

## Optimization of the degassing process of extruded crosslinked EHVDC cables

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### ABSTRACT

*This paper will show the potential of using a simulated model to predict the degassing behavior of full scale HVDC cables compare with analytical data. The study has been carried out using two different XLPE insulation systems using a 525 kV DC cable design, which has been produced on a vertical batch vulcanization line (VBV) and degassed under optimal conditions in order to verify the simulations. It will be shown that by combining analytical measurement with a simulated model it is possible for the cable manufacturer to optimize the degassing time for their specific XLPE DC cable designs and degassing conditions.*

### KEYWORDS

XLPE, EHVDC, insulation system, degassing, modelling, GC, HPLC, cumyl alcohol, acetophenone, methane

### INTRODUCTION

Extruded XLPE HVDC cable systems have been in operation for more than 20 years. The extruded HVDC cables in service today are all made of crosslinked polyethylene; mainly non-filled XLPE. These HVDC cables have been produced in different vulcanization set-ups where vertical continuous vulcanization (VCV) or catenary continuous vulcanization (CCV) are the most common. During the vulcanization process, the polymer is crosslinked by applying heat in high pressure tubes for a certain time and followed by a cooling process.

During the crosslinking process the peroxide is decomposed and forms decomposition products (PDPs) that are either gaseous or liquid at room temperature. The standard procedure to reduce these decomposition products is to "degas" i.e. heat up the cable core at an elevated temperature e.g., 70°C by using heated air in either larger baskets or on drums in separate chambers where the degassing process occurs [1].

This paper will discuss how to predict the degassing time for HVDC cables with a developed simulation model. This model is developed to make it easier for the cable manufacturer to decide how long time a certain cable design will need to be degassed under specific conditions; such as temperature, to remove the decomposition products.

### THEORY - DEGASSING PROCESS

The distribution and the concentration of the different generated PDPs as described earlier can vary with production parameters and cable design.

From history, still viable today, is that the methane formed in the peroxide decomposition reaction needs to be

evaporated in order to have a safe handling of the cables. This is true both during the installation and in service as this can form gas pockets either in between different surfaces such as joints, terminations or at the cable screen. This is the main reason for degassing process regarding AC cables i.e. to reduce the amount to safe levels of methane below 30-50 ppm, as stated in Andrews et al [2].

Several papers have earlier discussed the degassing process and the impact it has on cables [1-4] where the latter reference is mostly focused on the liquid decomposition products. It has been seen that the efficiency of the degassing process is dependent on several factors such as proximity to air inlet, hot surfaces and air flow plays a role for the degassing results.

In contrast to AC cables the degassing process for HVDC cables aims also to reduce the liquid decomposition products such as cumyl alcohol and acetophenone, which are seen as contributors to space charge formations and leakage current increase [5, 6] resulting in they need to be controlled. Depending on type of application and design of the cable, different degassing times and temperatures might be needed. There is a significant difference between methane and the other peroxide decomposition products. The methane is gaseous and the diffusion rate through polymeric materials is faster than for cumyl alcohol and acetophenone and as their boiling points are higher than for methane, they will also evaporate much slower from the surface of the cable. Hence, it is easier to reduce the amount of methane compared to acetophenone and cumyl alcohol. As described in Jarvid et al [1], the degassing of peroxide decomposition products can be seen as three separate steps: (i) the diffusion through the polymer for the PDPs, (ii) evaporation at the surface of the cable where the boiling point and partial pressures have a role, (iii) the transport away from the surface which is highly dependent on airflow and cable surrounding when degassing.

### EXPERIMENTAL STUDY

The experimental study is performed in optimal conditions and actual degassing process of long production lengths of HVDC cores may deviate slightly depending on factors such as curing and degassing conditions.

#### Model cable prototype design

In this study two full size EHVDC cable prototypes (525 kV) with a 2500 mm<sup>2</sup> aluminium solid conductor with 26 mm insulation, 2.0 mm inner semiconductive layer and 1.5 mm outer semiconductive layer thicknesses were produced. These cables were produced in a vertical batch vulcanizing (VBV) line with full-size triple extrusion set-up. The cables were manufactured with a recipe which is optimized for the chosen materials and line configuration, see Fig. 1.