Development and high temperature qualification of innovative 320 kV DC cable with superiorly stable insulation system

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ABSTRACT

P-Laser technology, based on use of thermoplastic materials as insulation of power cables, is a reality in the field of MV cables and is being extended to HV systems.

As one of the key features of the new insulation system is the absence of chemical reactions and consequently of by-products produced during the manufacturing process, the adoption of HPTE materials for HVDC cables looks particularly promising.

An activity was started in order to evaluate the properties of HPTE insulation on model cables, then extended to full-size prototype; finally a PQT loop has been set-up and is in advanced phase of execution.

KEYWORDS

HVDC, thermoplastic, insulation, PP, HPTE, degassing.

INTRODUCTION

The big demand for transmission of high electrical power in long distances has brought to the fast and successful development in the recent years of HVDC Transmission Systems at increasingly current and voltage levels. 320 kV DC cable systems have been developed, qualified and installed in numerous cases and the way to increase voltage levels and conductor sizes looks to be still well far from the finish line.

The big majority of the HVDC systems today qualified is based on the use of XLPE insulated cables, which performances are very well known and appreciated as far as HVAC systems are concerned as well. In the case of HVDC XLPE insulated cable systems, big accent must be given to the necessity of degassing the insulation material after crosslinking, as the presence of the by-products can play a very negative role in terms of insulation electrical resistivity and of space charge accumulation and consequently of the electrical properties in DC of the cable itself. In this sense very long degassing times for the insulated cores is the solution commonly adopted for reducing the effect of the by-products and stabilizing the electrical properties of the cable to values affordable at the high electrical gradients of the modern HVDC cable systems. The degassing times practically applied for HVDC cables are indeed even significantly higher than the times applied to HV and EHV cables for use in AC systems.

In this situation it looks very attractive to develop a cable system that, without penalizing the general performances of the transmission system (namely the maximum current transmissible), doesn't require a chemical crosslinking treatment during the production process, aimed to create the molecular interconnections in the polymeric insulation structure; and that consequently could be characterized by a changeless insulation system with steady and abiding electrical properties.

Recently developed cables with P-Laser technology, based on fully thermoplastic PP insulation with enhanced thermo-mechanical properties, provides nowadays an undisputable track record in Italian Power Distribution network, reinforced by the recent installation and plug–in of the first 150 kV cable system in Italian Transmission network (Lacchiarella project); for this reason P-Laser takes the form of a veritable starting point for the development of the above mentioned superiorly stable HVDC insulation systems.

The paper describes the activity performed in terms of development of the new insulation for HVDC cables based on P-Laser technology, tests on model cables, production of prototype for 320 kV insulation class, electrical assessment of the prototype and subsequent PQT performed at 90 °C on a complete system, based on Cigrè recommendation TB 496 [1].

PERFORMANCES AND POTENTIAL LIMITS OF EXISTING CROSSLINKED INSULATIONS FOR HVDC CABLES

The use of solid insulation is an attractive solution for HVDC cables systems. There is a list of advantages offered by polymeric insulation in comparison to traditional laminated and the limit for service conditions, likely the most important, was solved thanks to the new VSC converters.

However, space charges formation in XLPE under DC stress remains one of the main concerns for the use of this material in the HVDC field. Indeed, the space charges build up and distribution in the dielectric material change, as widely known, the electric field distribution. As a consequence, local electrical stress increase can modify the electric field distribution inside the insulating material, and may jeopardize the long time reliability of the cable.

Space charges can be electronic or ionic and can be injected from the semiconducting shield used in DC power cables design or can be created by residues of peroxide dissociation under the action of the electric field.

Even after intensive and longtime degassing treatments, the XLPE forming the insulation layer may contain a not-negligible amount of by-products, enough to affect final material resistivity.

According to recent experiences, the amount of residual by-products is an important parameter but it is not the only one that has to be considered. Distribution of such