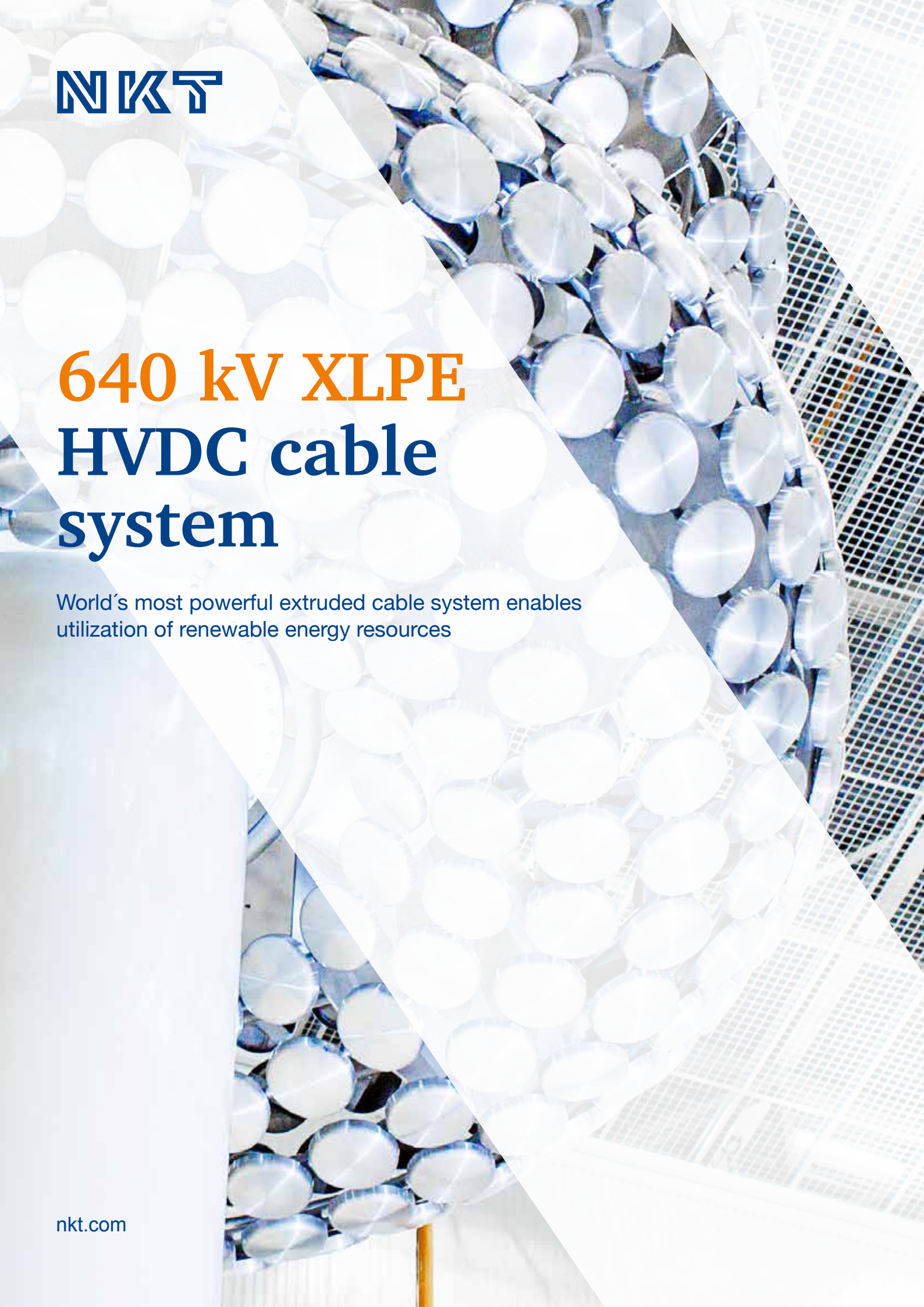
NKT

640 kV XLPE HVDC cable system

World´s most powerful extruded cable system enables utilization of renewable energy resources



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Demand for higher voltages

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

Since its introduction in 1998, XLPE DC cables systems, together with the converter technology, has provided a major platform for high voltage direct current (HVDC) power transmission.

The development and commercial introduction of XLPE HVDC cable systems starting at 80 kV level grew very rapidly to 150 kV and was followed by 200 kV and 320 kV. All these systems are based on the same technological platform. Feasibility studies indicated that in order to reach higher voltages, an upgrade of the XLPE insulation material was required. The novel material is a non-filled cross-linkable polyethylene (XLPE) building on the same technology platform and track record as materials at lower voltages, but with an improved cleanliness both in terms of physical and chemical contaminants in order to have an optimised composition designed for a low DC conductivity.

The material system together with NKT's know how in production and installation of DC cables and advanced field grading technology provided an even better platform for reaching far higher voltage levels. In august 2014, this new technology was introduced to the market by launching a complete HVDC cable system for both land and sea applications at 525 kV [1].

As the latest development in this product line, we proudly present NKT's new 640 kV extruded DC cable system for underground applications, using the same material and accessories solutions as the 525 kV system. This new cable system sets a new world record in the field of HVDC transmission technology which reaffirms NKT's commitment to this technology.

Extruded HVDC cable transmission development

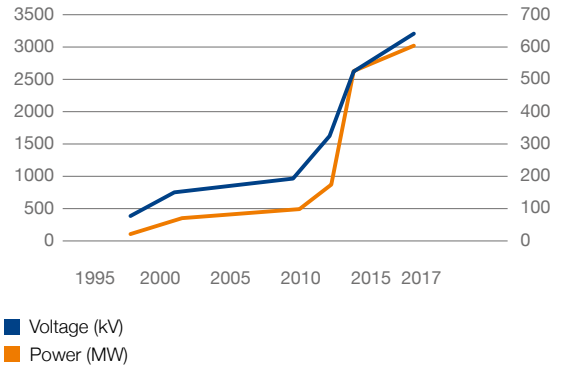


Figure 1. The extruded cable technology has developed rapidly and become an attractive solution on the market.

Testing is at the heart of product development. NKT has one of the largest test laboratories in the world, ensuring development of a reliable cable system.

Testing capabilities are key but not enough. Human knowledge and expertise are just as important and necessary to achieve milestones as 640 kV.

Project name	Location	DC voltage	Insulation	Year	Remarks
Gotland	Sweden	80 kV	XLPE	1999	World´s first commercial HVDC extruded underground cable link
Murray Link	Australia	150 kV	XLPE	2000	Longest (180 km) underground cable transmisson system
Cross Sound	United States	150 kV	XLPE	2002	World's first extruded HVDC submarine cable system
Troll	Norway	80 kV	XLPE	2005	World's first HVDC submarine cable system powering an oil & gas platform
SouthWest Link	Sweden	300 kV	XLPE	2015	First extruded HVDC system combining cables and overhead line
NordBalt	Sweden-Lithuania	300 kV	XLPE	2015	Longest (400 km) extruded HVDC submarine and underground cable system with cost-saving Al conductor

Over the years, NKT has built a pioneering track record of manufacturing and installing the most efficient, reliable and powerful high voltage cable technologies for submarine and underground cable system applications.

The new technological platform

The new 640 kV XLPE 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 completed prequalification test and type test according to the latest standards and recommendations.

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 the same design as the earlier announced 525 kV versions.

The technology utilizes former technological experience combined with cutting-edge developments and utilization of the novel, upgraded insulation material devised for the system. The pre-molded, factory-tested joints comprise a sophisticated, patented, electrical stress-relief control system that has been used in thousands of installed joints, accommodating copper or aluminum conductors.

The fact that the qualified 640 kV system uses the same insulation materials and the same accessory designs affirms the technical robustness of the system at 525 kV.

The new HVDC cable system product line

The insulation material as used for 525 and 640 kV is a cross-linked polyethylene (XLPE) 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. Vast global HVAC XLPE experience as well as two decades of HVDC XLPE form a solid base for continued responsible operation even at higher voltages and powers.

Application of non-linear field grading material (FGM) 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 XLPE HVDC cable system can be installed indoors or outdoors. The polymeric composite insulator offers maximum safety even in the event of an internal arc. The 640 kV HVDC termination is filled with dielectric gas (SF6) that is non-inflammable. The hydrophobic surface is more resistant to contamination compared to traditional porcelain surfaces.

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 for DC voltage and transients such as impulses.

Testing and qualification at 640 kV level

The 640 kV XLPE HVDC cable system is qualified according to international standards and recommendations. The latest document governing the qualification of extruded HVDC cables is the CIGRE Technical Brochure (TB) No. 496, issued in April 2012.

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.

New system means new possibilities

The 640 kV XLPE DC cable system can transmit about 20% more power over huge distances than the previous world record of 525 kV. The technology enables the lowest cable weight per installed megawatt (MW) of transmission capacity 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 for given installation conditions. It is possible to transmit up to at least 3 GW through one pair of cables with 3000 mm^2 copper conductor.

The environmental footprint of any high voltage cable system is mostly determined by the losses integrated during the lifetime of the system. Recycling of the cable system has a minor impact on that footprint also referred to as the total life cycle. In any case, if deemed necessary, XLPE cable systems can be recycled.

A robust cable system with flexibility

As expected, the introduction of the new voltage level of XLPE DC technology in 2014 received a great deal of interest from customers and it also influenced the manufacturers. Apart from providing a new voltage level to the qualification of the new 640 kV cables system is a further proof of the technical margin of the DC XLPE cable product line at voltage levels below 640 kV. With the highest voltage level, 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 development towards higher powers can be expected.

Internal laboratory tests have shown feasibility of at least 700 kV operating voltage by having performed tests on an XLPE cable system as high as 1300 kV. It is also expected that the current maximum operating temperature of 70 degrees C can be increased to higher values. This will potentially boost the technical margin or the transmission capacity even more.

640 kV XLPE DC cable system

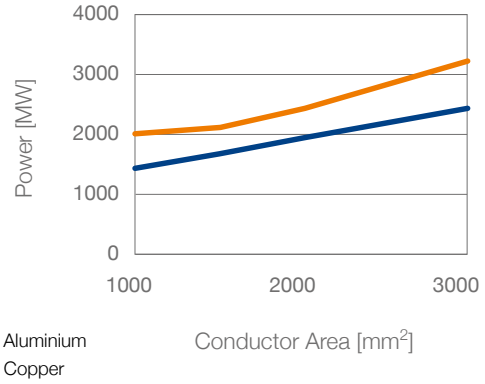
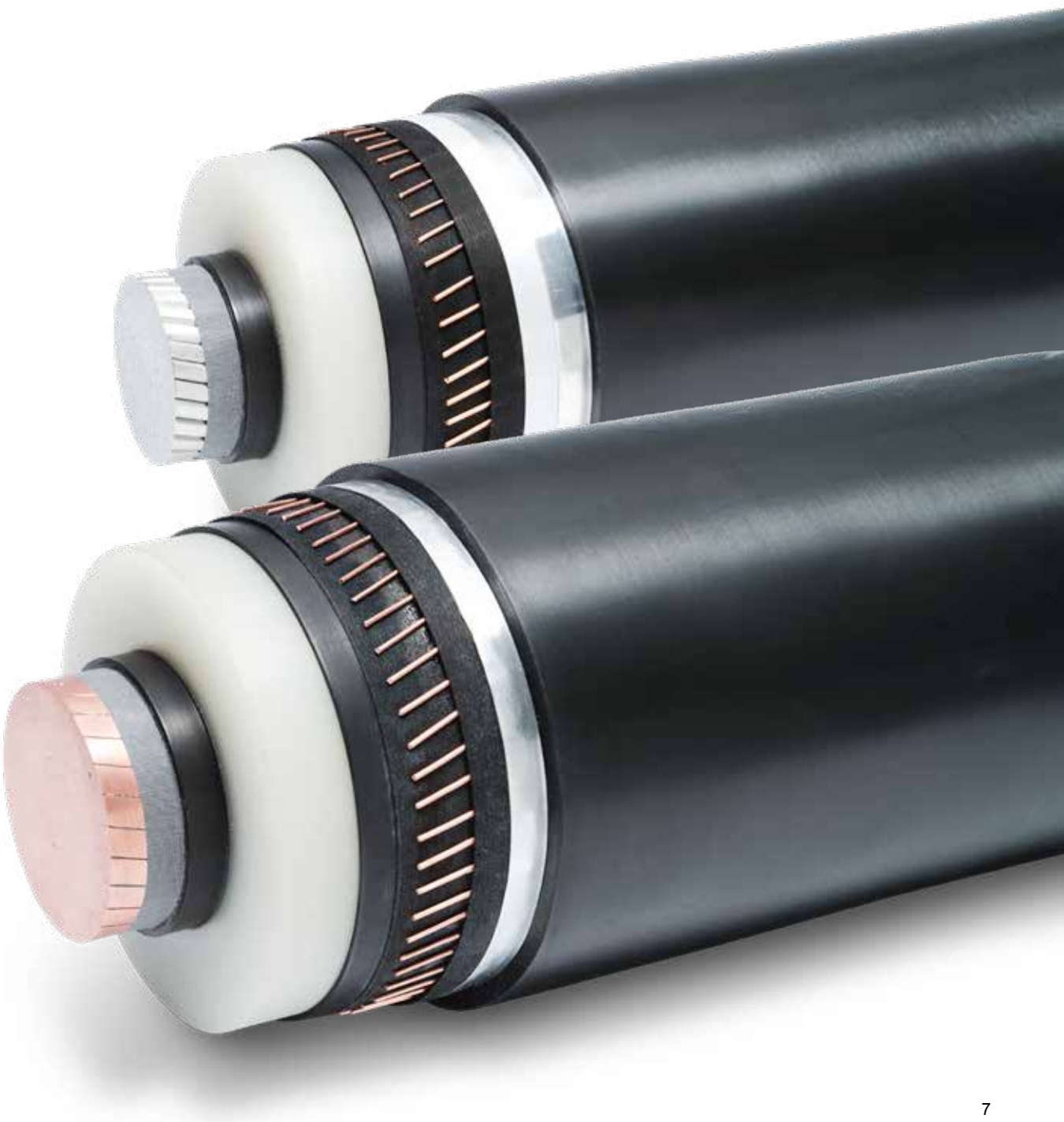


Figure 2. Transmitted power as a function of conductor area and metal for a cable pair. The copper (3000 mm^2) and aluminum (2000 mm2) 640 kV cables are shown in right.



NKT has pioneered the cable industry since 1891, and today we are still proactively meeting the world's constantly growing need for power. We achieve this with our unparalleled energy transportation expertise, cost-effective manufacturing at the highest technological level, and with the regeneration of the environment in sharp focus. We have a 'glocal' mindset rooted in trusted partnerships, and we firmly believe that by working together we can shape the future and use our passion to bring power to life.

NKT is a global and recognized provider of turnkey AC/DC cable solutions with dual headquarter in Denmark and Germany. We employ approximately 3,400 people, and realized a 2016 revenue of EUR 1 billion. NKT is listed on Nasdaq Copenhagen. www.nkt.com

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