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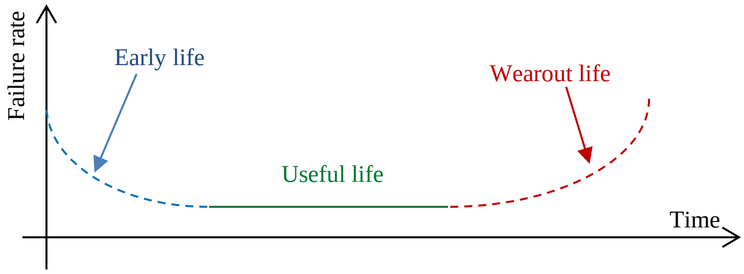
Submarine cables, Life data Challenges and Modeling

Answering the question that if currently available statistical data and models for submarine cables are sufficient for an accurate (or close to accurate) estimation of the cable system failure rates and reliability/availability, it must first be noted that the field data for reliability estimation should be from the same types of items with independent and identical operational and environmental conditions, that is hardly possible for power cables in operation, which are installed over long distances with different ambient conditions and may not necessarily built by the same manufacturer as well as with various operational stress. Second, there are a lot of factors influencing the estimation of reliability function including the cables population size for different types, technologies and voltage levels, the age at failures, fault location (land section, landfalls, submarine section) and relevant further information (land joints, transition joints, offshore field/factory joints, cables environment, water depth, etc), failure causes (internal/external, incipient event/sequence of events leading to a failure), geographical distribution of failures, seasonal dependency, etc. Although failures are generally low for submarine cables due to strict testing regimes, it is even more challenging for the internally caused failures since the majority of reported failures for submarine cables have external causes.

In addition, referring to the well-known bathtub curve for the failure rate variation over time, early-life failures may be misleading about the reliability of the cables technology since they are much related to manufacturing defects, poor quality assurance system and underestimation of significant environmental parameters. Due to the lack of sufficient data, it is also difficult to confirm that there is such a flat part with a constant failure rate for the useful life of the power cables; gradually increasing of the failure rate due to the aging may start immediately after the early life part.



Referring to the latest service experience report of CIGRE TB 815, currently available statistical data provides those details to some extent, however, due to the lacking operational/environmental conditions at the time of failure any attempt for estimating reliability function (and calculating failure rates) will suffer from inaccuracies. Confidentiality and sensitivity of the data for system operators and owners is an additional challenge for availability of the data. This is mainly the reason for discrepancies in the failure rate calculations using different data bases. As a conclusion, it is of crucial importance to determine the extent and conditions of validity of the estimations.

As required for the operational availability calculations, repair time has the same considerations as failure rate that must be taken into account. Influencing factors such as cable technology, route restrictions, weather conditions, availability of proper vessels and resources, preparedness plans, etc (an exhaustive list is provided in CIGRE TB 825) must be detailed in the statistical data, which is generally missing in the published reports of service experiences, in order to have an accurate estimation for the repair time. In fact, the repair of submarine cables is a case specific to high degree that is normally difficult to draw a figure for the repair time.

Knowing the above mentioned facts, model based methods for calculation of the failure rates and having an estimation for repair times are essential for submarine cables, which require deep understanding of the materials degradation (aging) mechanisms and internal/external threats as well as potential barriers that prevent developing sequential events towards a failure. Such an assessment system for a cable under operation will need large volume, various and real-time input data, which will require using big data analysis techniques and hardware (high performance computing machines).

Additionally, assuming sufficient life data and/or proper models are available for acceptable estimations of failure and repair rates, a methodology must be developed/adopted for the operational availability modeling of submarine cable systems considering the most significant influencing factors that is the main contribution of the paper ID 962 in CIGRE Session 2022.

Nevertheless, as can be learned from the available operational data, failures in submarine cable systems are not so frequent enabling to identify the statistical nature, yet they have high consequences. Hence, failures in submarine cables can be categorized in high impact, low probability events requiring its own analysis approach where sequential/cascaded events must be monitored and analyzed. This can be considered in the concept of system resilience, which takes account all hazards and events, preparation and measures prior to, and corrective and restoration operations during and after an unwanted event, as detailed in references CIGRE Technical Brochure 833,' Operating Strategies and Preparedness for System Operational Resilience', IEEE Power and Energy Society Technical Report PES-TR83, 'Resilience Framework, Methods, and Metrics for the Electricity Sector'.

Figure below illustrates different aspects of such a resilience study for submarine cable systems. For each aspect proper indicators can be defined for monitoring purposes. Aggregation of the indicators can provide the operators with degree of resiliency of submarine cables as well as sufficient data for calculating reliability indices such as failure rates and down times in case of a failure.