Application of extruded MVAC Cables for DC Power Transmission

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ABSTRACT

MVDC is an option for enhancing transfer capacity of AC lines (cable, overhead line) and providing improved power control at distribution networks. There are several advantages for network operation by converting existing medium voltage AC cable systems to DC operation. Different technical aspects need to be considered for refurbishing and the application of MVAC cable systems for MVDC. Investigations with respect to CIGRE TB 496 and IEC 62895 show that a 12/20 kV XLPE insulated AC cable system might pass the prequalification test for an extruded 55 kV MVDC cable system.

KEYWORDS

MVDC, extruded DC cables, MVAC XLPE cables, PQ test, CIGRE TB 496, IEC 62895

INTRODUCTION

Nowadays, transmission grids worldwide are based on Alternating Current (AC), which is well established but comes along with some restrictions. Through the need of reactive power e.g. the maximum transmission length of cables is limited. In addition to that, dielectric losses as well as the skin effect influence the efficiency of power transmission. Due to these restrictions, the use of Direct Current (DC) is beneficial in terms of efficiency and transmission length. Power transmission with High-Voltage Direct Current (HVDC) will help to overcome challenges related to shortage of transmission capacity [1].

However, also Medium-Voltage Direct Current (MVDC) power transmission is a promising approach to enhance the transport capacity of lines like cables and overhead lines. Furthermore, a MVDC link provides improved power flow control at distribution grids and is an instrument to improve power quality [2 - 6].

Extruded DC cables show some phenomena, which are based on the temperature and electric field dependent conductivity of the insulation material and are unknown for AC cables: field inversion, space charge accumulation and thermal runaway [7, 8]. The mentioned effects need to be considered carefully in case of DC operation for new or existing extruded AC cable systems (Fig. 1).

In this contribution, the application of extruded MVAC cables for DC power transmission is described and discussed in detail. Experimental investigations according to CIGRE TB 496 resp. IEC 62895 and FEM simulations will be presented. A MVAC XLPE cable with usual AC joints and terminations (all of 12/20 kV voltage level) is tested according to the LCC prequalification test (LCC PQ test) described in CIGRE TB 496. For this test the commercially available 12/20 kV MVAC cable system was defined to be a 55 kV DC cable system. The chosen DC nominal voltage would result in an increase of transport capacity by a factor of about 3.5 compared to the MVAC cable system. The test setup and some modifications on the PQ test sequence will also be presented.

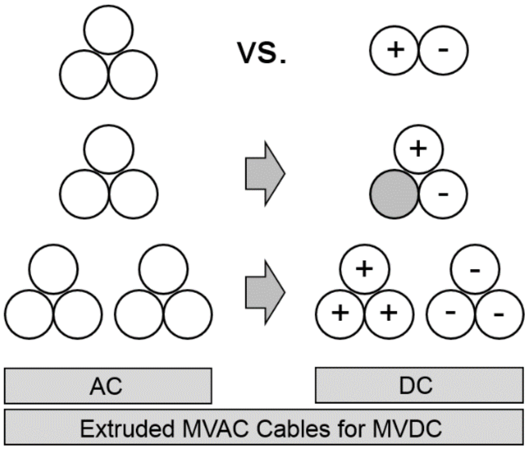

Fig. 1: MVDC with extruded MVAC cables

MVDC USING EXTRUDED MVAC CABLES

General advantages

The main advantages of using DC instead of AC for energy transmission are the lack of capacitive charging currents, skin effect and induced additional losses. Current heat losses have to be considered in both cases with regard to the thermal conditions of the cable. A further aspect is the required amount of material for power transmission. A DC transmission line can be established with two cables whereas for an AC transmission line three cables are necessary.

From a current perspective, the use of extruded standard MVAC cables for MVDC could provide economic advantages due to availability, the high product quality and long-time production experience.

Enhancement of transmission capacity by converting AC cable systems to DC operation

The conversion of AC cable systems to DC operation can enlarge the transmission capacity. The DC topology (bipolar DC systems: m = 2), the DC system voltage U_{DC} and the possible increase of the DC nominal current I_{DC} due to the missing skin effect are influencing the transmission capacity of a DC system according to Equation 1 [4].

$$\frac{P_{DC}}{P_{AC}} = \frac{m \cdot U_{DC} \cdot I_{DC}}{\sqrt{3} \cdot U_{AC} \cdot I_{AC} \cdot \cos\varphi} \qquad (1)$$

Table 1 shows the possible increase of the transport capacity of a bipolar MVDC transmission system compared with a 12/20 kV AC cable system and with variations in DC