Challenge of Fault Location on Long Submarine Power Cables

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ABSTRACT

Repair of damaged submarine power cables requires specialized ships and experts to recover the cable from the seabed and replace the faulty cable section. Fast and efficient fault detection is essential to reduce the overall outage time. Fault location on submarine power cables differs significantly from conventional cable fault location on buried land cables in terms of condition and measuring methods. The paper illustrates the most efficient cable fault location methods for submarine cables. Field results relevant to submarine power cable faults are provided, which were measured on AC submarine cables as well as on the longest HVDC submarine links.

KEYWORDS

Cable fault location; Cable joint detection; flashing fault; High resistance cable fault; Intermittent fault; Long HVDC Cable; Long length power cable; low resistance fault; Murray Bridge Method; Offshore wind park submarine cable; Submarine power cables; TDR on long power cable

INTRODUCTION

Development of long submarine cable links are strongly motivated by today´s growing demand on electrical energy. The growth in energy demand requires fundamental re-engineering of the electrical grid structure for availability of electric energy, secure power supply, balance of peak power consumption, as well as linking low cost energy production sites to regions with high electric energy consumption.
Especially investments in technical infrastructures for connecting international electric grids and the drive towards the sustainable use of renewable energy generated by offshore wind parks lead to investment in long submarine cables [1-3]. With growing reliance on offshore-based renewable energy, submarine power cables become more and more important for the power infrastructure. Likewise, the demand for electric power supply of oil and gas production platforms increases.
For protection against external damages, the submarine cables are usually buried in the seabed [1,4-6]. Submarine power cables are designed to withstand extreme conditions for very long periods of time. Despite the mechanical precaution against damage and the reinforced cable armouring, cable faults on submarine cables may occur during operation causing expensive power outages. Cable faults on submarine cables are mostly caused by human activities. Even the most robust designs cannot always survive the natural and manmade mechanical forces present. Ship anchors, fishing gear and dredging are common causes as emphasized in Table1 [7]. Submarine cables are also exposed to a range of natural hazards at all water depths and these include submarine earthquakes, submarine landslides, seabed erosion, turbidity currents, current waves, hurricanes,

Cause	Pre 2007	2007 - 2008
Fishing	67%	33%
Anchors	8%	48%
Dredging	2%	0%
Other	23%	19%

Table1. Submarine cable fault distribution [7]

volcanic activity, free hanging cable sections, fish and mammal bites (e.g. sharks) and other natural hazards [1,4,5].

FAULT LOCATION ON LONG SUBMARINE CABLES

Statistically, the amount of cable faults increases with the number of installed submarine cables. Once a cable fault appears on a submarine cable line, it paralyzes the entire energy transport in that submarine cable line. Often the required electrical energy cannot be substituted by other available energy sources or alternative supply routes, and thereby creates a severe contingency for the Transmission System Operator (TSO). Thus, once a submarine cable fault occurs, the time to find and repair the fault is critical.
Fast response and efficient fault location based on available and well-proven fault location equipment can be applied on buried land cables of short length. However, a cable fault on a submarine cable poses a difficult task for the TSO. Based on standard fault location equipment and standard operator´s knowledge, cable faults on submarine cables are difficult - and often unfeasible - to locate.
Especially faults on long cable lengths may cause unsolvable problems. In particular it has to be understood that cable faults on submarine cables are inaccessible.
Short and medium-length submarine power cables are designed as AC cable systems. HVDC systems are required for the transport of large energy amounts over long distances. Therefore, long power cables are designed as HVDC link. Cable fault location on long and extra-long cables is a particular challenge. On long submarine cables, most of the commonly used measuring methods developed for application on short length of buried land cables are not successful.
A submarine cable typically consists of a number of sections, starting from a HV termination connected to a HV land cable, thereafter connected with a special transition joint to a submarine cable. Depending on cable length and laying depth, the submarine cable may consist of different sections and the cable design may change passing from shallow water to deep water. At the far end, the submarine cable is commonly connected to a land cable ending with a HV termination.
Experience has confirmed that once a cable fault occurs, it most likely appears in the submarine cable section and is less likely to appear in the land section.