EPR insulated cables for modern offshore systems

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FEATURES OF MODERN OFFSHORE SYSTEMS

In recent years the offshore industry is experiencing a marked technological development driven by challenging applications and need of overall system costs reduction.

Some of the following features are often involved in modern offshore systems:

- Longer distance to shore
- Deeper water areas
- Higher unit power

In order to design and operate those offshore systems economically and reliably it is sometimes necessary/beneficial to make use of:

- Floating platforms
- Higher system operating voltage
- Flexible cables
- Deeper power/umbilical cables

BACKGROUND ON EPR INSULATED CABLES

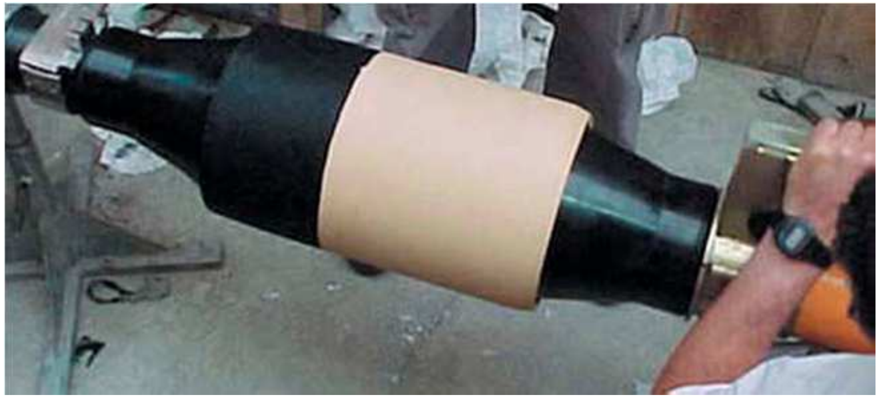
EPR insulated cables are **covered by the IEC standards and by many National Standards** and are currently used in several countries in power distribution and transmission networks at voltages up to 150 kV.

The first EPR insulated cables appeared in the market in the sixties and, during the following 40 years, they have achieved an **excellent track record** in terms of reliability.

Use of EPR insulated cables reached its peak during the seventies and eighties following the failures in service caused by water treeing phenomenon in the first generation of polyethylene insulated cables.

Nowadays use of EPR insulated cables is **preferred for applications requiring superior mechanical and thermal performances**, that include industrial, oil and gas, nuclear, submarine, and renewables systems **up to 150 kV**.

Most premoulded type accessories for EHVAC and HVDC cable systems are made of EPR.



EPR CHARACTERISTICS – PERFORMANCE IN WATER

During their history, **EPR insulated cables have been mainly characterized by their relatively immunity to the water treeing phenomenon**, providing reliable service for more than 40 years in a broad range of applications.

On the other hand **XLPE insulated cables have been found to be very sensitive to moisture owing to water treeing** phenomenon which decreases the electrical strength of the cable and eventually results in premature failure. Tree Retardant XLPE (TR-XLPE) materials have been developed to improve XLPE performance in wet environment by means of special fillers.

Scientific works provided evidence that **wet electrical ageing has differing effects on TR-XLPE and EPR dielectrics**.

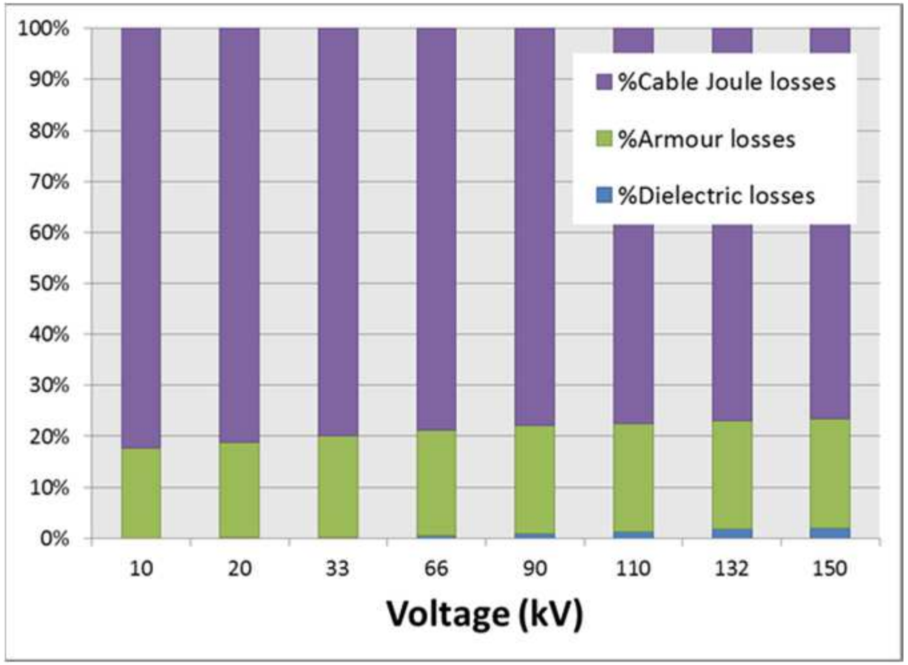
As well known, both EPR and TR-XLPE exhibit a drop of **ac strength** at the beginning of wet electrical ageing and the level off to acceptable values in the long term.

Although, electrical ageing in water has less impact on the **impulse strength** of EPR than TR-XLPE.

It should be noted that most of the failures in service of cables are due to impulse overvoltages, which also explains the high reliability of EPR insulation after wet electrical ageing.

EPR CHARACTERISTICS – DIELECTRIC LOSSES

Although the outstanding electrical, thermal and mechanical properties of EPR, its use as cable insulation is generally limited to voltages up to 170 kV owing to its dielectric loss factor which is slightly higher than some other high-voltage-grade insulation materials. On the other hand EPR is widely used as insulation in the premoulded joints up to 550 kV both AC and DC.



Percentage of cable losses, based on a 3 x 400 mm^2 Cu submarine cable with EPR insulation and steel wires armour (Calculation according to IEC 60287).

COMPARISON OF HEPR AND (unfilled) XLPE COMPOUNDS

Feature	HEPR	(Unfilled) XLPE
• Thermal Performance	Excellent Operating 105° C Overload 130° C	Good Operating 90° C Overload 105° C
• Mechanical characteristics	Good and uniform beyond 90° C	Good up to 90° C, poor beyond the crystal transition temperature
• Thermopressure Resistance	Excellent	Weak
• Dielectric strength		
Initial	Good	Excellent
After ageing	Good	Weak
• Resistance to partial discharges	Excellent	Weak
• Insensitiveness to water treeing	Excellent	Weak
• Dielectric loss	Moderate	Very moderate
• HF attenuation	Good	Weak
• Cable flexibility	Good also at low temperatures	Moderate
• Insulation shrinkage	Inexistent	Strong

NEW GENERATION ARRAY CABLES FOR OFFSHORE WINDFARMS

Current wind farms standard layout consists of an “inter-array” network that collects power from many wind mills at 33 kV typical nominal voltage.

- Moving the cable array system from 33 kV to 66 kV will provide significant cost reduction per transmitted MW
- A step up to 66 kV would require an extruded lead screen in case of unfilled XLPE insulation while this is not necessary in case of EPR insulation which can be operated in wet environment
- The avoidance of an extruded lead screen would yield a **much lighter and cost effective cable design** while providing a substantially better fatigue performance which is crucial for dynamic cables.
- “wet-design” is not a new concept for EPR insulated HV cables, with several systems worldwide successfully in operation since more than 40 years up to 72.5 kV class
- A similar design is being considered also with TR-XLPE insulation, however at the time of writing there is no operational experience with TR-XLPE beyond 33 kV

CABLES FOR HEAVY TORSION APPLICATIONS

Since the direction of the wind can be changed frequently, the nacelle containing the wind mill generator is subjected to rotation around its vertical axis and is submitting the cable connecting the nacelle to the fixed part of the structure to continuous mechanical strain and in particular to **heavy torsion**. Although no specific standards are available for these kinds of cables there are some requirements from wind mill generators manufacturers, which are mainly based on special fatigue tests under specific torsion and tension conditions.

Typically these cables are specified to resist to more than 5000 cycles at around 100 degree per meter torsion angle and temperature ranging from -40 °C to 90° C. After this torsion test the cable is submitted to electric type test as requested by relevant standards.

CABLES FOR HEAVY TORSION APPLICATIONS

Cables designed for this application are typically composed by **flexible** copper conductors, EPR insulation, semiconducting layers, grounding conductor and a rubber outer sheath.

Moreover, cables installed in these structures are specified to meet some additional requirements in terms of low emission of smoke and toxic/corrosive gasses and non-propagation of fire. Due to the application in proximity of moving mechanical apparatus some resistance to oil is also required.

OIL & GAS

EPR insulation is extensively used in Oil & Gas applications, including offshore ones.

Umbilical cables, including electro-hydraulic ones, are used in many applications, including subsea installations, fixed and floating platforms.

They have been installed at **water depths in excess of 2500 meters** in both static and dynamic applications. These umbilical cables include the following typical functions:

- High-pressure hydraulic control hoses;
- High-pressure chemical injection hoses;
- Electric cable
- Optical fibre control cores

Cables feeding **Electrical Submersible Pumps** (ESPs) are designed to withstand high temperatures and harsh environments. EPR insulated cables are conveniently designed to withstand very high temperature in presence of hydrocarbons muds and gasses that are present in the oil extraction areas.

DYNAMIC MV AND HV SUBMARINE CABLES

The realization of wind farms in very deep waters as well as other marine renewable energy systems will require more and more dynamic cables that have to withstand the repetitive **dynamic forces** caused by marine wave, tides and currents. MV and HV submarine cables intended for these applications require superior fatigue resistance and mechanical performances.
The associated resistance to water and to any mechanical stress makes **EPR the most suitable insulation material** for this kind of application.

46 kV submarine dynamic cable with EPR insulation

ULTRA BENDABLE MV AND HV CABLES

Ultra-bendable “**Feltoflex**” medium and high voltage cables have been developed to be installed and operated in a wide range of ambient temperatures (-50/+40° C) and provided with resistance to fatigue, ozone, UV, Oil and flame propagation. High flexibility and very small bending radii both in mobile and fixed installation are some additional outstanding features.

The main features of Feltoflex cables are:

- Ensure **easy installation** with small bending radii. (also cold laying)
- Suitable to **withstand dynamic forces**

Both of these conditions may be faced in applications like offshore windfarms and Oil & Gas platforms.

ULTRA BENDABLE MV AND HV CABLES

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ULTRA BENDABLE MV AND HV CABLES

The cable design includes highly flexible copper conductor, EPR insulation, copper braid screen and a cross-linked rubber outer sheath.
This HV cable has been **successfully type tested** according to IEC 60840 standard, including some specific dynamic tests.

EXTENDED BENDING TEST/ APPLICATION TEST

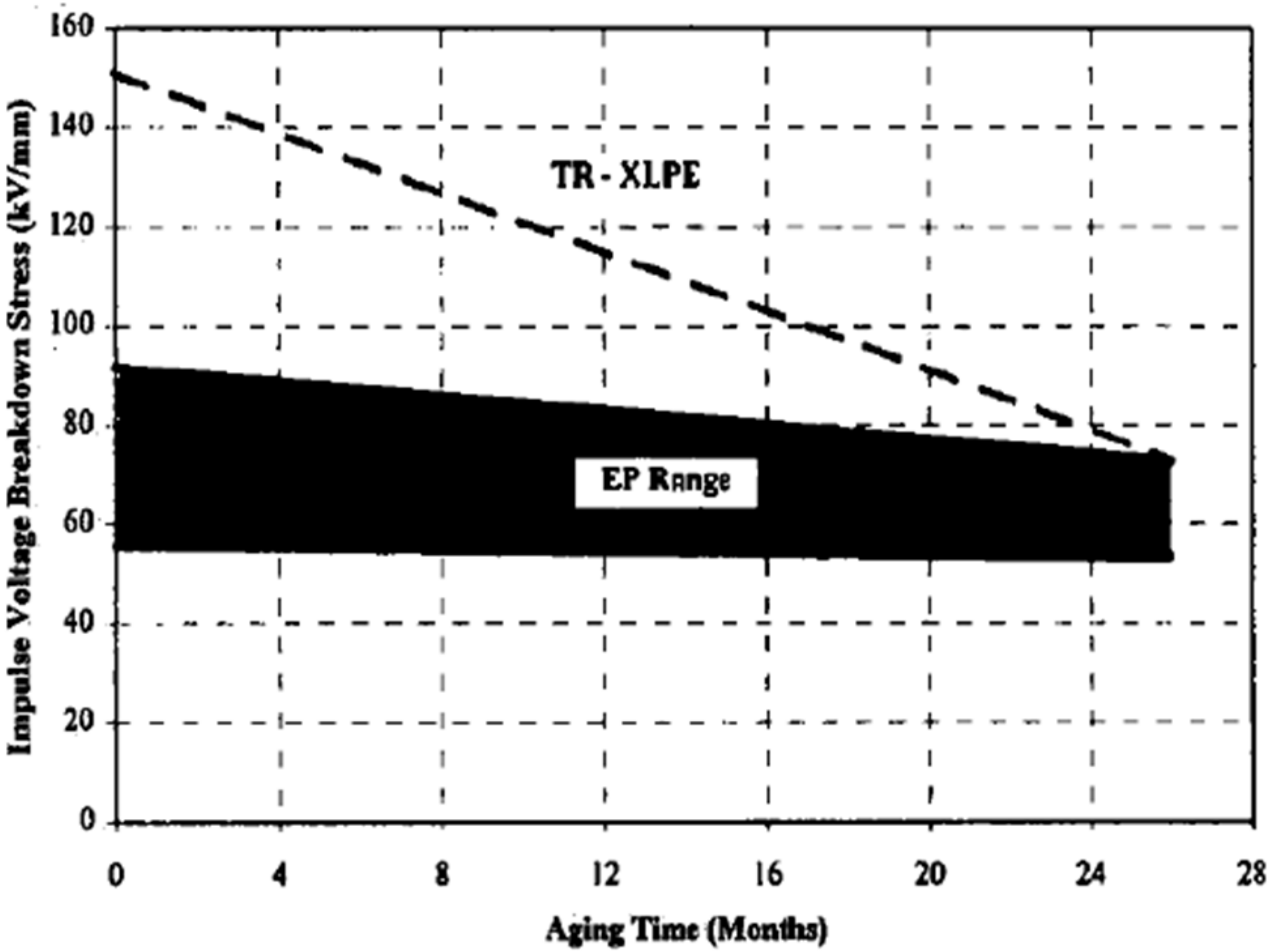
132 kV 1x240 mm^2 Cu
Transport to bending test equipment

No of cycles: up to 142.255
Result: no wire breaks
Samples:
1x240 mm^2 Cu 132 kV
1x800 mm^2 Cu 155 kV

CONCLUSIONS

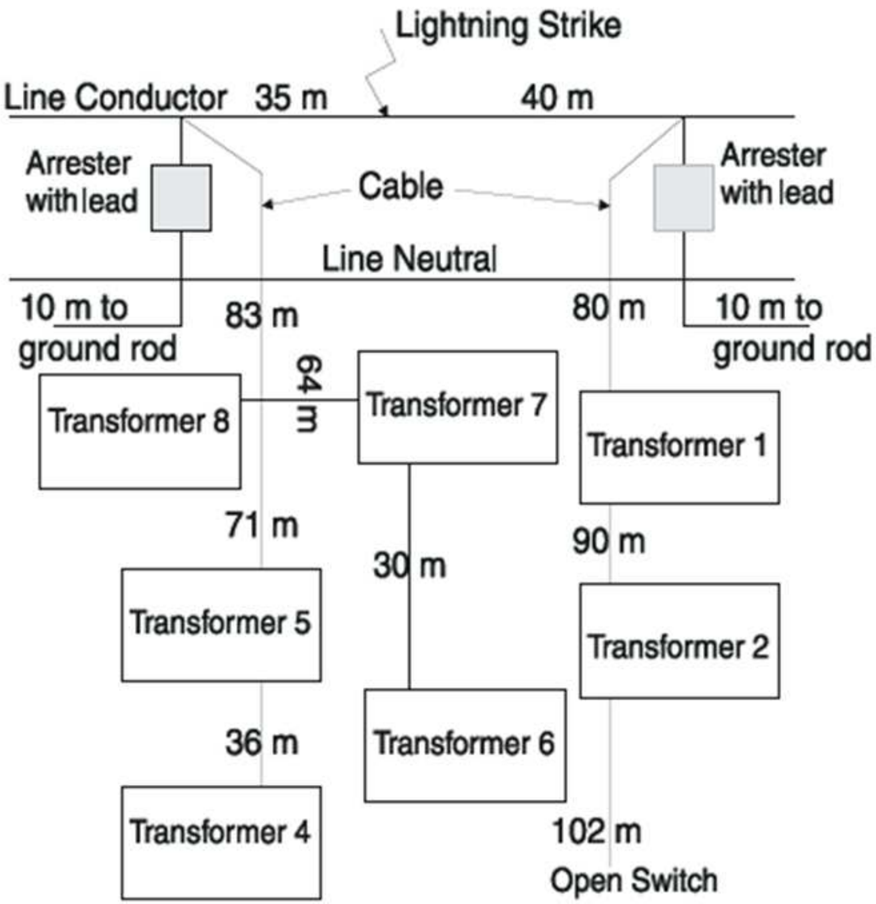
- EPR insulation is a mature technology.
- EPR insulated cables are preferred for applications requiring superior mechanical and thermal performances, which include industrial, oil and gas, nuclear, submarine, and renewables systems up to 170 kV.
- Most premoulded type accessories for EHVAC and HVDC cable systems are also made of EPR.
- Thanks to its outstanding electrical performance in the wet environment and superior thermo-mechanical characteristics, EPR insulated cables are particularly suited for modern offshore systems.

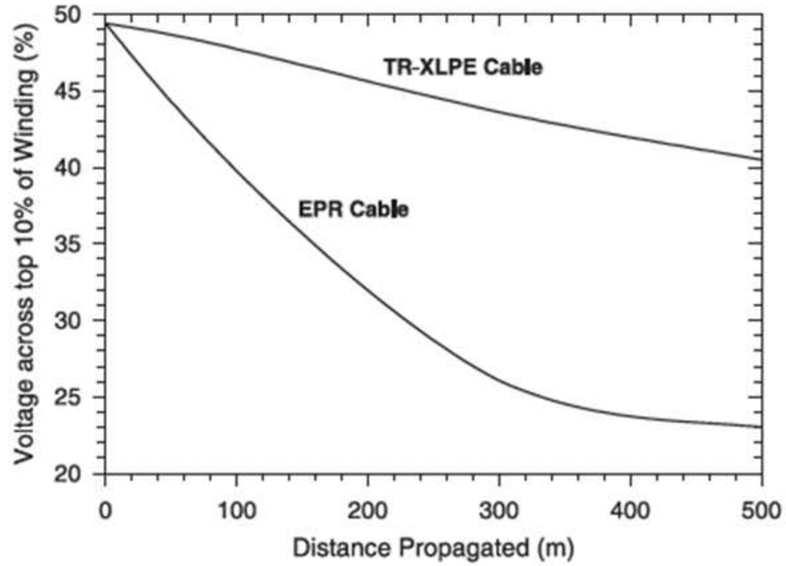
THE IMPULSE STRENGTH OF EPR AND TR-XLPE

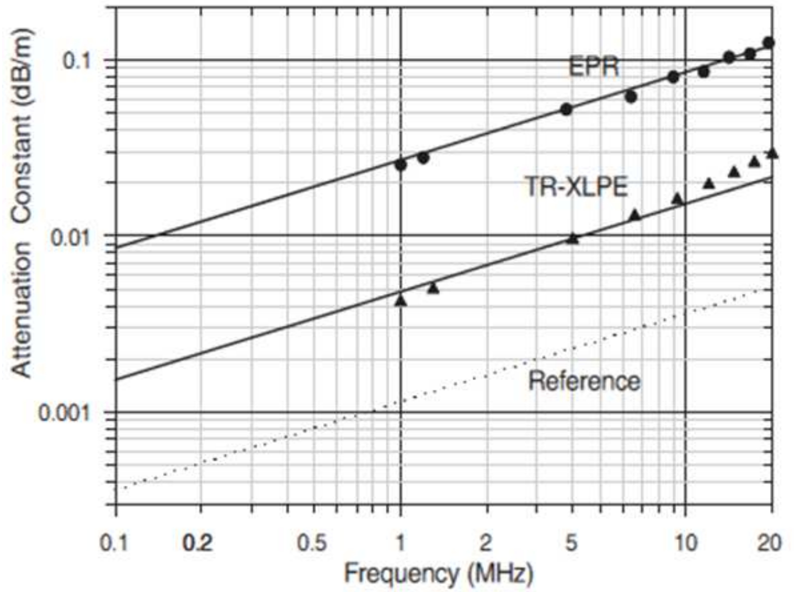


Source: Katz, C., B. Fryszczyn, A.M. Regan, W.A. Banker, and B.S. Bernstein. "Field Monitoring of Parameters and Testing of EP and TR-XLPE Distribution Cables". IEEE Trans. PD, Vol. 14, No. 3, July 1999. pp. 679-684.

HF CABLE ATTENUATION OF EPR AND TR-XLPE







Source: L. Zhou and S. Boggs "*Effect of High Frequency Cable Attenuation on Lighting-Induced Overvoltages at Transformers*"