Study Committee B1

Insulated cables

10774-2022

PD, temperature and acoustic measurement of Eleclink HVDC interconnector – anticipate failures to minimize service disruption and impact on train circulation

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Motivation

This aim of this paper is to describe the features of an innovative asset management monitoring system, fully conceived, designed, built and installed for the 68 km long Eleclink interconnector between Sellindge (UK) and Coquelles (FR). The Eleclink is a unique interconnector, whose DC portion is the first HVDC cable laid in air in a railway tunnel and in close proximity to the running trains. The aim of this innovative asset management monitoring system is to anticipate an incoming issue lowering the risk of a fault and consequent unplanned outages thus minimizing the outage duration and the disruption to train circulation. This is achieved thanks to the Partial Discharge (PD), Distributed Temperature Sensing (DTS), Real Time Thermal Rating (RTTR) and Distributed Acoustic Sensing (DAS) monitoring system mounted along the 54 km long UK/FR HVDC link and along the 14 km long HVAC power system between Folkestone and Sellindge in the UK. In this HVAC link, the asset monitoring system is able to control not only the above-mentioned parameters but also the status of the Sheath Voltage Limiter (SVL), the sheath currents and the earth currents along the circuit. The schematic of the Eleclink interconnector is depicted in the Figure 1.

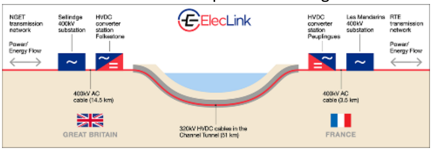

Figure 1: Schematic interconnection of Eleclink project

Method/Approach

The system depicted in Figure 1 has been designed, manufactured and installed taking into account several constraints, the main ones being:

- the 54 km long HVDC portion laid in air (51 km inside the tunnel) and buried (3 km outside the tunnel in the two countries)
- the 14 km long HVAC portion buried
- the whole cable system constantly and thoroughly monitored, and any anomaly immediately detected and communicated to the Client via the SCADA protocol IEC60870-5-104
- the several components of the monitoring system directly installed on the accessories or in close proximity to them
- Fiber Optic Cables (FOCs) laid along the power cables, 2 on the AC portion and 4 on the DC one
- the design of the LVac (Low Voltage alternating current) distribution systems powering the Monitoring Systems on both the HVAC and the HVDC separate circuits carried out taking into account:
  - the monitoring devices consumptions and type of supply (single phase)
  - the Miniature Circuit Breakers (MCB);
  - the earthing connections;
  - EMC constraints along the tunnel and inside the two Stations
  - induced voltages from any HV and MV (trains' catenary) cables to the LV cables
  - The British Standards BS76-71:2008
  - The UE 1303/2014 European Commission Regulation

PD, Currents and SVL Monitoring system in the HVAC route

The PD sensors are placed on the HV cables (in close proximity to the accessory to be monitored), in order to capture the PD signals [1], [2], [3]. The captured PD signals are acquired by the PD acquisition devices (called Grids) and transmitted - by mean of dedicated fibres - to the Asset Management processing unit (server) installed in Folkestone CS, where the signals are assessed. The shields and earth currents are designed to be captured by Rogowski coils while the status of the SVL by infrared sensors. All the data are acquired by the current/SVL acquisition devices (named DLog) and then transmitted - via dedicated fibres - to the same processing unit dedicated to the PD in Folkestone CS. The main concept of a typical monitoring point placed along the HVAC route is depicted in Figure 2

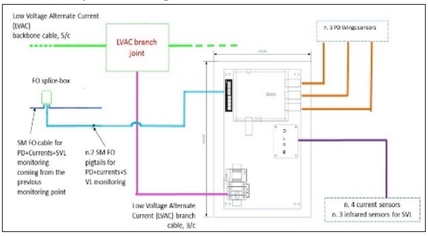

Figure 2: MP concepts on the AC route

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Two of the 14 Monitoring Points (MP) are placed in the two Substations (SS) near the GIS terminations, the other ones are located near the HV joints. A typical MP is shown in Figure 3. Figure 4 shows the Rogowski and the infrared sensors placed inside the link pillar, Figure 5 shows the PD sensors installed close to the HV joints and figure 6 the PD sensors close to the GIS terminations.

Figure 3: MP in the HVAC circuit

Figure 4: Rogowski and infrared

Figure 5: PD sensors close to the HV joints

Figure 6: PD sensors close to the HV GIS terminations

PD Monitoring system in the HVDC route

The design of the PD monitoring system in the HVDC route is based on the same concepts and fundamentals of the HVAC route. The main concept of a typical monitoring point placed along the HVDC route is depicted in Figure 7

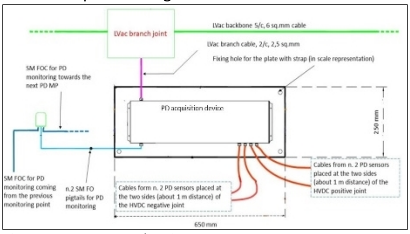

Figure 7: MP concept on the DC route

The installation in the HVDC route is quite different with respect to the HVAC one. Indeed, 19 out o the 24 MP's are installed inside the Channel tunnel on the same metallic structure (called CMS = Cable Management System) where the two HVDC cables and the all the ancillary cables (FOCs, ECC, LVac) are laid. For the 5 MP's outside the tunnel, the approach is the same as per the HVAC. Figure 8 shows the MP installed onto the CMS close to the HV joints (not depicted in the figure) inside the tunnel, Figure 9 shows the MP installed under the DC outdoor termination in UK

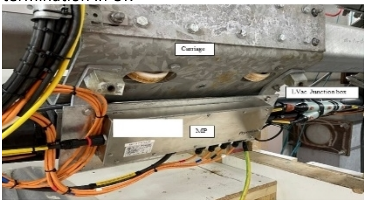

Figure 8: MP inside the tunnel

Figure 9: MP at the terminations

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DTS and DAS Monitoring system in the HVDC and HVAC route

For the HVAC route, the temperature monitoring is performed by 1 DTS interrogator installed in Folkestone CS which monitors the temperature of the FO cable laid in contact with the central phase of the HVAC power system. On the HVDC route, the temperature monitoring is performed by 2 DTS interrogators, one of which placed in UK CS and one in FR CS for redundancy purposes. In addition to the DTS, the two HV power systems are also equipped with the RTTR algorithm which produces as output the cables conductor temperature profiles starting from the temperature measured by the DTS interrogators. The acoustic monitoring is performed by means of two DAS interrogators, installed one in each Converter Station. The DAS concept is shown in Figure 10. They utilize the FOCs laid along the power cables to detect any acoustic disturbance occurred near or onto the cable system. Both DAS monitor the DC portion of the cable system, allowing a complete redundancy for the system. The system one installed in Folkestone CS also monitor the AC route. The design of the monitoring systems was executed taking in account the peculiar environment in which their devices are installed and operate. More in specific, the equipment into the tunnel respects the strict EM emission requirement to avoid any disturbance to the train communication and guidance system. Similarly, the EM emission caused by the trains is filtered to avoid any interaction with the monitoring system and consequent false reading.

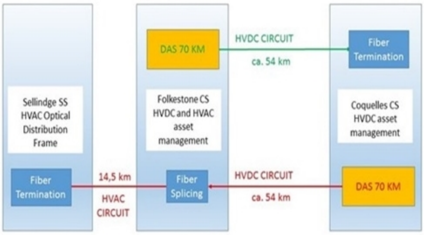

Figure 10: DAS schematic concept

Monitoring system operation

The PD captured by the system are assessed with the aim of discriminating the external to the internal ones, filtering the noise, analyzing those indicating a possible issue for a further assessment to predict the defect development. The temperature monitoring provides real time measurement of the HV power cable temperature every 0.5 m of its length. The system generates alarm and warnings in case the measured temperature exceeds pre-set threshold values. DAS monitoring is even more meaningful for this specific cable system, which is installed in air for a length of 51 km in close proximity to a train which is running to a speed of 160 km/h.

The DAS is capable to detect acoustic activity in proximity of the cable and distinguish possible threats from normal signals, such that of a passing train. The DAS is also monitoring underground sections of the projects. In this case, the DAS alarm algorithm is configured to identify excavation events. In the case that the system detects any critical activity of the PD and/or the temperature exceeds the set threshold values and/or there is a localized increment of the temperature and/or it is identified an acoustic signature of a cable breakdown an alarm is triggered and sent to the Client control room via Scada protocol.

Conclusion

The here described monitoring system is the first ever able to detect Partial Discharges in HVDC cables and has been fully conceived, designed, built and commissioned for the specific Eleclink interconnector. The system is also able to detect the temperature and the acoustic noise of the HVDC and HVAC cables themselves, representing this way a cutting-edge technology for the identification of faults and of pre-faults. The system increases the power system reliability and supports the maintenance operators optimizing the planning and shorten the out of service in case of fault. This is extremely important in the case of the Eleclink interconnector since the intervention on the cable system affects the rail service between the two countries, highlighting that the here described Monitoring Systems extends the benefits well beyond the interconnector operation and the end users.

References

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