Medium Voltage DC Cables: A Look to the Future

Andrew **LAPTHORN;** University of Canterbury, Department of Electrical and Computer Engineering, (New Zealand), andrew.lapthorn@canterbury.ac.nz

Uwe **SCHICHLER;** Graz University of Technology, Institute of High Voltage Engineering and System Performance, (Austria), uwe.schichler@tugraz.at

ABSTRACT

MVDC power cable applications today are minimal and handled on an "ad-hoc" basis adapting from either MVAC standards and materials, or HVDC standards and materials. MVAC standards do not generally account for aspects unique to DC applications such as interdependency of conductivity with temperature and field strength and the potential risk of space charge accumulation. Whereas the stringent testing requirements for HVDC cables may be too onerous due to the lower field strength leading to a lower impact of conductivity, potentially adding costs. This paper presents an overview of the technical issues related to MVDC cables, a discussion on possible approaches, and some initial results from testing MVAC cables under MVDC conditions at various high-voltage laboratories around the world.

KEYWORDS

MVDC Cables, Standards, Type Test, PQ Test

INTRODUCTION

Throughout the world, there is a growing need from society to reduce carbon emissions to prevent the worst outcomes of climate change. In 2019, approximately 34% of total net anthropogenic GHG emissions came from the energy supply sector, 24% from industry, 22% from agriculture, forestry and other land use, 15% from transport and 6% from buildings [1]. The electricity sector is considered by many to be a key component in decarbonising global energy use. To achieve this, not only will there need to be a major shift in generation towards renewable sources, but there will also be a significant increase in demand as the transport and industry sectors move towards electrical sources for energy [2]. All this leads to an enormous investment in new electricity infrastructure over the coming decades on a scale never seen before [3-5].

To complicate matters, planning regulations in many countries make it difficult to install new transmission networks adding significant time and costs to projects [6-9]. Thus, utilities are looking for ways to increase power transmission through existing corridors. Medium Voltage DC looks to be an area where such transmission improvements can be made. For example, S. Krahmer et al. show that when using AC cables with DC, an increase in power transmission of 1.75 is possible [10]. In another study, A. Burstein et al. found capacity gains of up to 2.08 over the AC equivalent using two AC cables in a symmetric monopole or bipolar configuration with the DC voltage at the peak AC voltage [11]. Meanwhile, Ratheiser et al. found that by increasing the DC voltage to 10kV/mm of insulation (a value still half that of HVDC cables), an MVDC cable link (±55 kV, 240 mm²) can transmit up to 5.7 times more power compared to a standard AC cable system (12/20 kV, 240 mm²) [12].

<u>MVDC Studies</u>

Several research groups are actively researching MVDC topologies and a number of manufacturers are developing solutions in this area. For example, the CIGRE WG C6.31, recently released TB 793 which was a feasibility study into MVDC networks. The report looks at the needs of MVDC grids, a review of the current (at the time) research and development status of various MVDC projects around the world, and a look at some possible topologies and technical issues. The conclusions of TB 793 state that, although MVDC power grids have obvious advantages as outlined above, there are still some technical challenges that need to be addressed through continued research and detailed studies [13].

The International Conference on Electricity Distribution (CIRED) published a report in 2021 investigating MVDC distribution [14]. In the report, the working group looks at the drivers for MVDC systems, examines some use cases and pilot projects, and looks into the state of the art of current technology. The report's findings show that despite all the development, the majority of technical solutions and devices remain in pilot project stage and the commercial markets are missing. The authors identify the need for standardisation in MVDC as being mandatory and a major factor for success.

In New Zealand, the government has funded a major research programme called Architecture of the Future Low-Carbon, Resilient, Electrical Power System [15]. This 7 year program involving universities from New Zealand and abroad aims to investigate what the future electrical power system might look like, with the main hypothesis being that high penetration of DC transmission and distribution (conveyance) into the AC grid will provide many benefits to transition to a low-carbon power system. The major research challenge is to determine the future architecture, topology and a transition pathway.

In Dresden, Germany, a research program called AC2DC is underway. This program is looking at increasing the transmission capacity in the distribution network by using existing AC connections as DC routes, and is split into two sub projects. The first is looking at DC to DC converters and the grid-related functions of the grid-side converter, point-to-point connections between line-side and plant-side converters, and the system-side interface located on the converter. The second sub-project is looking at the system design and electrical stress. They are investigating possible topologies for converting AC to DC systems. The electrical stresses that occur are identified, which the components of the energy system have to withstand. Since the goal is to convert existing cable routes, the focus of these investigations is on operationally aged AC cables that are subjected to higher DC voltages. The heating behaviour is also checked by the new types of current loads [16].