Laboratory and Field Partial Discharge Measurement in HVDC Power Cables

Malcolm **SELTZER-GRANT**, Riccardo **GIUSSANI** ; HVPD Ltd, Manchester, United Kingdom,
malcolm.seltzer-grant@hvpd.co.uk, riccardo.giussani@hvpd.co.uk
W H **SIEW**, Edward **CORR**, Xiao **HU**, Minan ZHU; University of Strathclyde, Glasgow, United Kingdom,
wh.siew@strath.ac.uk, edward.corr@strath.ac.uk, xiao.hu@strath.ac.uk, minan.zhu@strath.ac.uk
Martin **JUDD**, High Frequency Diagnostics and Engineering Ltd, Glasgow, United Kingdom, m.judd@hfde.co.uk
Alistair **REID**, Glasgow Caledonian University, Glasgow, United Kingdom, Alistair.Reid@gcu.ac.uk
Alex **NEUMANN**, ORE Catapult, Blythe, United Kingdom, alex.neumann@ore.catapult.org.uk
Joseph **AWODOLA,** Mutual Energy, joseph.awodola@mutual-energy.com

ABSTRACT

A range of experimental and field measurements of partial discharge (PD) activity under high voltage direct current (HVDC) conditions have been conducted with the goal of developing effective monitoring techniques for PD in HVDC cables and ancillary equipment, particularly in offshore renewable energy HVDC grid installations. Laboratory measurements on insulation test objects and cross linked polyethylene (XLPE) cable samples have been conducted to better understand the characteristics of PD activity under direct current (DC) stress in comparison with AC. In addition, long-term PD measurements carried out at both an HVDC cable aging laboratory and an in-service HVDC interconnector circuit are presented together a description of the monitoring system architecture.

KEYWORDS

HVDC, cables, partial discharge, on-line PD monitoring, OLPD, offshore, renewables, electricity transmission.

INTRODUCTION

Monitoring for HVDC Transmission Cables

HVDC technology for transmission of electrical power is developing rapidly. Applications in which HVDC excels include the transmission of power over long distances on land (typically from remote renewable energy sources to urban load centres) and as a key enabling technology for international subsea supergrids. For example, to achieve the scale and capacity required to make offshore wind renewable energy more affordable, large OEMs are in the process of developing and proving the technical capability of new HVDC hardware required to operate at these higher voltages in the offshore environment at distances much further from shore (100 – 500 km) than the present generation of HVAC systems (typically 10 – 50 km).

The technologies required to form the backbone of this infrastructure, including the use of HV AC/DC power conversion and long HVDC XLPE/Paper insulated subsea cables and interconnectors are relatively new and untried over the long term in the offshore environment. The cables are distributed, sub-sea components in which, should a failure occur, it is necessary both to locate the fault and then to raise the cable from the seabed for repair. This involves onerous logistical challenges and major expense due to the fact that it is difficult to accurately 'pinpoint' the location of any subsea fault and a lift/repair vessel is needed to make the repair. A preferable situation is to avoid 'blindness' with regard to the condition of these critical cables through an ability to locate incipient insulation faults, which are in most cases preceded by partial discharge (PD) activity in the cable. Such systems provide the operator with an early warning of cable degradation to support preventative maintenance interventions and avoid unplanned outages / downtime. Effective condition monitoring systems, including PD monitoring, therefore have potential to improve system availability and reduce the ownership and operating costs of these key assets. This paper outlines a number of research activities and measurement campaigns that are being carried out in order to advance PD monitoring for offshore HVDC cables and equipment.

PD under HVDC Conditions

Partial discharge phenomena under DC conditions have generally received less attention than AC PD until recently. A review of previous research in this field can be found in [1], which includes investigations into the physics of PD at DC voltages and practical measurements in which PD events were characterised by their time of occurrence and magnitude, leading to possible classification methods for PD under DC conditions.

Some early research carried out in 1960 [2] analysed the PD behaviour of dielectrics under DC stress through both calculation and accelerated aging to assess the suitability of various materials for use in HVDC cables. More recent research has demonstrated that PD under DC conditions can contribute to degradation [3] and showed that the PD repetition rate tends to increase with conductivity of the insulation. This is manifest through higher PD repetition rate at high operating temperatures, for example. Studies of PD activity in lapped polypropylene film insulation [4] have shown that under DC excitation PD activity at butt gaps in the lapped insulation increased with the temperature and the applied electric stress.

Testing of mass impregnated cables under DC load cycle conditions [5] led to a suggestion that the repetition rate of the PD activity as a function of discharge magnitude could be used to eliminate poor cables. Similarly, investigations of PD in mass impregnated non-draining (MIND) cables [6] during Cigre type testing [7] studied the repetition rate of PD activity as a function of time during the "current off" stage of the type test for warm and cold cables. The main findings were that the number of defect sites increased as a cable cooled and that the time to reach the maximum in the repetition rate was longer for a warm cable than for a cool cable.