Study Committee B1

Insulated Cables

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Lessons learned in the maintenance of REE's submarine lines

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Introduction

Submarine power cables are essential to improve security and guarantee supply, increasing the efficiency of the electrical systems and allowing a greater integration of renewable energies.

The Spanish TSO owns more than 1.200 kilometres of submarine power cables:

- Links between Spanish mainland and Balearic Islands
- Interconnections between the Spanish and the Moroccan electrical systems
- Interconnections between islands in the Canary and the Balearic islands

Those submarine power cables are different in type of technologies, insulation, voltage, length or depth, which makes maintenance of these assets a challenge.

Fig. 1. Location of the submarine power cables in the Spanish grid

Aim

To minimize maintenance costs by maximizing the availability of these facilities. This strategy is essential due to three factors:

- Importance of existing submarine links for the grid
- High cost of the maintenance operations
- Need of anticipation to the growing number of submarine electrical installations projected for the coming years

Maintenance strategy

The maintenance strategy design has to begin from the Engineering, Procurement and Construction (EPC) phase. It is important to take under considerations some aspects that will affect the assets in the maintenance operations.

- **SPARE MATERIALS**

They play a key role in the strategy. The company has defined a minimum spare materials stock based on the following fault hypothesis:

1. Faults in two phases of a single-core submarine cable
2. Faults in two areas of a three-core submarine cable

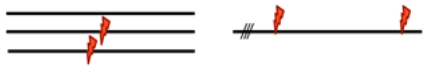

Fig. 2. Fault hypothesis considered for spare material designed

- **SUBMARINE POWER CABLES PROTECTION**

Protection of the submarine power cables is important to ensure the integrity of the assets during its whole life operation. The objective of this is to protect the cable from fatigue, overbending or external damage. The company's experience has proven that burying the cable in seabed is the most effective protection system to prevent any external damage. Other protection methods:

1. Concrete mattresses
2. Rock dumping
3. Sandbags
4. Cast-iron shells

- **AS-BUILT DOCUMENTATION**

All this documentation must be stored following a similar structure for all projects so that all information is easily found and can be used in a unique way and without discrepancies, saving time and misunderstandings when a fault occurs, and action is required in a fast and agile way.

Fig. 3. Cable Protection Systems (CPS)

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Preventive and predictive maintenance

Experience in asset's maintenance has allowed us to evolve from traditional periodic maintenance to a risk-based maintenance model. It is important to analyze the situation of each submarine installation to determine specific actions to implement in order to minimize the risk of failure.

- **CONTINGENCY PLANS –** The aim is to optimize repair times since an optimized planning will save a high cost in the submarine power cable repair.
- **SUBMARINE SURVEY –** Along the cable route in order to be aware of the actual state of the submarine cable. The aim is to detect areas where the cable is exposed or any relevant event that can affect the submarine assets operation under rated conditions. All detected events must be analyzed in order to propose and **schedule maintenance activities.**
- **EXTERNAL AGGRESSION MITIGATION** – Experience has demonstrated that a high percentage of the faults happen due to an external aggression. In order to mitigate this fact, REE has implemented tools and actions to prevent this:

1. AUTOMATIC IDENTIFICATION SYSTEM (AIS) - this system allows to identify vessels sailing above the submarine lines.

2. SURFACE SURVEILLANCE PATROL – The aim of this patrol is to warn on-site those vessels that are ignoring the restricted areas established in the nautical charts and AIS SRMs.

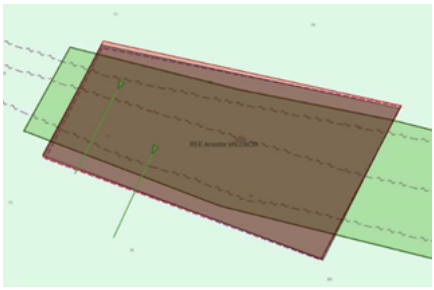

Fig. 4. AIS and surface surveillance

Fig. 5. AIS and surface surveillance

Fig. 6. AIS Alerts in Gibraltar Strait

- **MONITORING SYSTEMS** – These systems take advantage of the fibre optic cable installed inside the power cable or bundled to it to track the changes of the environment and to adequate the maintenance strategy.

  1. DISTRIBUTED TEMPERATURE SENSING (DTS)

  2. DISTRIBUTED ACOUSTIC SENSING (DAS)

- **CROSSINGS IDENTIFICATION** – Crossings with other power or communication cables to establish agreements and protocols between both companies.
- **COMPATIBLE ACCESSORIES DEVELOPMENT** – To minimize the spare material stock and to have less dependence on external agents.
- **COLLABORATION AND COMMUNICATION MANAGEMENT**
- **INFORMING THIRD PARTS** - To demonstrate transparency and avoid misunderstandings that may impact the company reputation.

Fig. 7. Power submarine cable crossing with a FO cable

Lessons learned in the maintenance of REE's submarine lines continued

Corrective maintenance

When a fault occurs, it is essential to be prepared in order to minimize the unavailability of the installation. Over the last years, the Spanish TSO implemented some actions based on the experience to improve the management of faults, in order to reduce the impact and cost of these activities:

- **FAULTS PRELOCATION AND LOCATION** – The company has acquired its own testing equipment and technically trained its personnel to be able to pre-locate the fault and avoid external dependency.

- **FAULT COMMUNICATION** - To the owners of the surrounding infrastructures in order to evaluate the impact of the repair campaign and to agree on the operations to be carried out.

- **PERMITS OF THE MARITIME AUTHORITIES** - The TSO provides support by contacting the Maritime Authorities to explain the situation and to obtain the permits in the shortest possible time.

- **ACTIVITIES SUPERVISION** – Activities carried out by the contractor are supervised to guarantee proper performance of work and to ensure that the operations are being performed following the agreed procedures. We have trained and qualified its own personnel to be able to supervise on board the activities in the repair campaigns.

- **SPARE PARTS MANAGEMENT STRATEGY** – It will limit repair times. Besides this, experience has shown the necessity to have extra joints on board the vessel in case of unexpected events.


Fig. 8. Submarine power cable team.

Phase	Days
Pre-localisation	1
Localisation	2
Offshore activities: unprotect cable	10
Offshore repair activities: 2/3 joints scenario	45/60
HV Test	1
Total	**58/74**

Table 2. Typical submarine cable repair duration for U ≥ 132kV

Conclusions

Through this series of lessons learned, we manage **optimizing** both **response times** and **efficiency in the use of resources**. Thanks to this learning, reduction of costs and enhance of the benefits (in the control and quality of maintenance work) are obtained, as well as greater availability of the assets. REE has implemented the following actions to improve the quality of its maintenance strategy:

- Evolve the periodic maintenance survey model to a risk-based asset maintenance model.
- Development of repair preparedness plans to improve the response times.
- Implement a surface surveillance patrol in areas of high maritime density to reduce the external damage risk.
- Identification of crossing and agreement management.
- Adhere external organizations to promote awareness of submarine cables as critical infrastructure.
- Develop a spare parts management to reduce spare material cost.
- Acquire testing equipment and technically trained its personnel to pre-locate the fault and avoid external dependency.
- Train in-house personnel to supervise the activities carried out by third parties.