Asset management of submarine cables and lessons learned from a repair

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Development of a three-terminal ready HVDC interconnector between France and Great Britain via Alderney
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REE N°1/2018 JICABLE HVDC'17 DOSSIER 2 REE N°1/2018 Z 109 JICABLE HVDC'17 DOSSIER 2 REE N°1/2018 Z 109 Asset management of submarine cables and lessons learned from a repair Jean Charvet, RTE (France), Jean.charvet@rte-france.com Context Service experience of HVDC submarine cables CIGRE brochure TB379 – Update of service experience of HV underground and submarine cable systems, December 2009 – presents a failure rate for HVDC cables of approximately one failure per year per 1000 km of circuit, mostly caused from external damage. However, this figure is to be taken with great care because it is based on rather old service experience between 1990 and 2005, while in the past ten years, a lot of improvements has been achieved in marine engineering and routing, cable design, installation, protection and preventive maintenance. TB379 is currently being updated by CIGRE Working Group B1.57 with more recent data but results will not be published before end of 2018. In the meantime, RTE carried out a similar survey on the following sample: s
failures may only affect one or two cables) and after commissioning. Results of this survey is that for MI insulation technology, there is an average of less than one failure per year per 3000 km of circuit, while no failure has been reported for 8.0% TECHNOLOGY SO FAR. WITH A VARYING LIMIT SAMPLE, % EVEN IF THOSE FIGURES SEEMS REASSURING A TREND OF decreasing failure rates, it is worth mentioning that HVDC submarine links are being built on increasingly long length, and thus can be more vulnerable to faults. Unavailability and cost of repair SUBMARINE CABLES GENERALLY DONT NEED ANY PLANNED unavailability, but can suffer from unplanned availabilities due to faults or the need for remedial protection works. Even with low failure rates, the fact that HVDC submarine cable failures takes a long time to repair can lead to significant impact on interconnector business models and security of electricity supply. &OR AS A SINGLE FAULT TWO TO THREE MONTHS IS A TYPICAL TIME to be considered for repair, excluding hazards, while cost of repair and losses of revenue can be in the order of tens of million euros. &OR A LONG INTERCONNECTOR OF KM FOR INSTANCE SUP

posing a failure rate of one failure per year per 3000 km would mean that, as an average, 2 to 3 months unavailability CAN BE EXPECTED ON A YEAR PERIOD. THIS IS CORRESPONDENT TO AN average of 3 to 4% of the time which is significant to impact profitability of the interconnector. KEYWORDS: SUBMARINE CABLES REPAIRED OFFSHORE, REPAIRED SPARE PARTS Provided that submarine cable are correctly designed and installed, failures are rare but do happen on some occasions. Consequent repairs can be very costly and cause long unavailabilities. This article aims to identify the levers to improve reliability of submarine cable assets by limiting occurrence of failures and induced losses. Asset manage- ment policies including preventive maintenance, repair preparedness, and spare parts are described and discussed from a TSO perspective. Finally, lessons learned are shared from repairs managed by RTE on HVDC submarine cables of the IFA2000 interconnector (FR-UK) during the winter 2016-2017. ABSTRACT IFA 2000 experience WITH A THOMS OFFSHORE FAILED TO SHORE LEADING TO THE LOSS OF CAPACITY IF THE CONSEQUENT MOBILIZATION OF RESOURCES TO PERFORM REPAIRS AS QUICKLY as possible, the interconnector recovered 500 MW CAPACITY WOIRST CABLES REPAIRED ON THE 2ND OF MARCH 2017. Lessons learned: > It took slightly more than three months in total to repair four cable damages, > CONSIDERING THE EXTENT OF WORKS THIS GOOD PER formance was made possible by hiring two repair vessels and two jointing teams working in parallel. JICABLE HVDC'17 DOSSIER 2 110 Z

Design measures Fault causes and preventive design measures Risk mitigation regarding fault occurrence and induced losses starts from the design phase of submarine links. Type of faults and design measures to prevent them are described below. External faults may be caused either by human activities, natural phenomena or a combination of those: 3EABED MOVEMENTS LINKED TO SEISMIC ACTIVITY OR CURRENTS AND WAVES, BUISEION OR FISHING NET NON BURIED CABLES AND FREE SPANS, IMPACT OR HOOK BY ANCHORS, SISHING GEARs, AMAGE CAUSED BY WORKS IN THE AEDDREDGING CABLE OR PIPELINE LAYING EXTRATION OF AGGREGATE, ALLING OR JECT SHIP WRECK, RIDANCE EXPLOSION IN THE VICINITY To prevent external faults, the cable route and the level of protection shall be carefully designed depending on the above mentioned risks. Internal faults may be caused by: %, ROROR DEFECT DURING MANUFACTURING OR ASSEMBLY OF JOINTS AND TERMINATION, -ECHANICAL DESIGN PARAMETERS EXCEEDED DURING TRANSPORT STORAGE OR INSTALLATION, AD THERMAL ENVIRONMENT LEADING TO EXCEED TEMPERATURE DESIGN VALUES, SERVOLTAGE OVERLOADS ABOVE DESIGN VALUES. PREVENT INTERNATIONAL FAULTS IT IS CONSEQUENTLY RECOMMENDED to select properly tested materials, have a robust inspection and test plan during every step from design, manufacturing and installation of submarine cables, have a robust thermal DESIGN BASED ON ON, SITE MEASUREMENTS AND PUT IN PLACE proper protections against overvoltage and overloads. Maintenance friendly designs in order to allow an effective preventive maintenance and QUICK REPAIR THE FOLLOWING KEY POINTS MUST BE CONSIDERED INTEGRATION OF UNITINSIDE POWER CABLES OR ALTERNATIVELY BUNDLED VS BENEFICIAL TO ALLOW BASED CABLE MONITORING AND FAULT LOCATION. ABLE MUST BE EASILY ACCESSIBLE IN CASE A REPAIR IS NEEDED this may be contradictory to preventive protection measures AGAINST EXTERNAL THREATS AND SHOULD BE CAREFULLY BALANCED, IMITING THE NUMBER OF DIFFERENT CABLE DESIGNS AND ACES s or making sure they are compatible between each other in order to rationalise spare parts storage. Preventive maintenance The purpose of preventive maintenance policies is to de crease the probability of failure. Cable awareness It is obvious that precise cable position shall be reported on every relevant marine charts. Figure 1: IFA 2000 cable damage. IFA2000 experience SINCE IT HAS BEEN COMMISSIONED THE SUBMARINE PART OF THE INTERCONNECTOR has experienced TWO SIMULTANEOUS EXTERNAL FAULTS AFFECTING four cables, presumably caused by anchors although cables were well buried at approx. 1.5 m in relatively stiff soil, 5 km away from English coast and relatively far from shipping lanes. Lessons learned: > Emergency anchoring is probably more likely to happen in nearshore areas and not inside a shipping lane. IFA2000 experience SINCE IT HAS BEEN COMMISSIONED THE SUBMARINE PART OF THE INTERCONNECTOR has experienced one internal fault in 2003, affecting one cable, caused by mishandling during installation which created a weak point. Lesson learned: > OT ALL DEFECTS CAN BE DETECTED DURING COMMIS

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sioning tests, neither warranty period, which means that controls during all steps from cable design to cable installation are crucial. REE N°1/2018 Z 111 Asset management of submarine cables and lessons learned from a repair it is also recommended to work with fishermen to define good practices when they work in the vicinity of the cables. Moreover, it is also possible to monitor vessels positions and movements in the vicinity of cable routes using real time data detected risk situation can then lead to contact the vessel captain or marine authorities in order to prevent unauthorized activities in the vicinity of the cable. Cable monitoring standard practice for repair is generally performed in two steps: standard practice for repair is generally performed in two steps: a) detection of hotspots could indicate an internal defect or an unfavourable thermal environment, while local "cold spots" could reveal deburial. b) data analysis should be provided to the responsible engineer to implement any necessary repairs or maintenance actions.

Marine vessels to mobilize depends mainly on water depth, and are generally: a) anchor; b) barges; c) tugboats. Anchored barges and tugs for repairs in shallow waters < 15 m WD are often used for deferred maintenance works, while ships for repairs in deep waters can be directly integrated to each power cable.

Deployment of local hotspots could indicate an internal defect or an unfavourable thermal environment, while local "cold spots" could reveal deburial. Partial discharge measurement are also sometimes considered but its interpretation can also be tricky. Those systems have a limited range and only a part of the submarine link may be monitored for long interconnectors, although technology is constantly improving. In order to ensure the efficiency of & based systems, best practices and learning phase in the first month or years of operation may be necessary to fine tune the interpretation of monitoring data. In case an anomaly occurs and depending on its severity, it may be decided to launch surveys and/or remedial works. AIS: Automatic Identification System, système d'échanges automatisés de messages entre navires par radio VHF qui permet aux navires et aux systèmes de surveillance de trafic de connaître l'identité, le statut, la position et la route des navires se situant dans la zone de navigation (NDLR). Geophysical marine surveys - minimum frequency and extent of surveys are often part of regulatory or insurance obligations, which can vary depending on the asset. The data to collect which are project specific generally include multi-beam bathymetry and sometimes side scan sonar, measurement of cable position and burial depth, environmental monitoring, etc. Because marine survey operations on long links are very costly activities, the best practice is to adapt the frequency and the extent of planned surveys depending on risks, notably seabed mobility and external threats/anchor fishing. Moreover, unplanned surveys may be decided upon occurrence of extreme meteorological event or anomaly detected on monitoring systems. "RealCareShallBetakenOnFormatOf"> Data order to be able to compare each survey data from the previous surveys, and make the data usable for potential future works on or next to the link. Repair preparedness The purpose of repair preparedness is to reduce the time for a repair, and thus the induced losses. Organisation and emergency contingency plans % Laborating and maintaining an up to date emergency contingency plan for each submarine link is a key point for a quick response after a fault. IFA2000 experience immediately after fault happened in November and based on its experience of emergency situation, RTE put in place an operational project team involving local personnel from project management and maintenance departments, relying on the support from internal cable expertise and offshore project departments, procurement and legal departments and outsourced marine and legal experts. Lessons learned: > AVING24% QUALIFIED PERSONNEL ON BOARD OF REPAIR VESSELS allowed to handle interfaces between different contractors on board, which were sometimes critical and it surely has saved time and participated to quality and safety improvements. Experience from repairs is valuable to improve contingency plans. jicable HVDC'17 dossier 2 112 ZREE N°1/2018 3UCHAPLANNOULD TYPICALLY INCLUDE s $escription of internal organisation, input in place including human resources role and responsibilities, decision making, e2e repair procedures, for different plausible fault scenarios, list of relevant contacts and providers, interface management, safety requirements, periodical revision of contingency plans shall be performed and data is recommended to perform regular crisisexer. cises. Fault location &ault location is the critical path of a repair. In general performed in two steps: a) RE LOCATION FROM LAND USING 4S2 BASED METHODS ON THE power cables, s) ON POINTING USING MAGNETIC AND DORACOUSTIC MEASUREMENTS at sea, and/or with fibre optic when available. Reliability and reactivity of those operations is of paramount importance and thus it is recommended either to have an internal expertise or frame agreement with a specialised provider. Marine operations Mobilization of an adapted marine spread to allow the repair needs to be done as soon as possible after fault location is confirmed. In addition to vessels that are necessary for fault location and surveys, type of marine vessels to mobilize depends mainly on water depth, and are generally: a) ACK UPBARGES AND TUGS FOR REPAIRS AT LAND FALLS s) INCHORED BARGES AND TUGS FOR REPAIRS IN SHALLOW WATERS < 15 m WD s$360 S 0 VESSELS FOR REPAIRS IN DEEP WATER? s$ Because it is very costly to keep in standby all those type of potentially necessary vessels for repairs, it is general practice, upon a failure, to hire vessels that are available on the market, through a specialized broker for example. - oover repair operations need specific equipment to be installed onboard which can vary depending on the vessel.
The critical equipment which can be project specific are listed below.

- Tools for de-burial and re-burial mainly depending on the type of soil and cable diameter.
- Spare cables and cable MBRs, able to de-burial and re-burial mainly depending on cable coilability.
- Chute and quadrant mainly depending on cable length and weight of spare and cable MBRs.
- Able chute and quadrant mainly depending on cable weight and water depth.

Three of the four cables with 50 m accuracy were completed within 9 days after faults occurrence and later double confirmed by surveys showing anchor scars on the seabed. 24% has an internal expertise in fault location and pin pointing of faults on the four cables with 50 m accuracy were completed within 9 days after faults occurrence.

A specially developed and patented magnetic field based equipment was used. Lessons learned: Having internally the equipment ready for mobilisation together with regularly trained maintenance teams proved to be very efficient.

With a specialized contractor, the purpose of spare part storage is to make sure that reliable spare materials of the cable system is immediately available in case a repair is needed without waiting for remanufacturing. Quantity of spares is project specific and mainly depends on: risks and failure scenarios to cover, water depth, areas where jointing will have to be avoided (sand, possibly rock, berms), emergency times and minimum quantities to store. Storage site usually a nearby quay in a port with direct and permanent access to sea, in a controlled and secure area aired and protected from UV and rain.

Conclusion Lessons learned from submarine cable repair experience makes possible to improve asset management policies. Sharing of service experience and collaboration for more standardization of repair solutions must be encouraged.

Glossary

- AIS: Automatic Identification System
- DAS: Distributed Temperature Sensing
- DTS: Distributed Temperature Sensing
- DP: Dynamic Positioning
- DSV: Diving Support Vessel
- FO: Fibre Optic
- GIS: Geographic Information System
- MBR: Minimum Bending Radius
- MI: Mass Impregnated
- TDR: Time Domain Reflectometry
- XLPE: Cross-Linked Polyethylene

IFA2000 experience and National Grid Interconnector Ltd share a frame agreement for mobilization of marine spread. Considering that failures happened on two distinct locations for each pair of cables, it has been decided to work as much as possible in parallel in order to save time. Two repair vessels and one support vessel were hired within one month and ready before the jointer teams. The support vessel was dedicated to prepare cable cuts, de-burial, seaming, checks and tests on cables, sealing ends) while the two others were dedicated to jointing operations. Lessons learned: Having the possibility to install compatible joint from a different supplier than the original cable was beneficial and saved time.

ANDMOBILIZACONSEQUENTMEETWITHINASHORTTIME IFA2000 experience Because of the extent of the repairs to be done and limited availabilities of jointing teams, RTE contracted those operations to 2 different suppliers who were both competent to perform the cable jointing operations on the 24% of submarine cables. Those operations appeared to be on the critical path of the repair, as marine spread was ready before jointing teams. Lessons learned: Having the possibility to install compatible joint from a different supplier than the original cable was beneficial and saved time.

Tests confirmed that spare cable that was stored for more than thirty years in cable tanks were still in good condition. Two cable joints from the spare parts have been used for training of jointers, prior to perform the offshore repairs. Lesson learned: Regular inventory and maintenance on the spare parts is valuable.