology enables the lowest cable weight per installed megawatt (MW) of transmission capacity and the higher voltages provide reliable transmission and low energy losses.

Figure 2 shows the transmitted power as a function of conductor area for both copper and aluminum as the conductor material. It is possible to transmit up to at least 3 GW through one pair of cables with the 3000 mm^2 copper conductor.

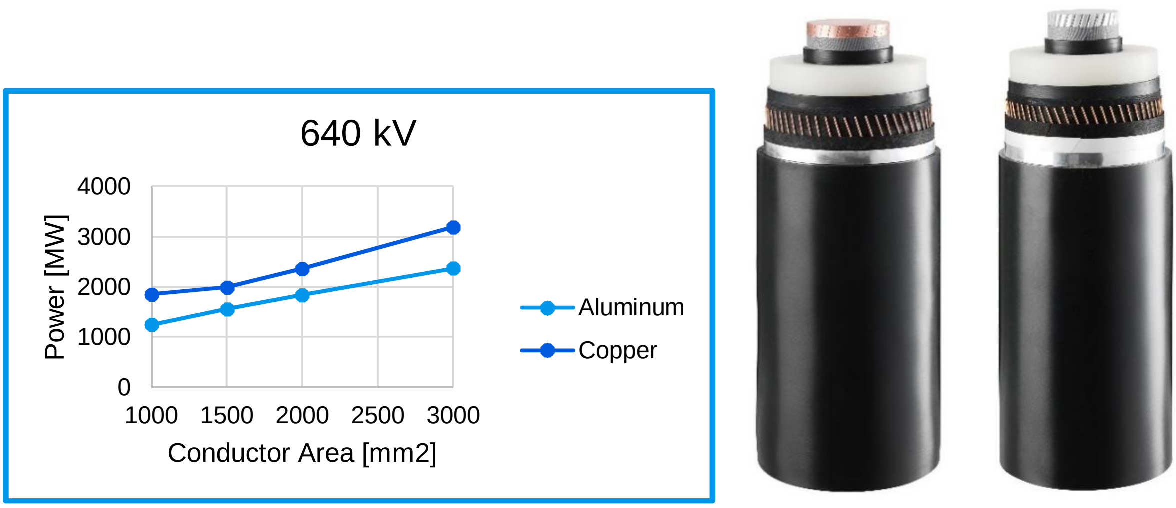

Figure 2. Transmitted power as a function of conductor area and metal for a cable pair. The Copper (3000 mm^2) and Aluminum (2000 mm^2) 640 kV cables are shown to the right.

What to expect next?

As expected, the introduction of the new extruded DC technology in 2014 received a great deal of interest from the customers and also influenced the producers as well. Aside from providing a new voltage level to design for, the qualification of the new 640 kV cables system is a further proof to the technical margin of the DC extruded cable product line at voltage levels below 640 kV. With the new cable system, power levels as high as 3 GW can be transmitted with the 640 kV system which is of interest for future power transmission projects. Besides, feasibility studies on the new technology show potential for systems with even higher capabilities, therefore new developments towards even higher powers can be expected.

1. Bibliography

1. A. Gustafsson, M. Jeroense, H. Ghorbani, T. Quist, M. Saltzer and A. Farkas, “Qualification of an extruded HVDC cable system at 525 kV”, JICABLE 15, June 2015, Paper A7.1.