Paper ID - 10999 Session 2022
B1 - INSULATED CABLES
PS1/LEARNING FROM EXPERIENCES

Future long-distance AC XLPE submarine cable from Khanom to Samui Island. Guidelines to protect the cable against external hazards

Puriwat SUTTITHAM
Electricity Generating Authority of Thailand
Thailand
Puriwat.s@egat.co.th

SUMMARY

Samui is an island located in Surat Thani Province which is a major tourist area and essential economic zone in the southern part of Thailand resulting in growing electricity demand continuously. However, the present system capacity will be able to accommodate the power demand only up to year 2030. Therefore, the Authority will implement a 230kV 2- circuit AC XLPE submarine power cable project that the distance per circuit between the mainland; called Khanom, and Samui is 52.5 kilometers. In addition, this project will be also the first 230kV submarine project in Thailand.

Samui is largely dependent on power supply from submarine power cable system out of the mainland. Therefore, any damage to the cable could result in a prolonged power outage and the repair work would take several months. The main cause of damage to submarine cables is external hazards. This presents the Authority to design the protection scheme and enhance the power reliability against external hazards for the proposed 230kV submarine cable project.

The project has three principal guidelines in order to protect the cable from external hazards. They are protection design, operation and maintenance, and repair processes, respectively

The design process for protection consists of 8 processes: (1) selection of appropriate cable route to avoid hazardous areas by desktop study; (2) design of cable protection using threat line method; (3) design of monitoring system using Distributed Temperature Sensing (DTS) and Distributed Strain Sensing (DSS); (4) design of fault location system using bridge measurements and Optical Time Domain Reflectrometry (OTDR); (5) design of a shore sighting tower to identify the cable route; (6) design of security surveillance to warn when a ship enters the cable zone (using AIS warning system); (7) planning of spare parts to support maintenance and repair work; and (8) updating of the as-built cable route for mariners through the related marine departments.

The operation and maintenance process consists of continuous monitoring to detect changes and irregularities in operating parameters, inspection when abnormal operation is detected after 1 year from commissioning and every 5 years thereafter, and remedial works when the free span cable and the minimum/maximum cable protection do not conform to the design.

The repair process consists of (1) emergency response contract to reduce repair time; (2) fault location system to check and determine coarse locations of the fault together with signal current transmission technique to verify the fine location of the damage before starting the repair work; (3) repair work; and (4) requalification to re-evaluate the design under changed conditions.

This paper describes details of three principal guidelines as mentioned. An example of calculation method of cable protection is prepared. Finally, aspects of protection methods against external hazards are presented.

KEYWORDS
submarine cable, external hazards, protection

1.Introduction

Samui is an island located in the south of Thailand which is a major tourist area and essential economic zone. This factor results in growing electricity demand continuously within the island and other neighboring islands. With the existing system's capability, though it can accommodate the power demand only until 2030. As a result, the Authority as a national grid utility is planning to implement a 230kV 2-circuit AC XLPE submarine power cable project to serve the area. The cable distance-per-circuit is approximately 52.5 kilometers. That will make this project the first-ever 230kV-submarine project in Thailand.

Presently, Samui relies on power supplying from the mainland; called Khanom, via submarine system. Therefore, any damages on the cable can cause power outages with long duration, saying in hours to days. The repair work also takes several months [1]. For instance, the power outage on March 8, 2021, when an anchor of Navy Ship dropped-on and damaged the submarine cable as shown in Figure 1, causing a widespread blackout of Samui and other neighboring islands. This challenges the Authority to design the protection scheme, against external hazards for the proposed 230kV-submarine project, ensuring power reliability of Samui. The first-circuit of this project is planned to Scheduled Commercial Operation Date (SCOD) by 2027. The project has three principal guidelines in order to protect the cable, prepare for risk allocations, and enhance the power reliability of Samui and neighboring islands. They are protection design, operation and maintenance, and repair processes, respectively.

Figure 1: Submarine cable was damaged by Navy ship.

2. External hazards

External hazards that damage a submarine cable can be divided into two main categories: natural threats and human threats.

2.1 Natural threats are difficult to predict [2]. The most common natural threats are submarine landslides and sediment mobility which directly affect the burial depth. They scour the seafloor beneath submarine cables, causing some cable lengths to become unsupported, known as free span cables. When submarine currents occur at the free span cable, vortex-induced vibrations (VIV) take place. VIVs lead to fatigue of the cable sheath.

2.2 Human threats are the main cause of damage to submarine cables [2]. The most common human threats are fishing and anchoring. The penetration depth of anchoring is generally deeper than fishing. However, fishing and anchoring above the cable route can directly damage the cable.

3. Design of experience

The project has three principal guidelines in order to protect the cable: protection design, operation and maintenance, and repair processes.

3.1 The protection design process

The protection design process consists of 8 processes: (1) selection of appropriate cable route to avoid hazardous areas; (2) design of cable protection; (3) design of monitoring system; (4) design of fault location system; (5) design of shore sighting tower to identify cable route; (6) design of the security surveillance system to warn when a ship enters the cable zone; (7) planning of spare parts to support maintenance and repair work; and (8) updating of the as-built cable route for mariners through the related marine departments.

3.1.1 Selection of the appropriate cable route to avoid hazardous areas

In selecting the appropriate cable route, we should consider the following factors: (1) regulatory requirements; (2) commercial operations, restricted areas, obstructions; (3) geology and seismicity; (4) meteorological and marine conditions; and (5) natural environment. A desktop study should be conducted to collect data on these factors. Cable route selection is an iterative process to find the appropriate route. The result of route selection in this project is shown in Figure 2.

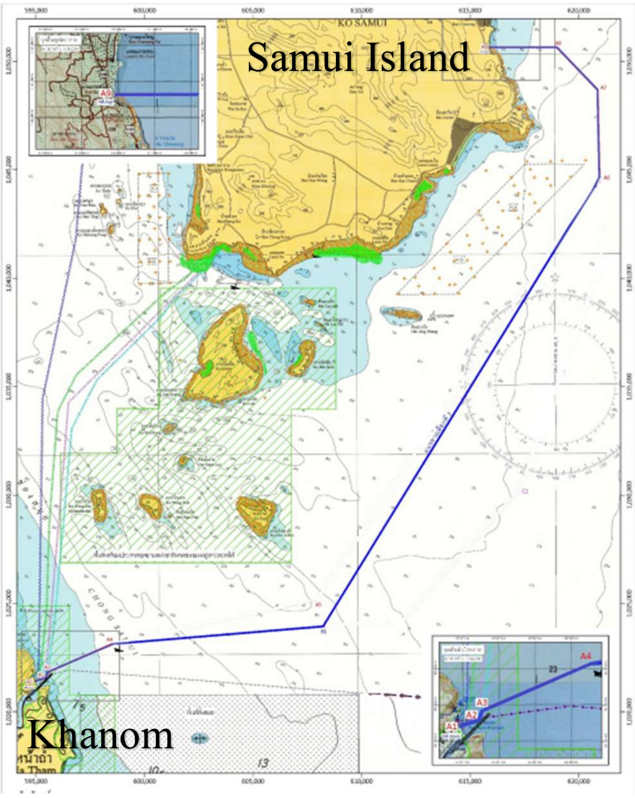

Figure 2: Submarine cable route (Khanom to Samui Island)

3.1.2 Design of the cable protection

This project will evaluate desktop study, survey data, empirical data from nearby cable routes, fishing and maritime activities, cable ampacity, and soil shear strength using the threat line method.

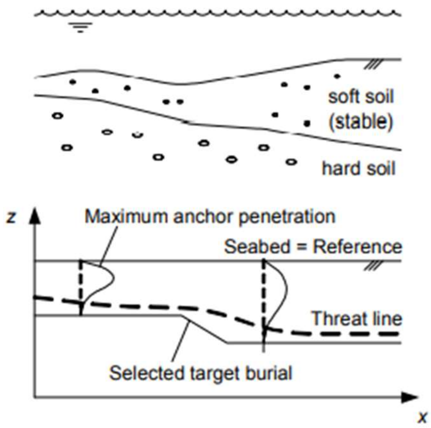

Figure 3 Threat line method

The threat line method is used to determine the depth of penetration of external hazards (e.g., fishing gear, anchoring, submarine landslides, and sediment mobility) into the seabed. Then, the target burial depth is selected as shown in Figure 3 [3]. An example of the application of the threat line method for the Samui Island submarine cable project is given in Table 1.

Table 1: Example of the application of the threat line method

Kilometer Point (KP)		Shallow Geology	Threat Line			Recommended Depth of Lowering* (m)	Comment
From	To		Fishing (m)	Anchoring (m)	Mobile Sediment(m)		
19.00	21.00	Very loose SAND (SC)	0.3	1.86	0.0	2.79	Fishing and small ships

* Recommended Depth of Lowering = (Maximum human threat x safety factor) + Maximum nature threat; which safety factor is 1.5 for shipping or anchoring [5].

3.1.3 Design of the monitoring system

The monitoring system will be selected via an optical fiber in the submarine cable that can be measured online. The monitoring system will detect changes and irregularities in the operating parameters. In this project, the following sensor systems will be selected.

- Distributed Temperature Sensing (DTS), DTS measures the change in cable temperature. It reflects the burial depth of the submarine cable and the impact of the environment. If the submarine cable is too deep or there is a heat source near the cable, the sensor will indicate a hot spot.

- Distributed Strain Sensing (DSS), DSS measures the mechanical stress of the cable, e.g. the free span.

3.1.4 Design of a fault location system

The fault location system is used to find the coarse locations of the damaged points, and the error of the system should not be more than 1% of the cable length. The following sensor systems will be selected.

- Bridge measurement, This method is able to find the fault location by measuring the conductor resistance and needs a parallel healthy cable or a healthy core cable for bridge measurement. In this project, if one circuit faults, another circuit will be used for bridge measurement.

- Optical Time Domain Reflectrometry (OTDR), OTDR is able to find the fault location by transmitting and reflecting a pulse in the optical fiber.

Another popular fault location system is Time Domain Reflectometry (TDR). TDR can determine the fault location by transmitting and reflecting a pulse in cables. However, this method requires determining the actual propagation speed of a pulse in a cable after installation. TDR is more difficult to detect high-ohmic faults [4].

3.1.5 Design of a shore sighting tower to identify the cable route

This project will install a shore sighting tower to identify the cable route to alert mariners near the coast to see the submarine cable route at sea (see Figure 4).

Figure 4: a shore sighting tower to identify the cable route of PEA at Samui Island.

3.1.6 Design of security surveillance system to warn when a ship enters the cable zone

In this project, the security surveillance system will be the AIS warning system. The general operation of the system is that ships travelling at sea are usually equipped with AIS (Automatic Identification System). AIS transmits its position to other ships via the VHF frequency in the marine band. The other ships receive the position of all ships to inform the position of each ship within the radius of the ship 's transmission towers.

For submarine cable operation of the AIS warning system, if a ship enters the vicinity of the submarine cable or passes through the cable zone, the AIS warning system will notify the ship. The system will automatically send a notification to the AIS device installed on the ship. The ship will then know that the area is being passed by submarine cable route. This prevents the ship from dropping anchor or performing activities that could endanger the submarine cable. And the system sends a message to the cable operator via SMS or email. The operating range of the AIS warning system is approximately 23NM and can be extended to a wider area by installing a higher transmitting antenna.

3.1.7 Planning of spare parts to support the maintenance and repair work

Submarine cable systems are tailor-made. When we order submarine cables for production, it takes several months for them to be produced and delivered.

In this project we are using spare parts not only for operation and maintenance but also for installation. We will do a risk assessment of failures to determine the number of spare parts. The submarine cables will be stored on the seabed (wet storage) and the other accessories will be stored at Khanom Substation (near the port). We will check at certain intervals to see if the expiry dates have been met.

3.1.8 Updating of the as-built cable route for mariners through the related marine departments.

After installation and commissioning, an as-built of cable route shall be submitted to us. We will update the as-built of cable route to marine departments. Mariners will see the updated submarine cable route in their map and avoid to fishing and anchoring in that cable route.

3.2 Operation and maintenance processes

The operation and maintenance process consists of continuous monitoring, inspection, and remedial work.

3.2.1 Continuous monitoring

Continuous monitoring aims to detect changes and irregularities in the operating parameters.

3.2.2 Inspection

A cable inspection is used to determine the position and condition of the submarine cable when the cable changes from its as-built or the monitoring system indicates abnormal operating parameters. In this project, we will perform the inspection 1 year after commissioning and every 5 years thereafter.

3.2.3 Remedial work.

If the free span cable and the minimum/maximum cable protection do not comply with the design. Remedial works will be carried out. Appropriate methods to remedy the deficiencies include post-lay burial, mattresses, or rock placement.

3.3 Repair processes

The repair process consists of emergency response contract, fault location system, repair work and re-qualification.

3.3.1 Emergency response contract

Normally it takes several weeks to contact the maintenance team and the ship. In this project, we will make an emergency response contract to shorten the repair time.

3.3.2 Fault location system

The first information about the possible location of a cable fault can sometimes be obtained from the fault recorders [4]. The fault location system is used to check and find out coarse locations of the fault (not more than 1% error of cable length). By transmitted the signal current into the cable, the magnetic field is measured and detected to verify the fine location of the damage before starting the repair work.

3.3.3 Repair work

After we find the location of the damage. Before the repair work, we have to make a repair work plan. For 230 kV submarine cable repair, there are 3 main methods such as "Cut and Lift", "Lift and Cut" or "Cut and Pull" which depend on the location of the damage spot to shore, the water depth at the damage spot, the cable type and the condition of the cable.

3.3.4 Requalification

After the repair work, requalification must be performed. Requalification is a re-evaluation of the cable design under changed conditions before connection to the main grid.

4. Conclusion

In this project, to protect the submarine cable against external threats, we first selected the cable route with the lowest risk of natural and human threats through a desktop study. Secondly, we will design the cable protection for small ships (anchor size = 500 kg). For other ships whose anchor size is larger than the burial design, we will set up security surveillance to warn all ships passing the cable zone, set up a shore sighting tower to warn ships near the coast and update the as-built cable route to mariners. We will also set up an online monitoring system and inspection to check for abnormal operation of the cable. Finally, if we unfortunately find abnormal operation or damage spot, we will have emergency response contract, spare parts, remedial work and repair process to handle this problem.

BIBLIOGRAPHY

[1] CIGRE TB 680, "Implementation of long ac HV and EHV cable systems", March 2017

[2] PG. Allan, "Selecting Appropriate Cable Burial Depths A Methodology" IBC Conference on Submarine Communications, The Future of Network Infrastructure, Cannes, November 1998.

[3] DNVGL-RP-0360, "Subsea power cables in shallow water", March 2016

[4] T. Worzyk, "Submarine power cables. Design, installation, repair, environmental aspects", Springer-Verlag Berlin Heidelberg, 2009

[5] Carbon Trust, "Cable Burial Risk Assessment Methodology: Guidance for the Preparation of Cable Burial Depth of Lowering Specification", February 2015