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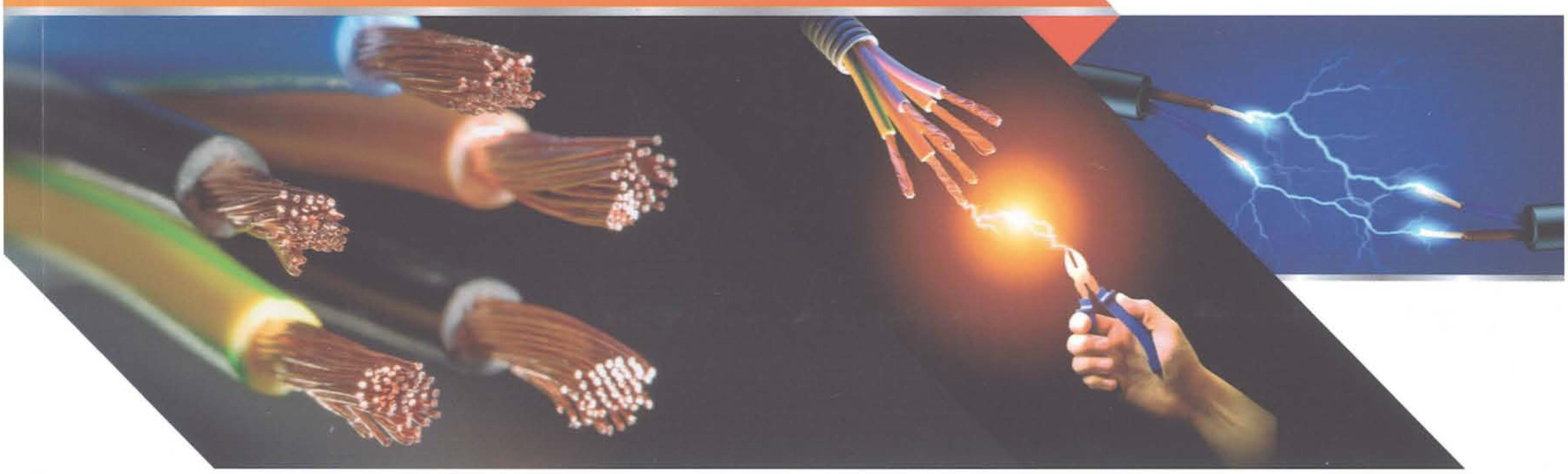

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8th INTERNATIONAL CONFERENCE on CABLES and WIRES

23rd - 24th August 2018, Hotel Le Meridian, New Delhi, INDIA

Submarine Power Cables: A Technological Option for the Future

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Abstract

Submarine power cables are specialised power cables that are used to transport electric current at high voltage below the surface of water. Though these cables have been in use since the early 1800s, their use was primarily limited to transmitting electricity from conventional sources such as coal plants, either between countries or out to islands or oil platforms. Rising energy prices and concerns about climate change in the mid-2000s brought about a forced development of deep-water renewal energy sources (such as wind, wave, tide, etc.) which in turn renewed the interest in submarine power cables as there was a need to transmit the generated power to land from out-in-the-ocean renewal energy installations.

Though there are several issues (such as complex and unclear regulations, few consulting firms to conduct sea floor surveys and availability of cable-laying ships) that could impede the growth of submarine power cables, under-construction and future projects due to the increasing demand for renewal energy from offshore energy sources are ensuring that the necessary expansion, diversification, development and use of these cables cannot be stopped.

This paper aims to provide an insight into submarine power cable while differentiating it from a power cable used on land. The market drivers that support development of this technology and opportunities and challenges that India offers to this industry are discussed.

Key Words: Submarine Power Cables, Power Cables, Undersea Cables, Underwater Cables, Renewal Energy.

1. Introduction

The modern system of underwater cables (also called submarine cables) has its roots in the telegraph. With time, the telephone cables and eventually the fibre-optic cables, on which the Internet relies upon, joined these undersea telegraph cables on the ocean floor. Accordingly, the associated technical developments have taken the cables through three distinct eras: telegraphy with single-conductor copper wires, beginning in the 1850s; telephony by means of coaxial cables with repeaters, beginning in the 1950s; and data transmission through optical fibres, beginning in the 1980s.

Unlike the telecommunication submarine cables, the submarine power cables have had a modest history where their use began "out of necessity" to provide power connection to isolated offshore facilities such as lighthouses, infirmary ships, etc. Later, the power supply of near-shore islands became the main objective. Today, the submarine power cables are used to connect islands close to the mainland with the mainland power grid to increase power availability and replace island-stationed, inefficient power generating diesel generators. Owing to their geographical character, some countries, such as Norway, the Philippines and Japan have had a long tradition of installing submarine power cables between their numerous islands.

The main difference between the submarine cables used for telecommunication and those used for power is the amount of copper. While the power cables carry a lot of copper, little copper is used in the telecommunication cables. With the advent of optic fibre the need for copper in telecommunication cables has been done away with entirely, while the submarine power cables continue to use copper or aluminium for their core. The submarine power cables vary widely in size, governed by the route length, voltage and current they need to carry and can be anything from 70mm to, exceeding, 210mm in diameter while the telecommunication submarine cables are typically between 20mm and 50mm.

Till 1954, submarine power cables primarily transmitted Alternating Current (AC). In 1954 the world's first submarine Direct Current (DC) carrying cable using HVDC technology, named, Gotland 1, was installed. This was 98km long from Gotland Island (located 90kms east of Swedish mainland and 130 kms from Latvia) to the Swedish Mainland and had a capacity of 20MW. This changed the thinking of the world about submarine electricity transmission. It has become possible now to connect to other countries overseas that were previously thought unreachable. Further, events such as rising energy prices and concerns about climate change in the mid-2000s helped the development of deep-water renewal energy sources (such as wind, wave, tide, etc.), which in return brought focus on the submarine power cables for transmitting the generated power from these out-in-the-ocean installations.

Rising interest in deep-water renewal energy and trans-national sharing of surplus capacities has shown the tremendous potential of the submarine power cable industry and that "they cannot be ignored". Keeping in mind this importance, the paper aims to provide an insight into a submarine power cable while differentiating it from a power cable used on land. The market drivers that support development of this technology and opportunities and challenges that India offers to this industry are discussed.

2. Power Cables

A power cable is an assembly consisting of one or more power cores with individual or common screen and sheath, assembly fittings and covered by a common protection. Fundamentally, a power cable, whether to be used on land or underwater, necessarily requires a conductor and an insulator to perform its defined task of transmission of electricity. The remaining components (sheath, screen and armour) are purpose based components which are provided to fulfil purposes such as water blocking, armouring against mechanical damage, additional mechanical strength, good abrasion, corrosion resistance and high reliability while having minimum environmental impact.

The type of current to be transmitted has an influence on the voltage used, the capacity and the maximum length of the line and the intermediate electric equipment used. Two types of currents are considered as industry standards. These being the Alternating Current (AC)[1] that flows in one direction for half a period and for the next half switches direction and is produced by most of the power plants across the world as three-phase AC. The second type is the Direct Current (DC) which always flows in the same direction and is produced by batteries, solar cells and fuel cells. DC produced in photovoltaic panels (and parks) is converted into AC before being fed into the grid.

Usually, the transmission of electrical energy is done by AC networks at a high voltage. These networks are reliable and designed respecting safety and human/ industrial needs. However, to enhance power transmission, reduce costs and losses, while being environmental friendly, the High Voltage Direct Current (HVDC) technology was developed. This technology started to be used in power transmission at the end of the 19th century but only a few lines and facilities were built, many of them experimental. The trend continued into the 20th century but only in the '70s they gained momentum and became commercially attractive. Today the HVDC technology is mostly used in power transmission over long distances in overhead lines, in submarine power cables and to connect separated power systems. Since the HVDC systems need to interact with AC networks, at least two converter stations, AC to DC and DC to AC, are needed in the network along with the DC cable link. The late development of this technology is primarily due to the need of reliable and economic power electronic devices that could work with high voltages.

Though AC is the most economical system being a cheaper technology, it is limited by the distance over which it can be used. AC cables are "three-phase" cables, and are laid either as a bundle in a three core formation (three conductors), or as three separate cables to carry the same power.

For longer distances the HVDC technology needs to be used. HVDC cables require less material since they need only one power line to transport electricity. These

[1] Produced by placing a coil of wire into a revolving magnetic field. If one coil is used, a single-phase AC is produced while by using three coils, a three-phase AC is produced

cables consist of one primary conductor by which the current is transmitted and a return path represented by another conductor or via seawater using an anode/ cathode arrangement. The configuration of the HVDC cables is of two types, dependent on the DC system and is seen in Table 1.

Table-1: Types of configuration- HVDC cables

Configuration type	Arrangement	Diagrammatic arrangement
Bi-polar	Two separate single-core cables	○ ○
	Bundled two single-core cables	⚭
Mono-polar	Single-core cable with metallic return	○ ●
	Two single-core cable with metallic return	○ ● ○
	Concentric cable	◎

3. Structure of a Power Cable

The structure of a power cable must ensure a high efficiency in electrical transmission, a good insulation and magnetic shielding along with a strong mechanical resistance. This structure may differ in materials and layout depending on the manufacturer and environmental conditions but necessarily includes a set of layers around the conductor to ensure the physical insulation, impermeability, mechanical strength, flexibility and electrical and magnetic shielding. The main constituents of a power cable, as seen in Figure 1, are discussed in the succeeding paragraphs.

Conductor

The starting point of any cable is the conductor (or the core). The conductor is usually made of stranded copper or aluminium (to reduce weight and cost).

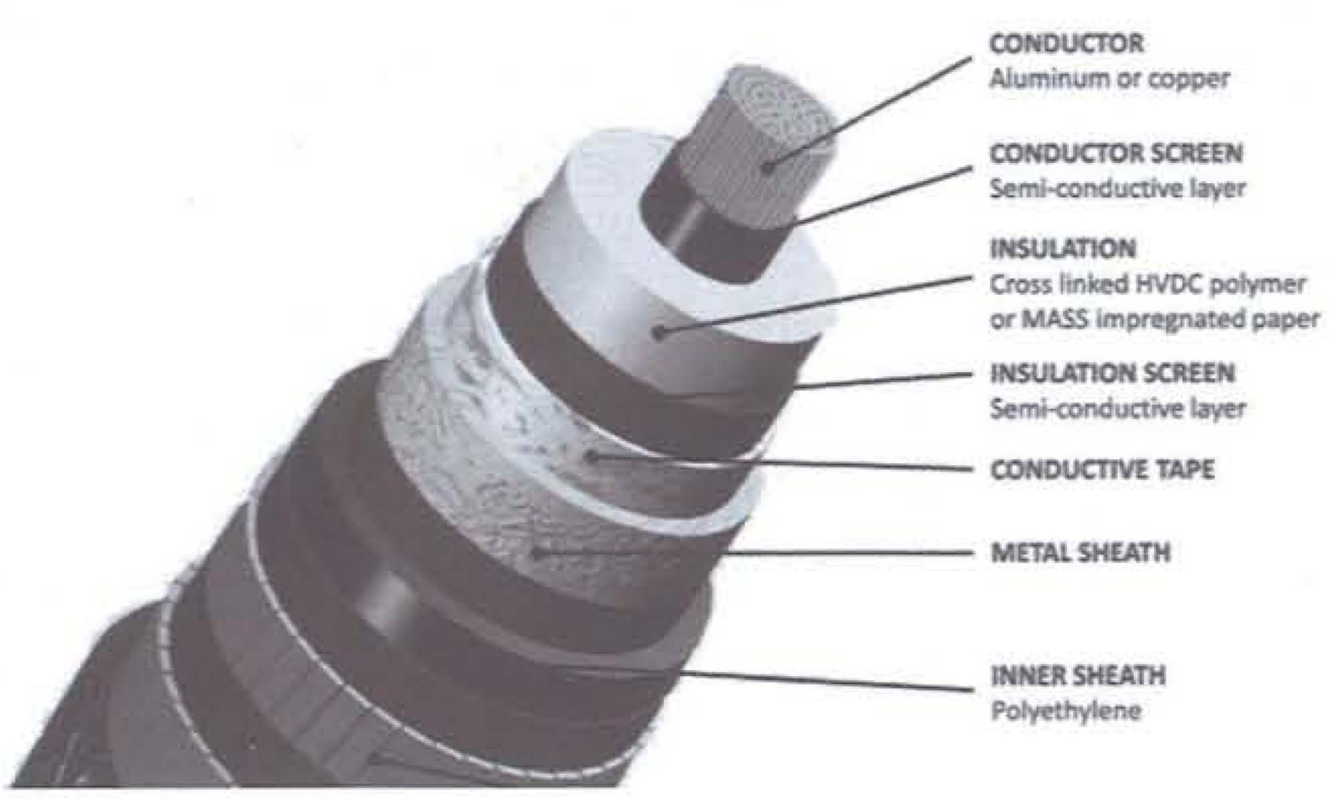

Figure-1: Cross section of a submarine cable assembly

(source: DNV GL, 2014 [1])

Insulator

The conductors must be insulated against any external contact for the whole length of the cable. It is the insulation that distinguishes between various types of cables. This insulation can be made from a variety of dielectric materials of which the three main types that are widely used are discussed below with Table 2 showing the types of insulations used for various European projects.

Self-contained Fluid-filled (SCFF). SCFF cables require the use of pressurized insulating fluid within the conductor and insulation. They are used for very high voltages, usually up to 500 kV. They are suited for conditions where there are no hydraulic limitations and for short distances. Their diameter spans between 110 mm and 160 mm and their weight is 40-80 kg/m while the conductor size is up to 3000 mm². Although SCFF cables are very reliable, very few cable manufacturers are capable of supplying them. Maintenance of the fluid pressurizing system is relatively expensive and there are risks of fluid leaks into the environment. These have the following variations

- SCFF/SCOF (self-contained fluid-filled / self-contained oil-filled).
- HPFF/HPOF (high-pressure fluid-filled / high-pressure oil-filled).
- HPGF (high-pressure gas filled) and GC (gas compression).

Paper insulated (lapped insulated) or Mass-impregnated cables are the most used since they have proved to be highly reliable for more than 40 years since they are in use. They are used up to 500 kV and operate up to a maximum temperature of 55 °C, with newer types operating safely at 85°C and a voltage up to 600 kV. The conductor size is up to 2500 mm² while the external diameter spans between 110 mm and 140 mm with a weight of 30-60 kg/m, which makes this cable lighter in comparison with the SCFF. These have the following variations:

- MI (mass-impregnated) or PILC (paper-insulated lead-covered) cables that have mass impregnated paper with high-viscosity insulating compound.
- PPLP (paper polypropylene laminate).

Extruded cables are used for voltages up to 300 kV. They are associated with Voltage Source Converters (VSC), which permit to reverse power flow without reversing the polarity and increasing the maximum transmissible power to 800 MW. However uneven distribution of charges inside the insulation can cause localized high stress causing accelerated ageing of the insulation. Their low weight of 20-35 kg/m and diameter of 90 mm to 120 mm, make them very competitive. The following variations exist for these types of cables:

- EPR (ethylene propylene rubber).
- PE (polyethylene).
- XLPE (cross-linked polyethylene) which consists of a network molecular structure suited for high temperatures.

Screen

In high voltage cables, especially those underground, the cable is shielded, or screened, with an earth conductor. If someone was to cut/ damage through the cable, it will generally connect the conductive inner core directly with the protective screen around the outside causing the fuse to blow at the feeding station rather than travelling up through the digger and killing him.

Table-2: Insulation types- European projects

Current Type	Max. Voltage	Typical insulation
AC	≤ 36 kV	Extruded (XLPE, EPR)
	>36 kV to 170 kV	Extruded (XLPE, EPR)
	>170 kV to ≤550 kV	Extruded (XLPE)
DC	≤ 320 kV	Extruded
	≤ 600 kV	Mass impregnated

Sheath

Around the insulation is placed a metal sheath that prevents moisture ingress and corrosion and provides mechanical strength to the cable. For submarine power cables various water-blocking agents such as swelling powder, swelling yarns, hydrophobic compounds or gels are used. They are inserted between the wire layers to achieve water tightness. The sheath along with the metallic screen and armour wires (when available) carries a fault current.

Armour

A layer of armouring is provided to increase the cable's tensile strength and allow it to better support its own weight during installation. This is usually a layer of flat or round galvanised steel wires wound helically around the cable in a single or a double layer. This armouring adds to the weight and reduces the flexibility. The most common wire for armouring is galvanized steel wire, but, copper, brass, bronze and aluminium wires are also used.

Outer sheath / serving

A radial water barrier in the form of a metallic sheath usually of aluminium laminate (for shorter medium-voltage cables) or lead (for submarine power cables) is applied in uniform thickness between 2 mm and 5 mm. The lead may be alloyed with antimony, tin, copper, calcium, cadmium, tellurium and others. The lead sheath is vulnerable to mechanical damage and needs to be protected by additional layers usually of plastic over-sheath.

Optic fibre

Modern three-core power cables carry optical fibres for data transmission or temperature measurement, in addition to the electrical conductors.

4. Comparing Power Cables On Land And Underwater

Like any other power cable, a submarine power cable too transports electric current. However unlike a land power cable, the submarine power cable is used underwater and hence the name "sub-marine". It is this requirement to function underwater that makes the submarine power cable unique and largely different from the land power cable.

Both the land power cables and the submarine power cables have the required metal conducting core surrounded by insulation and screens. Since the submarine power cables need to address various physical, environmental and installation challenges, they have additional components that provide water blocking, armouring against mechanical damage, additional mechanical strength, good abrasion and corrosion resistance and high reliability while having minimum environmental impact. The areas of difference between them are shown in Figure 2 and discussed in Table 3.

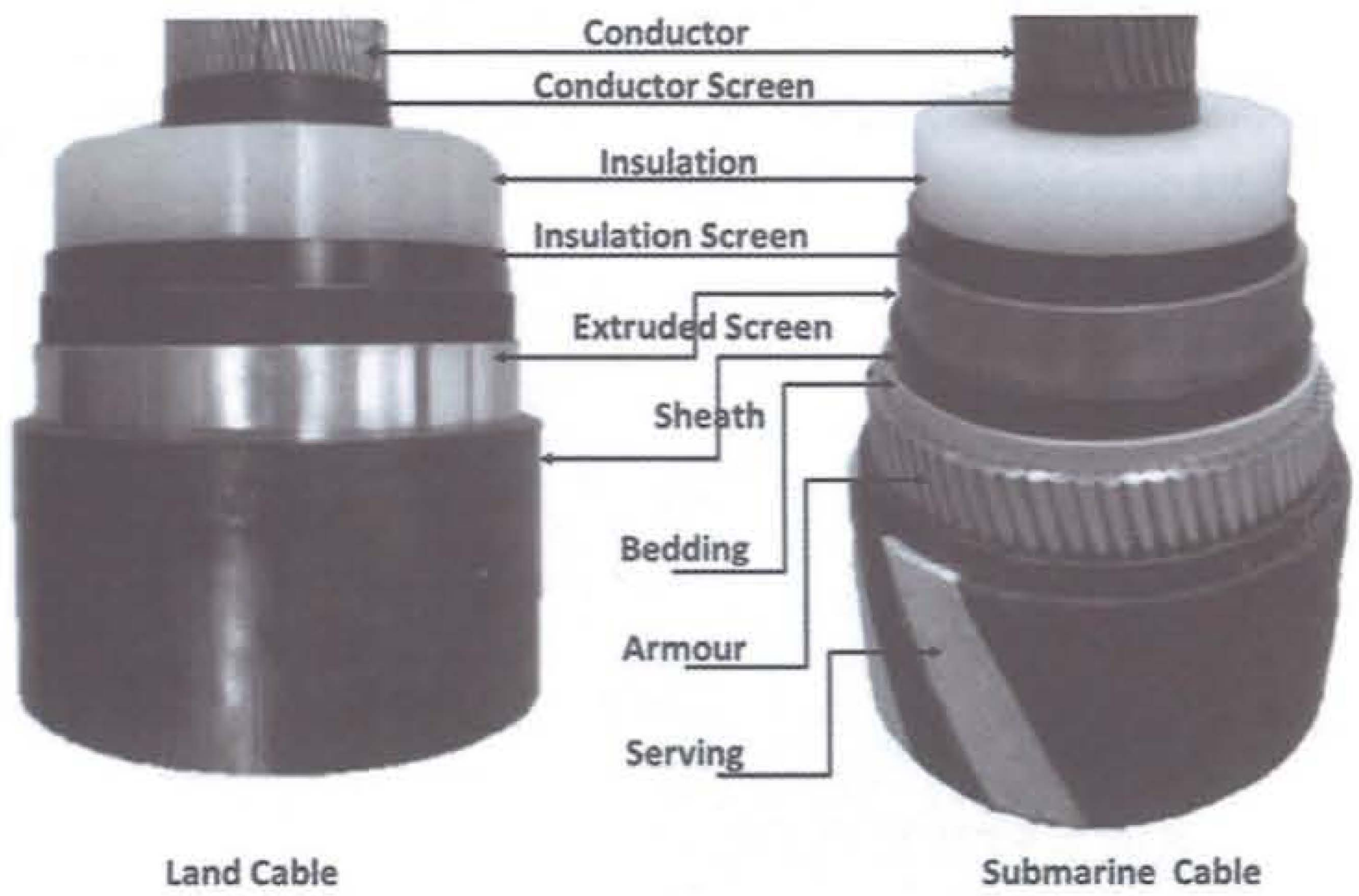

Figure-2: Comparison of land and submarine single-core cable (source: modified from Balanuye et al.[2])

5. Alternating or Direct Current

Since AC technology is a more economical technology but cannot be used for distances longer than approximately 80kms due to the cable capacities absorbing the available usable electricity, HVDC technology was developed as an alternative. It is thus essential that both AC and DC cables are looked at when discussing submarine cables. The AC cable so used is usually a 3-core cable (see Figure 3) while the DC cable used is a single core cable (see in Figure 4).

To see how these cables compare, consider the requirements for a 550 MW subsea connection over a distance of 75 km. For a conventional AC scheme on land, three single-core 220 kV XLPE cables would

Table-3: Comparison of elements- Land cables and Submarine cables

Property	Land Application	Submarine Application
Conductor	Majority use aluminium	Majority use copper[1] Aluminium for deeper waters Copper for shallower waters Usually thinner than the land cables of equal capacity Superconducting materials (carbon nano-tubes) being researched
Insulation		Oil impregnated paper and polymeric materials
Screen	Two sheets of screens present. Both made of semiconductors. • Between conductor and insulation to equalise electric field. • Immediately outside the insulation to seal off the electric field from leaking to outside of the cable	
Sheath (water barrier)	Layers made of lead alloy, aluminium, copper and polymeric material.	Layers made of lead alloy, aluminium, copper and polymeric material. Basic water barrier layers installed inside the sheath.
Wire Armour	Not present or light	Layer or layers of metallic tapes or anticorrosive wires (typically galvanised steel wires) to withstand the mechanical forces.
Outer Sheath		Formed using bitumen bonded polypropylene yarn. Improves corrosion resistance to sea water Fricative surface helps in cable handling
Length	Typically single core land cables are in lengths of around 1 km	Three-core cables can be in sections of 80 km
AC	Three single core cables	Three core
Protection	Adequate but lesser than submarine cables	Better protected
Maintenance cost & time	Expensive, but cheaper than submarine cables	Defect identification and fixing cost is sometimes 5-10 times more expensive
Outage	Shorter as defect identification and rectification is faster	Longer
Design		No two projects are identical. Each has to be designed to fulfil its own purpose, taking into account transmission distance, water depth, sea currents, risks of damage, etc.

be required with a copper conductor cross-section of 1600 mm^2 and copper wire tensile armour. The weight of the three cables would be 3 x 60 kg/m = 180 kg/m. However, an HVDC would require only two 150 kV cables with a copper conductor cross-section of 1400 mm^2 and steel wire tensile armour. The weight of the two cables is 2 x 32 kg/m = 64 kg/m, or around one-third of the AC scheme. This weight saving reduces both the cable cost and installation cost, while the shorter total cable length reduces the factory production time scales. [3]

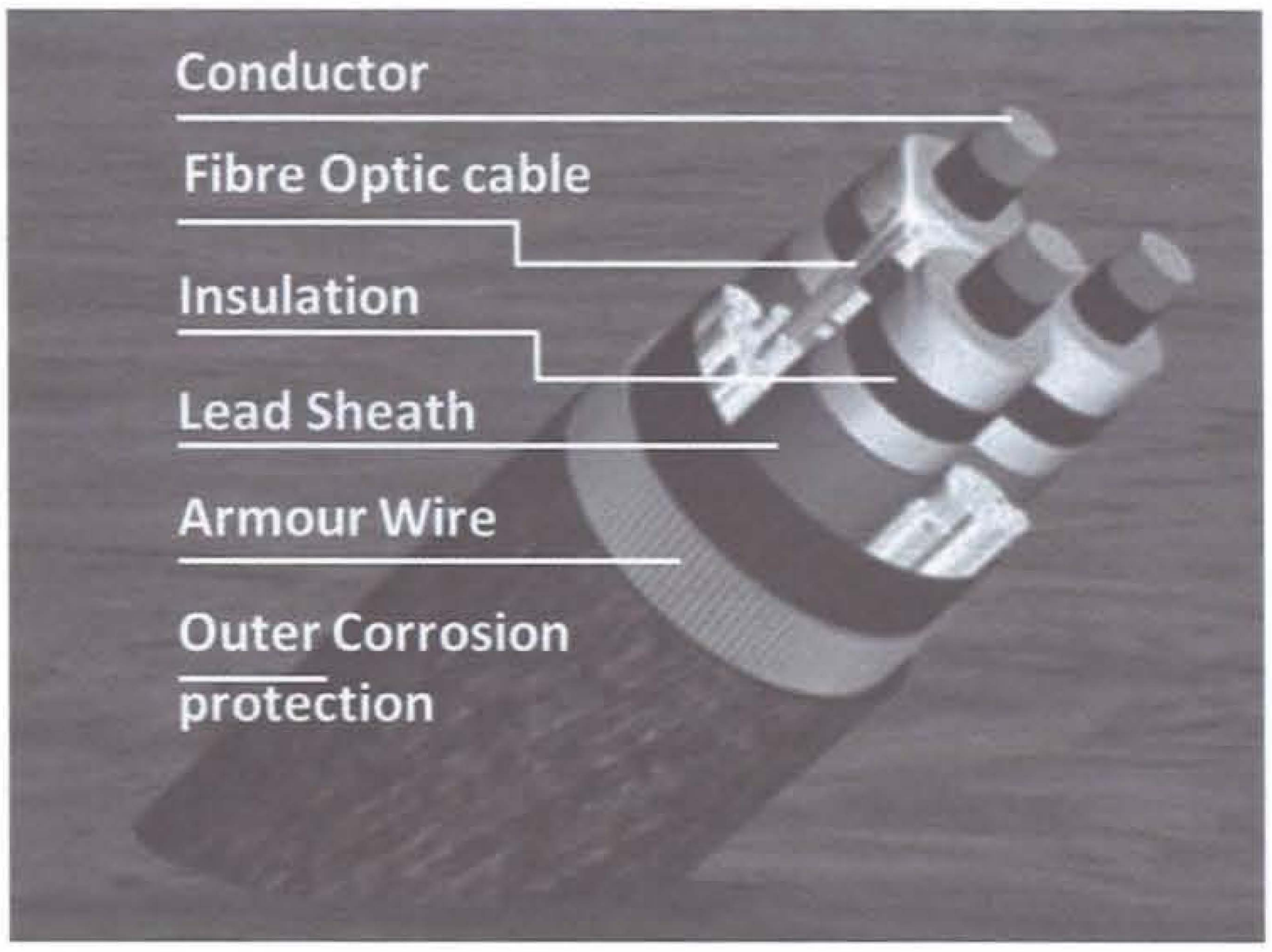

Figure-3: 3-Phase AC Submarine Power Cable (source: modified from Nexans)

The following are the advantages and disadvantages of using a single core cable as compared to a 3-core cable.

Advantages

- Lighter weight.
- Smaller diameter, hence smaller laying and repair ship acceptable.
- Longer lengths on drums possible.
- Fewer joints at factory and on site.
- Higher current rating.
- Voltage rating up to 500 kV.
- Reduced repair costs and spares as all three phases need to be repaired after a fault for a 3-phase cable.
- Lower material costs for each cable.
- Lower stability in high water currents.
- Cannot include optional fibre optics.

Disadvantages

- Higher external magnetic field.
- Lower corrosion resistance.
- Higher sheath/ shield current and voltages.
- Higher armour losses.

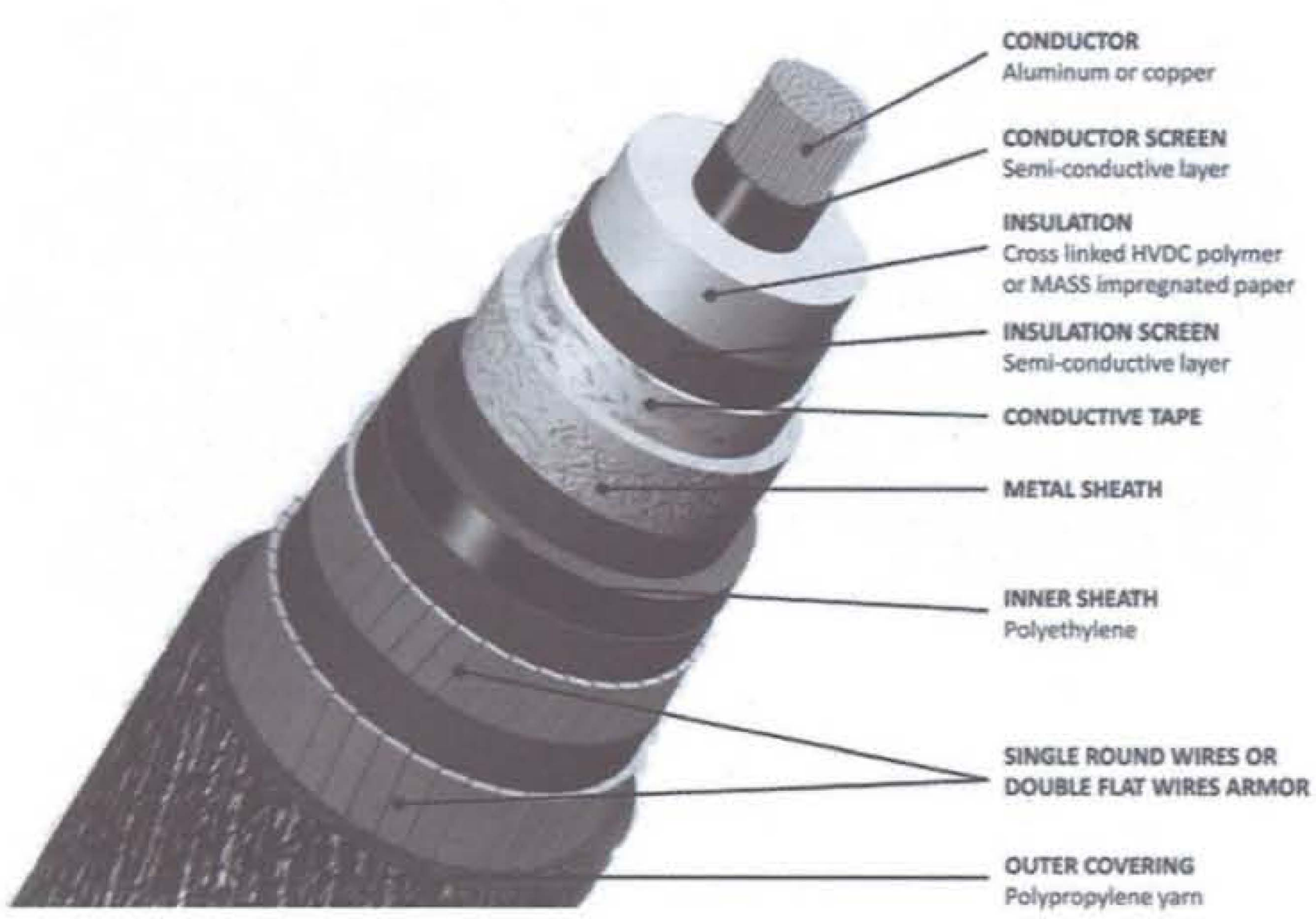

Figure-4: Co-Axial HVDC Submarine Power Cable (source: Nexans)

6. Economic Comparison - Hvdc And Hvac Cables

In order to undertake an economic comparison of systems supported by the two technologies, one would need to consider the associated lifetime costs. As on land, the HVDC technology becomes cheaper only over a longer transmission distance primarily due to the associated high investment costs and low losses for an HVDC technology. A general cost comparison between the two technologies shows that this break-even happens at a distance which is usually 800 km for land cables and between 40 and 80 km for submarine cables [4] as seen in Figure 5. For submarine cables this distance depends on various factors, as discussed in section 9, and an analysis must be made for each individual case.

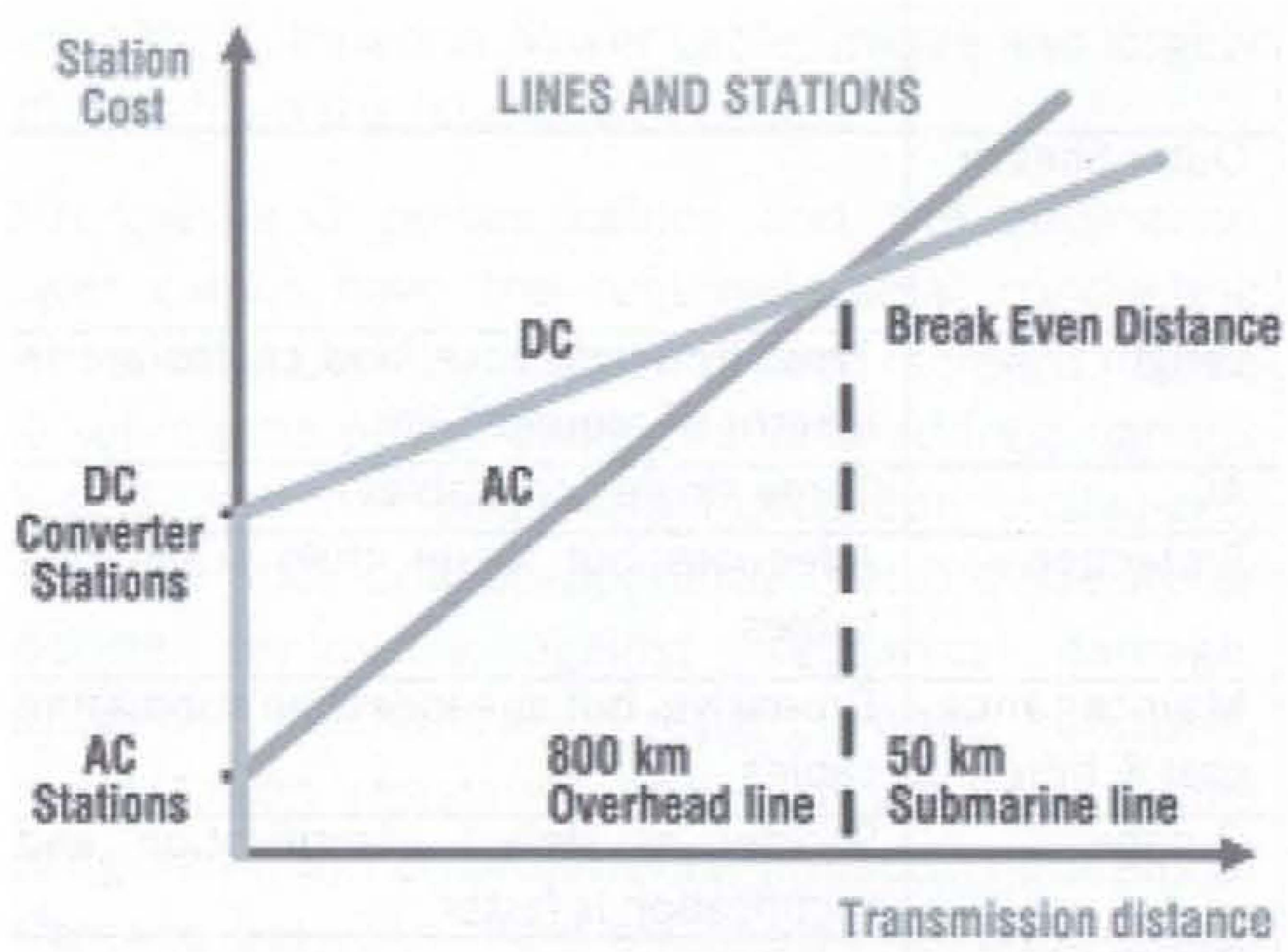

Figure-5: Comparative HVAC and HVDC costs (source: Electrical engineering portal [5])

7. Market Drivers

At the moment there are almost 8000 km of HVDC submarine power cables in the world. More than 70% of these cables, both in terms of number and length are located in Europe connecting countries separated by small to medium width water bodies. Majority of these submarine power cables have a length of less than 300 km.

The demand for HVDC transmission is increasing rapidly. In the last 40 years, HVDC transmission links with a total capacity of 100 GW (equivalent to the capacity of 100 large power plants) were installed. Another 250 GW will be added in this decade alone [6]. Some broad highlights of these cables are:

- The longest HVAC submarine cable is 104 km, installed from Isle of Man to mainland England in 1999/2000.
- The longest HVDC submarine cable is 580 km installed between Norway and the Netherlands in 2008.
- The highest voltage (500kV) and largest conductor (3000 mm^2) in a submarine cable was installed off Japan in 1998.
- The farthest offshore wind farm is 90 km off Borkum, Germany and was set up in, 2011.
- The largest offshore wind farm is of 300 MW capacity in England, installed in 2010.
- The first power-from-shore Dynamic AC cable for Floating Platform of capacity 40 MW at Gjøa Platform, Norway installed in 2010.

The submarine cables have potential for a variety of purposes as:

- Island connection. Integrated grids that can compensate for regional fluctuations in the production or consumption of electricity like that for the Western Link (England-Scotland), Inelfe (France-Spain) and BritNed (UK-Netherlands)
- Power supply for areas in which no new power plant is to be built (often via lines running through water) such as Mallorca and San Francisco
- Prevent fault passing. Back-to-back links, which connect two AC grids and serve as a "firewall" to prevent faults from passing into the neighbouring grid as seen in Georgia - Turkey, New York - New Jersey links.
- Power to offshore installations. As is seen in the case of Gjøa Platform, Norway.
- Power from wind farms. As seen in various wind farms in Europe providing the back bone for the 'European Super Grid'

8. Manufacturers

There are many companies producing power cables in the world but only a few of them have experience in manufacturing submarine power cables for long distances and high capacity. Key vendors in this market are Sumitomo Electric Industries, NKT Group (ABB disinvested into NKT), General Cable Technologies (A Prysmian Group Company), Prysmian Group and Nexans who manufacture most of the existing submarine power cables in the world. The last three have their own specialized vessels that allow them to install the cables at sea. Other prominent vendors in the market include Belden, Hangzhou Cable, Hengtong Marine Cable System, KEI Industries, LS Cable & System, Southwire, and ZTT Technologies.

- Prysmian is an Italy-based multinational company headquartered in Milan. Its main factory Arco Felice is located in Naples, Italy. It holds the "Giulio Verne" vessel, which was specially built and equipped for laying power cables at sea.
- Nexans is a French cable manufacture company headquartered in Paris. The submarine power cable factory is located in Halden, Norway. Nexans lays down the cables at sea with its purpose-built vessel "Skagerrak".
- ZTT Technologies. The ZTT Group entered the field of optical fibre communication in the early 1990s. They are active in the development, design, production, supply and installation of wide application ranges in telecom, power, renewable energy and oil & gas.
- General Cables (A Prysmian Group Company). The General Cable's subsidiary Norddeutsche Seekabelwerke GmbH (NSW), has been manufacturing submarine cables since 1899. Today, it is one of the world's leading brands of submarine power and telecommunication cable systems.
- Sumitomo Electric Industries. The J-Power Systems (JPS) Corporation of the Sumitomo Electric group was established in 2001 and is capable of providing comprehensive services from production to installation of submarine cables and contributes to power transmission infrastructure development in Japan and throughout the world.
- NKT Group. As part of the strategic partnership, ABB and NKT Cables worked together till 2016, before ABB disinvested. The proven capability to design and install the ideal cable system for a wide variety of applications, taking into account

production costs, installation costs, power losses and operational costs of ABB has been inherited by NKT.

9. Challenges In Manufacturing Submarine Power Cables

The market for submarine power cables is small and the industry is a highly specialized industry with the technology and know-how in the hand of only a few players. Like any industry, the submarine power cable industry too has its own share of both manufacturing and maintenance challenges.

The biggest challenge to this industry is regulatory (adhering to high sea regulations, national and regional regulations, cable protection committee regulations, environmental regulations etc.) and financial (investment towards route survey, design, manufacture and then laying is high, which may not be made available by the customer upfront, necessitating loans and investment of own funds).

The other biggest challenge is the design of the cable itself. Since, no two power submarine cable projects are identical, these cables cannot be manufactured and stocked Each project needs to be designed individually to account for the transmission distance (to define number of joints), bottom topography (that will define the length of the cable and the armour required to protect the cable), water depth (gives a design pressure to withstand and hence defines the material to be used for the cable sheathing and the connector casing), sea currents (gives the mechanical stresses and manoeuvres the cable will have to withstand, which defines the quality of the sheath to be used), risks of damage etc. which in return requires 'custom built' cable for each project. If the cable crosses an undersea gas pipeline, suitable protection needs to be provided over that region. Similarly, if the risk of cable damage during use is large (due to tidal currents and ocean bottom topography) a double armour cable may need to be provided which would make the cable difficult to bend and handle while necessitating shorter lengths for handling and hence larger number of joints. It is necessary to mention that the cable needs to be invariably designed to be handled by the existing cable laying ships. A new and innovative design may result in the need of a new cable laying ship which may be cost prohibitive.

Further, there are only a handful of companies worldwide who have the capability and the expertise to manufacture and lay these cables. According to Bloomberg New Energy Finance report[2] the three established players ABB, Prysmian and Nexans can manufacture a mere 800 km of HVAC cables per year. So to meet the increasing demands, either new companies will have to step in or these companies have to increase their manufacturing capabilities.

From a maintenance point of view, submarine cables do get damaged (due to fishing, anchor dropping, and natural disasters) and are relatively difficult to repair as isolation of defect takes time. Once the defect is identified, a dedicated cable repair ship does the repair with the entire activity taking close to 15-20 days at times, weather withstanding.

10. Opportunities For Submarine Power Cables In India

The potential of submarine power cables from the Indian context lies in the field of connecting islands, power from offshore wind farms and providing power to offshore installations. In this regard we discuss ways to address the power supply requirements of Andaman and Nicobar islands, Lakshadweep islands, support Sri Lanka to meet its power requirements, tap the growing offshore wind power industry in India and provide onshore power to the offshore rigs. Each of these have been discussed in the succeeding paragraphs.

Andaman and Nicobar Islands

The peak load of electricity in the Andaman and Nicobar islands is about 58 MW (FY16) which is met through cumulative Generation Capacity of around 109.45 MW in the various Islands of A&N. Out of the total generating capacity, the Diesel based generation is around 99.2 MW, Hydro based generation is around 5.25 MW and Solar PV generation is about 5.0 MWp. The islands use about 250 kilo litres of diesel every day for power alone. This power generation and distribution system is served by standalone systems and each island has its own generation & distribution system. This ensures 92.4% of the population to get power supply 24 hours while 2% population gets it for 5-16 hours a day [8].

These islands have a considerable potential for power generation through Renewable Source of Energy such as wind, ocean, tidal, bio-mass which are yet to be harnessed. Lack of a grid in the islands, large dependence on fossil fuels for power generation and non-utilisation of renewal energy resources present a

[2] Bloomberg New Energy Finance – Offshore wind market outlook- H1 2011 – 24 May 2011.

market for the use of submarine power cables.

Lakshadweep Islands

The power supplied in Lakshadweep is through diesel generating sets. These sets are of various capacities ranging from 24 to 400 KW. The power generating systems in all the Islands are stand-alone systems. There is no inter-island connection in the supply grid.

The island has achieved 100% electrification with supply available round the clock. However the source of supply is limited to diesel generators using 66 lakh litres of HSD oil per annum brought from the mainland [9].

Similar to the A&N islands, these islands too present a possible market for the submarine power cables.

The India – Sri Lanka HVDC Grid Interconnection

This grid interconnection is a proposed project to link the national grids of India and Sri Lanka. The project involves the construction of a HVDC connection between Madurai and Anuradhapura in central Sri Lanka, through the Palk Strait. The link would measure 285 kms in length, including 50 kms of submarine cables. Contemplated in 1970, it is to be implemented by the Power Grid Corporation of India Limited and the Ceylon Electricity Board. As of February 2016, the pre-feasibility studies on the project have been completed.

Offshore Wind Power

India has the fourth largest installed wind power capacity in the world [10] with the wind power being the cheapest energy resource in India. However the generating wind farms are all land based. The government plans to have close to 200 GW capacity of offshore wind power in place by 2022. This presents a major opportunity for the use of submarine power cables in the country in the immediate future.

Power to Offshore Oil

India has 34 offshore rigs which are situated at an average distance of 180 km from the mainland. These rigs need hundreds of MW of power, depending on the equipment available, to meet their internal requirements. Presently they meet their requirements by using Gas Turbines and Diesel generators which use fuel while being energy inefficient and environmentally unfriendly. To overcome these issues these offshore platforms can be provided power from onshore using submarine power cable as has been demonstrated around the world.

11. Challenges For Submarine Power Cables In India

While there are opportunities, there are also challenges that need to be overcome to encash on the available opportunities. These include:

Associated cost of offshore wind power

The capital cost of offshore wind power projects is very high as compared to onshore wind power projects with the average capital cost of 2006 in Europe being around 2.1 million € per MW at 37.5 per cent capacity utilisation factors (CUF).

Economies of scale

Larger volumes of necessity, standardisation and possibility of adoption of technologies would provide economies of scale to the industry, thus reducing cost and encouraging investment. However the delay in execution of the Indo-Sri Lanka HVDC connectivity conceived in 1970 does not send encouraging signals to the industry.

Clearances Required

The necessary clearances essential to undertake the offshore wind farming are large and sometime difficult and time consuming which does not at time encourage the involvement of business houses.

Data for site identification of offshore wind power

The data required (wind resource map and the bathymetry data) for the calculation of offshore wind potential and identification of suitable sites is not available for Indian regions which make identifying the potential sites for offshore wind farming difficult.

12. Conclusion

This article provides an insight into a submarine power cable while differentiating it from a land power cable. The market drivers that support development of this technology and the opportunities and challenge that India offers to this industry have been discussed.

Though excessive details into the submarine power cable technology have not been discussed, an effort has been made to ensure that the reader is not left looking for answers in understanding the special features of a submarine power cables.

13. Acknowledgement

The author would like to thank the 'blind referee' for the valuable comments that have helped in making the paper more holistic and meaningful.

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Synopsis

Submarine power cables are specialised power cables that are used to transport electric current at high voltage below the surface of the water. Though these cables have been in use since the early 1800s, their use was primarily limited to transmitting electricity from conventional sources such as coal plants, either between countries or out to islands or oil platforms. Rising energy prices and concerns about climate change in the mid-2000s brought about a forced development of deep-water renewal energy sources (such as wind, wave, tide, etc.) which in turn renewed the interest in submarine power cables as there was a need to transmit the generated power to land from out-in-the-ocean renewal energy installations.

Though there are several issues (such as complex and unclear regulations, few consulting firms to conduct sea floor surveys and availability of cable-laying ships) that could impede the growth of submarine power cables, under-construction and future projects due to the increasing demand for renewal energy from offshore energy sources are ensuring that the necessary expansion, diversification, development and use of these cables cannot be stopped.

This present paper aims to provide an insight into a submarine power cable while differentiating it from a power cable used on land. The market drivers that support development of this technology and opportunities and challenges that India offers to this industry are discussed.

Key Words: Submarine power cables, Power cables, undersea cables, underwater cables, renewal energy.