Development Process of extruded HVDC cable systems

Dominik **HÄRING**, Gero **SCHRÖDER,** Andreas **WEINLEIN**, Axel **BOSSMANN** Südkabel GmbH, (Germany)
dominik.haering@suedkabel.com, gero.schroeder@suedkabel.com, andreas.weinlein@suedkabel.com, axel.bossmann@suedkabel.com

ABSTRACT

Extruded HVAC cable systems up to 500 kV have been developed successfully in the past decades and several years of operating experience are available. Because of increasing demand in power and the ability to transmit electrical energy over long distances, HVDC cable systems become more important. However, due to DC specific influences on the insulating systems of the cable and accessories, a detailed consideration and evaluation of these effects must be taken into account during the development process of extruded HVDC cables and their accessories.

This paper addresses the main influences of DC stress on the components of HVDC cable systems. Fundamental aspects regarding the interface between cable and accessory will be discussed. The paper describes the empiric consideration of an extruded XLPE HVDC cable test system beginning with a model system to an HVDC cable test system with a voltage level of 150 kV from the perspective of a cable system manufacturer.

KEYWORDS

HVDC, cable system, XLPE, joint, testing

INTRODUCTION

The increasing power demand worldwide requires the transmission of electrical energy over long distances. Extruded HVAC cable systems have been developed successfully in the past decades and therefore many years of operating experience are available as mentioned in references [1] and [2]. However, based on the capacitive load and the eddy current losses, especially in large conductor sizes, the operation range to longer system lengths of HVAC cable systems is limited.

For this reason HVDC cable systems become more important. While oil filled HVDC cables are a well-known technology for more than 50 years, extruded HVDC cable systems have been developed and commercially introduced in the last decade [3, 5]. Actually the work on a new standard for extruded HVDC cable systems is in progress [9]. Based on the low level of experience in this area and in order to deliver a reliable HVDC cable system, detailed development actions are necessary to understand the DC specific effects on extruded cables and their accessories.

The main DC specific effects to extruded HVDC cable systems can be addressed as follows:

- Space charge accumulation in the insulation and interfaces
- Resistive field distribution
- Thermal dependence of insulation materials

According to this, it can be concluded, that the following aspects must be taken into account during the development process of an HVDC cable system:

- Space charge behaviour in the insulation materials and interfaces
- Conductivities of the insulation materials and their temperature and field strength dependence
- DC and impulse breakdown strength of the cable and accessories

With these aspects in mind, basic considerations on an extruded HVDC cable test system, including an extruded cable and a prefabricated joint, has been done and tested for VSC (voltage source converter) applications. This paper provides an overview of the systematic approach of such a HVDC cable test system, while the main aspects will be discussed from the perspective of a cable system manufacturer.

GENERAL DEVELOPMENT ASPECTS OF HVDC CABLE SYSTEMS

Since the successful development of extruded HVAC cable systems up to 500 kV, a high level of experience regarding operation behaviour of the components is available. In the case of extruded HVDC cable systems, essential differences in the operation behaviour compared to HVAC systems must be considered. The following section addresses those main effects on an HVDC cable system under the applied DC conditions.

Electric field distribution under DC conditions

The electric field distribution in a conventional AC cable can be easily expressed in the following equation [1]:

$$E(r) = \frac{U}{r \cdot \ln\left(\frac{r_o}{r_i}\right)} \qquad [1]$$

E(r) stands for the electric field strength, U is the voltage, r_o the radius of outer insulation screen, and r_i the radius of the inner insulation screen.

This behaviour is totally different and more complicated under DC conditions. As opposed to the AC field distribution, the field distribution in a DC cable is controlled by the resistivity of the insulation material. Furthermore, the resistivity of an insulation material is strongly dependent on the temperature and the applied electric field. The link between resistivity σ_0 and temperature respective to the electric field has been published in various mathematical expressions. One of the main mathematical expressions from [4] can be stated in equation [2] as: