Asset management of submarine cables and lessons learned from a repair

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ABSTRACT

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 aim to identify the levers to improve reliability of submarine cable assets by limiting occurrence of failures and induced losses. Asset management 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.

KEYWORDS

Submarine cables, Service experience, Preventive Maintenance, Repair Preparedness, Offshore Repair, Spare parts.

1. 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 1000km 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TB379 is currently being updated by CIGRE Working Group B1.57 with more recent data but results will not be published before end of 2018.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:

- HVDC submarine links in Europe, ranging from 250kV to 500kV;
- Service experience from 2006 to 2016;
- Failures known from public sources, counted per circuit (one failure may affect one or two cables) and after commissioning.

Results of this survey is that for MI insulation technology, there is an average of <u>less than one failure per year per 3000km of circuit</u>, while no failure has been reported for XLPE technology (so far on a very limited 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 don't 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.

For 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.

For a long interconnector of 500km for instance, supposing a failure rate of one failure per year per 3000km would mean that, as an average, 2 to 3 months unavailability can be expected on a 6 years period. This corresponds to an average of 3 to 4% of the time which is significant to impact profitability of the interconnector.

IFA 2000 experience

On 20th of November 2016, four out of eight cables of the IFA2000 interconnector failed offshore, leading to 1000MW lost capacity. After consequent mobilization of resources to perform repair as quickly as possible, the interconnector recovered 500MW capacity (two first cables repaired) on 17th of February 2017 and it was fully operational (repair of the two remaining cables) on the 2nd of March 2017.

Lesson learned:

- It took slightly more than three month in total to repair four cable damages,
- Considering the extent of works, this good performance was made possible by hiring two repair vessels and two jointing teams working in parallel.

2. 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.

<u>External faults</u> may be caused either by human activities, natural phenomena or a combination of those:

- Seabed movements linked to seismic activity or currents and waves;
- Abrasion or fatigue on non-buried cables and free spans,
- Impact or hook by anchors, fishing gears;
- Damage caused by works in the seabed (dredging, cable or pipeline laying, extraction of aggregate);
- Falling objects, shipwreck;
- Ordnance 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.

IFA2000 experience

Since it has been commissioned in 1986, the submarine part of the interconnector has experienced two simultaneous external faults in 2016, affecting four cables, presumably caused by anchors although cables were well buried at approx. 1.5m in relatively stiff soil, 5km 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.

Fig. 1: IFA 2000 cable damage

Internal faults may be caused by:

- Error or defect during manufacturing or assembly of joints and termination;
- Mechanical design parameters exceeded during transport, storage or installation;
- Bad thermal environment leading to exceed temperature design values;
- Overvoltage or overloads above design values.

To prevent internal 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.

IFA2000 experience

Since it has been commissioned in 1986, 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:

➢ Not all defects can be detected during commissioning tests, neither warranty period, which means that controls during all steps from cable design to cable installation are crucial.

Maintenance friendly designs

In order to allow an effective preventive maintenance and a quick repair the following key points must be considered:

- Integration of FO unit inside power cables, or alternatively bundled, is beneficial to allow FO based cable monitoring and fault location;
- Cable 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;
- Limiting the number of different cable designs and accessories or making sure they are compatible between each-other in order to rationalise spare parts storage.

3. PREVENTIVE MAINTENANCE

The purpose of preventive maintenance policies is to decrease the probability of failure.

Cable awareness

It is obvious that precise cable position shall be reported on every relevant marine charts.

It is also recommended to work with fishermen to define good practices when they work in the vicinity the cables.

Moreover, it is also possible to monitor vessels positions and movements in the vicinity of cable routes using real time AIS data. A 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.

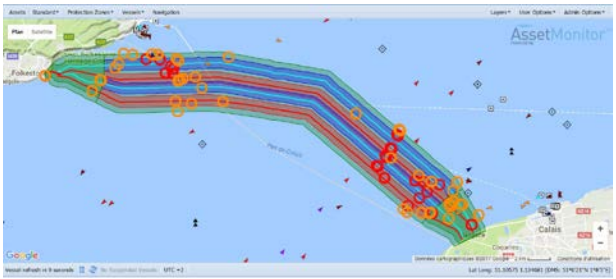

Fig. 2: AIS monitoring on IFA2000

Cable monitoring

Standard practice for newly built HVDC links is to monitor temperature along the link by implementing DTS systems. Development of local hotspots could indicate an internal defect or an unfavourable thermal environment, while local "cold spots" could reveal deburial.

It is also recommended to install DAS systems that could help locating deburials or external aggressions but experience is still very limited and signals are not easy to interpret. 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 FO based systems, best practice is that FO units are either bundled, or directly integrated to each power cable. This sometimes lead to install an extra FO unit when a pair of power cable is unbundled (which is often the case at landfalls).

The way of interpreting data from those monitoring systems can vary from regular checks with analysis reports to continuous check with pre-defined levels of alarm. A 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.

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 treats (anchors, fishing).

Moreover, unplanned surveys may be decided upon occurrence of extreme meteorological event or anomaly detected on monitoring systems.

Great care shall be taken on format of GIS data, in 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.

4. 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

Elaborating and maintaining an up-to-date emergency contingency plan for each submarine link is a key point for a quick response after a fault.

Such a plan would typically include

- Description of internal organisation to put in place including human resources, role and responsibilities, decision making;
- Repair procedures for different plausible fault scenarios;
- List of relevant contacts and providers;
- Interface management;
- Safety, Environment and Regulatory requirements.

Periodic revision of contingency plans shall be performed and it is also recommended to perform regular crisis exercises.

IFA2000 experience

Immediately after fault happened in November 2016, 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:

- ➢ Having RTE 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;
- ➢ Experience from repairs is valuable to improve contingency plans.

Fault location

Fault location is on the critical path of a repair. It is generally performed in two steps:

- Pre-location from land using TDR based methods on the power cables,
- Pin-pointing using magnetic field or acoustic measurements at sea, and/or with fibre optic when available.

Reliability and reactivity of those operation is of paramount importance and thus it is recommended either to have an internal expertise or frame agreement with a specialised provider.

IFA2000 experience

In November 2016, pre-localization and pin-pointing of faults on the four cables with 50m accuracy were completed within 9 days after faults occurrence, and later double confirmed by surveys showing anchor scars on the seabed.

RTE has an internal expertise in fault pre-location (TDR based systems) and owns specific offshore pin-pointing fault location equipment (magnetic field based) developed internally and patented.

Lesson learned:

➢ Having internally the equipment ready for mobilisation together with regularly trained maintenance teams proved to be very efficient.

Fig. 3: Offshore pin-pointing equipment

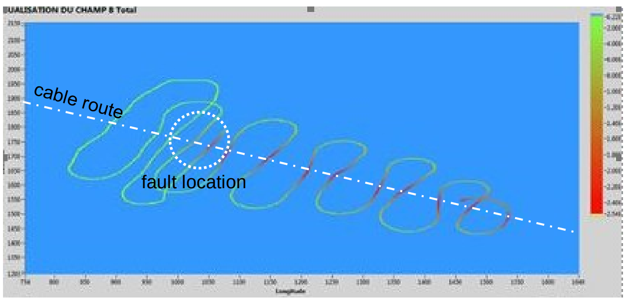

Fig. 4: Pin-pointing based on magnetic field measurements

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:

- Jack-up barges and tugs for repairs at landfalls
- Anchored barges and tugs for repairs in shallow waters <15m WD
- DSV or DP vessels for repairs in deep water >15m WD

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.

Moreover, repair operations need specific equipment to be installed onboard which can vary depending on the situation. Some of the critical equipment which can be project specific are listed below.

- Tools for deburial and re-burial, mainly depending on the type of soil and cable diameter
- Turntable or basket, mainly depending on cable coilability, length and weight of spare and cable MBR
- Cable chute and quadrant, mainly depending on cable MBR
- Tensioner, mainly depending on cable weight and water depth

Having pre-contractual arrangements or frame agreement for mobilization of marine spread, personnel and equipment with a specialized contractor is a common practice in order to save time for negotiations and engineering after occurrence of a fault.

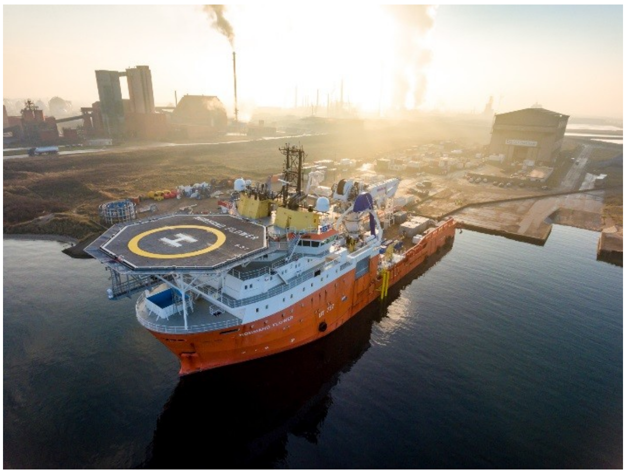

Fig. 5: one of the vessels hired for IFA2000 cable repairs, at mobilization site

IFA2000 experience

RTE 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 suppost vessel was dedicated to prepare cables (cable cuts, deburials, expertise of damages, checks and tests on cables, sealing ends) while the two others were dedicated to jointing operations.

Lessons learned:

➢ Having a frame agreement made possible to hire and mobilize a consequent fleet within a short time;

Jointing operations

Know-how of specialized jointing teams is a key point for a successful and reliable repair, especially in very high voltage ranges.

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 RTE IFA2000 submarine cables (MI technology), but still needed rehearsal on a piece of spare cable before going offshore.

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.

5. SPARE PARTS STORAGE

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 failures scenarios to cover;
- Water depth;
- Presence of areas where jointing will have to be avoided (for e.g. HDD and possibly rock berms);
- Lead times and minimum quantities to refill the stock after it is used;
- Hazards to consider.

Storage site is usually:

- Nearby a quay in a port with direct and permanent access to sea;
- In a controlled and secure area, aired and protected to UV and rain.

IFA2000 experience

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.

6. 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 Acoustic Sensing
DP: Dynamic Positioning
DSV: Diving Support Vessel
FO: Fibre Optic
GIS: Geographic Information Systems
MBR: Minimum Bending Radius
MI: Mass Impregnated
TDR: Time-Domain Reflectometry
XLPE: Crossed-linked Polyethylene