GSJ: Volume 10, Issue 3, March 2022, Online: ISSN 2320-9186
www.globalscientificjournal.com

High Performance Thermoplastic Elastomer (HPTE) HV/MV Cables instead of XLPE HV/MV Cables- A trend towards Circular Economy

Raji Johnson Chacko B Tech. MBA. PMP

Research Student (IIC University of TECHNOLOGY, Cambodia)

Abstract

High-purity plastics must be used to insulate cables running at medium, high, and extra-high voltages. XLPE (cross-linkable polyethylene) is most commonly used to insulate cables. The cross-linking of the XLPE, the cable passes through a continuous vulcanization tube (CV-tube), where it is exposed to high temperatures. In the manufacture of these types of cables, the CV tube is filled with nitrogen and operated at a pressure of 10 bar. To further process the cable, such as applying a screen and outer sheaths, degassing is necessary, which can take up to ten days. Normally, the line is built as a CCV or VCV line (Catenary Continuous Vulcanization or Vertical Continuous Vulcanization). Although the technology has been in use for decades, it is expensive to build and maintain.

In addition, there is another method on the advance that utilizes Polypropylene-based High Performance Thermoplastic Elastomer (HPTE) as insulation material. The new technology has been further invented by Prysmian and is published as the "P-LASER" technology.

High-Performance Thermoplastic Elastomer (HPTE) is a new thermoplastic insulating compound developed by Prysmian and it gone to a breakthrough in the field of MV and HV power cables. In spite of being polypropylene-based, these materials have excellent electrical , thermomechanical properties, when comparable or even very superior to those of XLPE, and are flexible and soft. Changing the crystallinity and other physical-chemical properties of HPTE can tailor its physicochemical properties to suit particular applications. Many years of research have led to the development of a proprietary special compound called HPTE within the Milan central R&D laboratories. In spite of numerous unsuccessful attempts to use polypropylene as insulation for high and medium voltage cables, it is now possible to develop a material that combines thermoelectricity and thermomechanical properties of a cross-linked polyethylene. The tensile strength of HPTE insulation is 30-35 MPa, its elongation at break is 700-800%, its

modulus of elasticity is 200-300 MPa, and its thermopressure is 95% at 130°C. Because of its flexibility and crystallinity, this compound guarantees thermomechanical properties at temperatures useful for medium and high voltage cable applications. HPTE is an innovative insulating material that doesn't require degassing treatments, doesn't generate amber, and can be filtered at high levels without degradation. As well as being recyclable, it does not emit methane or any other by-products during manufacture. The HPTE insulating compound and the thermoplastic semiconductive materials developed especially for this application are the key components of P-Laser technology, a very innovative method for producing medium voltage cables. As a result of the lack of degassing, it is in fact possible to produce the entire cable in one step, starting from the conductor and giving in one shot the finished cable. In the current R&D effort, HV cables based on this innovative insulating material are being

. Electrical and thermo-mechanical properties of the material are comparable, and sometimes superior to those of XLPE. There is no need for a cross-linking section or a degassing procedure in the HPTE. Thus, the complete cable can be manufactured in an inline process, where even the screening and outer sheathing can be applied in one step.

Regardless of the approach adopted, the dielectric strength of XLPE and HPTE remains at a high level and needs to be ensured. Cleaning the insulating material plays an important role here. Here we see the importance of the advanced purification inspection and sorting system in action.

During inspection and sorting system that detects contamination inside and on the pellets such as metallic or organic contamination, color variations, agglomerates, cross-contamination and foreign pellets. The highest detection probability for all kinds of contamination is made possible with a combination of X-ray and optical camera technologies. Therefore, the XLPE or HPTE material quality, and consequently the production process, is optimized and costs are reduced.

Brief history of HPTE cable

2002/2003. The development of the HPTE material were first commenced studies in Italy at the Prysmian R&D laboratory where MV cable prototypes were produced and evaluated in terms of physical, chemical and electrical parameters. After these first promising preliminary tests, the capital expense for production of HPTE insulated cable cores in Pignataro Prysmian factory (Italy – Caserta) was approved.

During 2004, HPTE's insulated production machinery was installed and pre-commissioned successfully.

HPTE development [7]

2003	Start of development activity in R&D, Milan Laboratory
2005	Prototype production in Pignataro Maggiore (Italy)
2006	Installation and plug-in in Italy for triplex 185 mm² 12/20 kV in Enel electrical network
2007	Installation and plug-in in The Netherlands for triplex solid 240 mm² 6/10 kV in Nuon/Liander network
2008	National approval release according to CEI 20-86 standard (Italy)
2009	Production of 3,000 km core achieved in Pignataro factory to support Italian customers
2010	Production of airbag cable with P-Laser technology. 7 layers extrusion in one single production step
2011	Extension of product range up to 30 kV for Wind projects
2012	Incorporation in the European standard for MV cables, Cenelec HD 620, of Italian and Dutch cable constructions with high-performance thermoplastic insulation
2013	Installation and plug in of 150 kV AC prototype in Italian Transmission network
2014	Long term test of 150 kV AC system
2015	PQ test for 320 kV DC 90 °C
2016	Type tests for 525 and 600 kV HVDC systems
2018	Qualification PQT HVDC for P-Laser 525 kV Cenelec HD620 compendia has been released for review; the new thermoplastic material will be included as standard
2019	P-Laser reaches 50,000 km production milestone

Photo 1 'HPTE insulated' 7-step single production line at Pignataro, Italy'

FURTHER DEVELOPMENT

The installation of the HPTE production line at Prysmian Delft in 2011 resulted in the type test of two cable types: the 6/10kV 1x240mm2 solid aluminium HPTE insulated cable for the 500Hz long-duration test and a 18/30kV 1x800 mm2 solid aluminium single core cable for a complete type test including compatibility test with Prysmian MV accessories, electrical test program in accordance with ENELEC HD620 S2, part 10, section J . Since above standards do not include HPTE insulation material, Prysmian submitted a proposal for an update of the HD620 to the Dutch National Standardization Committee NEC20. This proposal includes HTPE insulation for 3 and 1core MV cables and follows the XLPE standard in detail, including working temperatures and short circuit temperature. The only difference with the XLPE type test program is the adoption of a pressure test at high temperature on the HTPE core instead of the hot-set test. The adoption of the XLPE requirements for HTPE insulation underlines that the characteristics of HTPE material are similar or better than that the characteristics of XLPE insulated material. Prysmian expects a further growth of this environmental friendly insulation technique in the years to come.

Prysman P laser Technology : P-Laser concept:

Zero degassing technology :P-Laser MV cables are being manufactured on a single and uninterrupted production line, from production of conductor to jacketing, without crosslinking process and degassing treatments during production .
This is made feasible by a special type of insulating compound, called HPTE – Prysmian proprietary High Performance Thermoplastic Elastomer characterized by flexibility and good thermomechanical properties together with excellent electrical performances

P-Laser insulating material properties HPTE, which is called - High Performance Thermoplastic Elastomer is a polypropylene based compound, developed for P-Laser cables. The mechanical properties of this insulating compound HTPE are characterized by the values reported in Tab I:

TABLE I
HPTE mechanical properties

Tensile strength	30-35 MPa
Modulus of elasticity	300 MPa
Elongation at break	700-800%
Thermopressure at 130°C	95%

- These data show that P-Laser insulating compound, even though polypropylene-based, is characterized by exceptionally good flexibility, elongation and tensile strength at break together with high thermo-pressure. In general view ,all together thermoplastic polyolefins has lack of these properties
- For low density polyethylene, as an example, needs to be crosslinked for production of cables which satisfy thermo-mechanical properties at 90°C as operating temperature and at 130°C as overload condition.

  Therefore, thermopressure at 130°C was identified as an alternative test to hot set, aimed at selecting the best formulations for P-Laser insulation

Fig. 2 Electrical testing of cables

TABLE II
AC electrical breakdown strength of EFI models

HPTE	125-135 kV/mm
XLPE	125-130 kV/mm

These data show that P-Laser insulating compound, even though polypropylene-based, is characterized by exceptionally good flexibility, elongation and tensile strength at break together with high thermo-pressure. In general view ,all together thermoplastic polyolefins has lack of these properties .For low density polyethylene, as an example, needs to be crosslinked for production of cables which satisfy thermo-mechanical properties at 90°C as operating temperature and at 130°C as overload condition.

Therefore, thermopressure at 130°C was identified as an alternative test to hot set, aimed at selecting the best formulations for P-Laser insulation

HPTE was developed through a series of various tests of electrical characterization. The Electrical breakdown strength data of HPTE insulating compounds were obtained by manufacturing and testing EFI models and various model cables

HPTE was developed through a series of various tests of electrical characterization. The Electrical breakdown strength data of HPTE insulating compounds were obtained by manufacturing and testing EFI models and various model cables

As a result, HPTE has excellent mechanical properties up to high temperatures and excellent electrical properties.

- **<u>Advantages of P-Laser insulating materials</u>**

  Ambers are a well-known problem during the production of XLPE cables. These are created by material stagnation, if any, in the extruder, in the head and especially in the filter packs. The scorch phenomena responsible for amber formation limit the amount of cross linkable material that can be extruded during a production campaign, and they must be controlled carefully in order to ensure that cables have a high quality. Due to the thermoelectricity of HPTE insulation, ambers are totally absent in P-Laser cables, with great advantages for cable reliability. Fig. 3 Ambers in XLPE Fig. 4 Treeing from a contaminant Another advantage of HPTE insulation is related to material filtration. While there are some limitations in filtering cross linkable polyethylene due to the above discussed scorch phenomenon, HPTE insulating compound can be filtered more thoroughly, providing advantages in terms of material cleanliness. An effective filtration system is important, because the presence of contaminating particles in the cable insulation layer negatively affects electrical performance and, in general, cable reliability.

Fig. 3 Ambers in XLPE

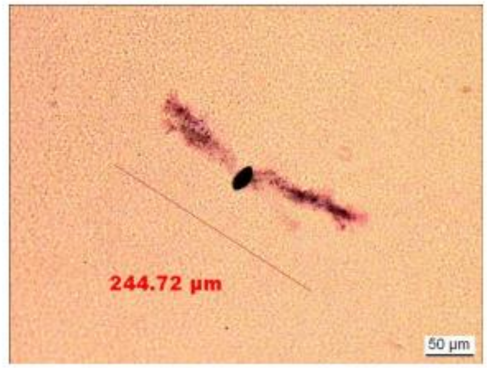

Fig. 4 Treeing from a contaminant

Figure 4 shows a typical effect of a contaminant in the insulation layer of a power cable, that is treeing phenomena. A high-level homogeneity of HPTE, as shown in the micrography reported in Fig. 5, has been reached as a result of using the proper mixing apparatus

Fig. 5 Optical micrography of P-Laser MV insulation

Fig. 6 Testing of SC screen on cables

The high electrical properties of HPTE are due to material homogeneity. A further advantage of HPTE material is that no degassing treatment is required since there is no crosslinking process.

PLaser's zero degassing technology permits the manufacturing of power cables without the need for extensive and long-lasting thermal treatments to remove crosslinking by-products.

Furthermore, since HPTE isn't just a formulation, but rather a technology that relates to the insulation of power cables, these materials open up new possibilities for several new applications. As a result of altering intrinsic material properties, it is possible for development and optimize specific compounds, such as the insulation for HVAC or HVDC power cables, without worrying about residual byproducts. Thus, HPTE formulations can be tailored according to market segments.

- **Semiconductive compounds for P-laser Cables.**

  The development of this innovative thermoplastic MV cable required a specific study focused to guarantee adequate conductor and insulation semiconductive screens, in order to control the electric field around the cable. Using a consolidated know how in formulating, developing and producing semiconductive compounds for cables and, for P-laser project, dedicated compounds have been developed. These are able to guarantee the required thermo-mechanical performances, smoothness and compatibility with the new dielectric materials used for the insulation; for this purpose, a specific production process has been also developed.

  Semiconductive compounds for P-Laser cables are qualified according to internal testing protocols. Data reported in Tab. III show the experimental conditions that were selected for HPTE semiconductive compound testing.

TABLE III
Internal qualification protocol of semiconductive compounds

Volume Resistivity f(T)	from room temperature up to 130°C
Thermal cycles	90 days 8h at 130°C; 16 h at room temp.
Bending cycles	up to 20 cycles
Stability in water at 90°C	up to 90 days
Tan delta f(T)	from room temperature up to 90°C

No significant increase of volume resistivity of P-Laser semiconductive compounds were evidenced due to mechanical bending, thermal cycles and water absorption

- **TECHNOLOGY A. One shot production line**

P-Laser production line is an innovative plant, designed for manufacturing medium voltage power cables.

Cables are produced by an uninterrupted process that comprises two main areas: insulation line and protection line, as shown in Figure 7

Insulation line is based on triple extrusion for the manufacturing of internal semiconductive layer, insulation and external semiconductive layer. HPTE insulating material is manufactured internally, specifically for this purpose. Unlike XLPE cables, that require a catenary line with a pressurized vulcanization vessel, P-Laser cables are manufactured with HPTE, therefore do not need any crosslinking step.

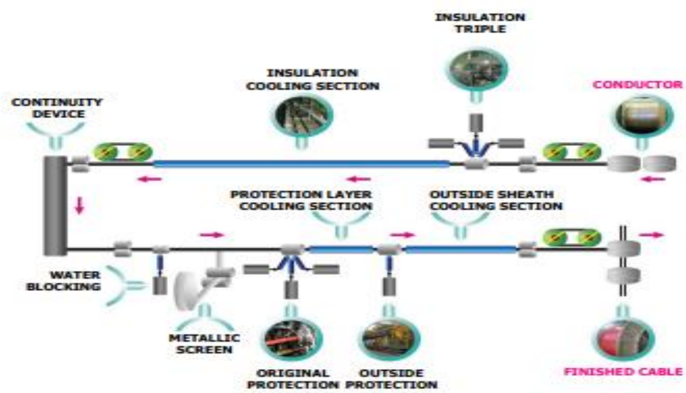

Fig. 7 Layout of P-Laser MV production line

This is evidenced in Fig. 7, showing that insulation and semiconductive extruders are installed directly on the same floor of the whole line. Immediately downstream of these extruders it is possible to observe in the picture the cooling system, since there is no vulcanization.

Fig. 8 No vulcanization line: cooling system device is installed after triple extrusion.

P-Laser cables are not subjected to degassing treatments, since this process is not accompanied by methane emission.

Cables can go therefore directly to the application of protection layers just in one shot, as evidenced in Fig. 7.

The protection layer usually comprises water blocking tapes, an electrical shield and an external polymeric sheath. However P-Laser MV production line is very versatile and allows introducing in the manufacturing program also an expanded polymeric layer for further mechanical protection.

Fig. 9 One shot production: from conductor to finished cable without any interruption

Figure 9 shows one of the most relevant aspects of P-Laser MV production line of this facility: on the right hand side it is possible to see the drum of conductor, while on the left hand side the finished cable is collected.
The whole production is carried out in one shot, without any interruption and without any intermediate treatment (degassing or steam curing).

Cable main characteristics and benefits

P-Laser cables main properties are summarized in Table IV. Good thermo-mechanical characteristics of HPTE are reflected in the properties of P-Laser cables that, in spite of thermoelectricity of materials, show equivalent, or even better, properties with respect to those of XLPE cables. The excellent electrical performances of P-Laser cables are evidenced by high lightning impulse breakdown strength at 95°C, ranging from 120 kV/mm to 130 kV/mm. Also dielectric losses of currently used HPTE are very low, with a value of 3 x 10-4, that is fully satisfying for MV applications but it is promising also in view of the development of HVAC P-Laser power cables. P-Laser cables are qualified according to CEI Italian Standard [8]. Benefits of P-Laser cables are summarized in Table V. P-Laser technology offers a better service to customers, such as shorter delivery times, and improved cable performances, in particular high reliability and better thermo-mechanical properties. The on line protection of cable core is also a valuable aspect of P-Laser MV production process, since any damages of cables during drums movement is avoided. Cable cores are directly protected by sheaths thanks to continuous production line. More than 3000 km of P-Laser MV cable were produced up to now, as a confirmation of market response to this new technology.

Environmental impact

P-Laser technology offers an efficient manufacturing process, characterized by lower power consumption, with energetic benefits. The absence of any degassing treatments avoids emissions in atmosphere, with a lower environmental impact of the whole process. Moreover, P-Laser production of MV power cables requires a compact manufacturing site, with lower soil occupation. Full recyclability of polymeric materials is also a valuable property of P-Laser technology.

CONCLUSION

P-Laser is a breakthrough in power cable systems, based on material, process and product innovation. The insulating material is a new thermoplastic compound, High Performance Thermoplastic Elastomer (HPTE) that was developed in Prysmian together with semiconductive compounds. P-Laser cable, based on HPTE, is produced in one shot process, including insulation and protection phases, from the conductor to the finished cable. P-Laser is now a commercial product with more than 3000 km of cable produced and sold up to now to different utilities.

References :

:Applications_of_HPTE_insulated_cables_systems_GRIDABLE_Giovanni_Mazzanti.pdf
:http://www.cired.net/publications/cired2011/part1/papers/CIRED2011_0345_final.pdf