GUIDELINES FOR THE USE OF STATISTICS AND STATISTICAL TOOLS ON LIFE DATA

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Introduction

The proper and systematic analysis of asset life and failure data is essential for the management of asset intensive industries, such as asset owner/manager of electricity network organizations. The task of providing a sound estimation of the future failure rate of these assets when only very little failure data is available is a challenge. Data sets are frequently incomplete, for instance in cases where utilities started collecting data only recently. Further, the effect of maintenance levels would be expected to influence the outcome of failure predictions; but how can this factor be assessed and checked for its effectiveness? Finally, one often has to deal with heterogeneous data, not necessarily belonging to a single failure mechanism. How to deal with such situations?

The availability, completeness and homogeneity of data differs strongly between utilities throughout the world. The work of WG D1.39 was aimed at providing guidelines to tackle these questions in practice. To that purpose, a number of statistical approaches were studied for the analysis of life data and failure data of high and medium voltage assets in the power network. The ultimate goal is to provide asset managers with advice on how to handle limited and incomplete failure data and which tool to use to obtain a representative future failure estimation based on the historical records of the population.

In different study committees within Cigré, ample attention is paid to reliability and asset management issues. In 2010, WG C1.16 published Technical Brochure 422 on Transmission Asset Risk Management. In TB422 one chapter is devoted to assessing the risk of equipment performance and the use of health indexes. This chapter partly overlaps the work described in our brochure. Only recently, WG A3.06 “Reliability of High Voltage Equipment” has prepared a total of six Technical Brochures (509-514) **Fout! Verwijzingsbron niet gevonden.** that deal with an international enquiry on the reliability of high voltage equipment. WG A2.37 is in the process of preparing a Technical Brochure about a survey of transformer reliability.

Within IEEE, the work of the Statistical Technical Committee of the IEEE Dielectrics and Electrical Insulation Society has led to the definition of an international standard, IEC62539 (IEEE 930) **Fout! Verwijzingsbron niet gevonden.**. The purpose of this standard is *to define statistical methods to analyze times to breakdown and breakdown voltage data obtained from electrical testing of solid insulating materials, for purposes including characterization of the system, comparison with another insulator system, and prediction of the probability of breakdown at given times or voltages*. The focus of this standard is on the use of the Weibull distribution.

Scope/Methodology

The scope of the work of WG D1.39 is related to failure of insulation systems, with an emphasis on the prediction of *future* failure rates based on the statistical analysis of life data. This is where the work of WG D1.39 differs from the work of other Cigré working groups that was focused on the determination of the *current* failure rates (a snapshot in time). This work contributes directly to recent international developments in the area of big data & analytics for predictive purposes. The main goal of the work of this WG was to provide guidelines for the use of statistics and statistical tools to describe and analyze failure data and processes for the purpose of determining future failure rates. An important challenge is how to deal with situations in which there is only very little data available.

The work of this WG is aimed at providing guidelines to tackle these questions in practice through a technical expert study by the members of the group. With a number of international case studies from TSO's and DSO's the application of statistical analysis of life data for asset management decision making purposes has been demonstrated in this TB.

Description of the TB

This TB is divided into 8 sections, as follows:

1. Introduction of the background and main objectives;
2. Broad overview of the definitions used;
3. Description of the main routes to failure of electrical insulation systems;
4. Introduction of the basic statistical concepts needed for a proper analysis of failure data and a description of the different approaches available for a systematic analysis of failure data;
5. The effect of maintenance and replacement on future failure statistics;
6. Three case studies are presented to illustrate the proposed approaches for failure data analysis;
7. Guidelines for how best to collect failure data;
8. Conclusions.

Case study 1

In fast developing countries such as China, the start of the failure rate bath tub curve with early mortality is of particular interest. The Cox Proportional Hazard Model (PHM) was first introduced in 1972 and widely used in the medical domain to study how influencing factors affected the survival time of patients. Compared with other statistical models, the greatest advantage of Cox PHM is that it can consider the impact of more than one covariate simultaneously, which is exactly the feature required in analyzing those failure data related to early mortality among power cables as is discussed in this case study.
Failure and life data are related to medium voltage 10 kV distribution cables and high voltage (110 kV and 220 kV) transmission cables collected from a regional electricity company in China.

The Cox PHM based approach is capable of providing an accurate and decisive verdict on the outstanding factors such as a particular manufacturer and/or an installation method which are responsible for the failures especially when more than one factor has an effect on cable failures. The model should help asset managers to deal better with early mortality failures as the model can help to identify weak links, with scientific proof, in the procedure of procurement, design and installations.

Case study 2

This case study deals with the statistical analysis of the incomplete life-data of large populations of 10 kV medium voltage cable joints of different types of Dutch DSO's. The procedure is shown for estimating the future failure rates for three populations of joints mainly relying on available life-data. How to deal with missing data is described, i.e. what to do when no information is available on failures in a certain period of time. The failure probability curves of three types of cable joint is shown in figure 1.

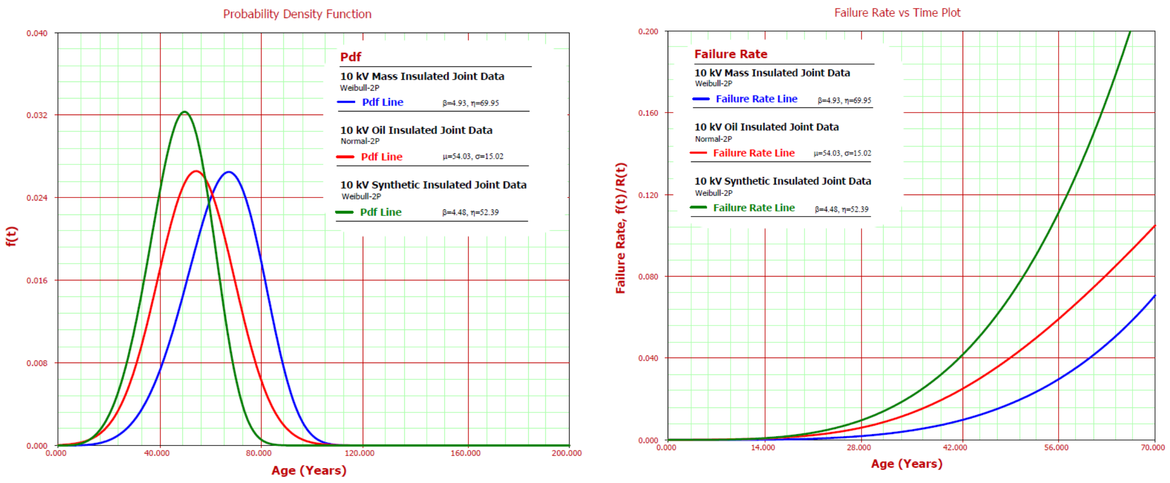

Figure 1 – Probability density functions (pdf) (left) and hazard rate curves (right) for three different types of 10 kV cable joints based on statistical life data analysis of actual utility data.

Moreover, in another case study from the Dutch perspective, the effect of maintenance and replacement on failure statistics is discussed in detail as shown in figure 2. In this case, the analysis considered a continuation in operation of the population as is, with no proactive joint replacements and this option is compared with options of replacing proactively 200, 500 or 750 joints per year over the planning period. The results indicate that the more joints are proactively replaced the lower the numbers of expected failures.

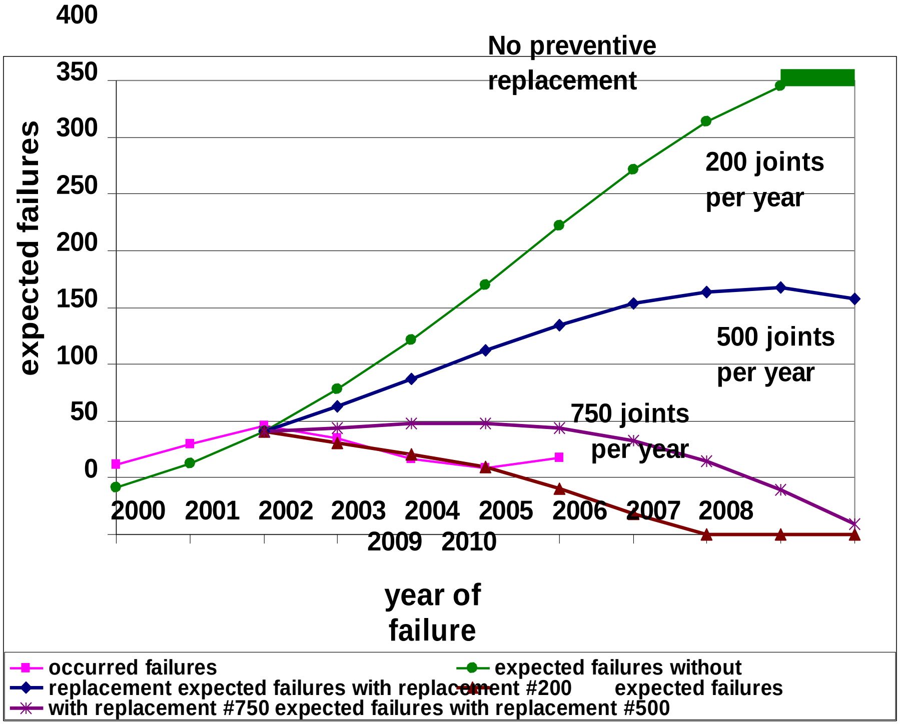

Figure 2 – Effect of a preventive replacement strategy of a number of the oldest joints in service each year on the expected failures development for different number of joint replacements

Case study 3

This study aims to demonstrate National Grid's approach to understanding the deterioration of its transformer assets and prioritizing their replacement and how failure information can inform this process. A number of criteria are used to assess transformer condition. These include consideration of the transformer design family, routine testing of ageing indicators, such as chemical analysis of the oil, as well as information obtained from condition monitoring, where appropriate. A scoring system based on the condition of dielectric, thermal and mechanical elements is applied to each transformer on the National Grid Transmission System to inform its Asset Health Index and this is combined with its Criticality Score to produce a Replacement Priority.

Conclusions

The Technical Brochure presents and discusses a number of statistical tools for the analysis of life data characterizing populations of components installed in power network. The ultimate goal is to provide asset managers with advice how to handle limited and imperfect failure data and which tool should be used to obtain a representative future failure estimation based on the historical records of the population.

The brochure starts with a review of the work done by other CIGRE bodies on the topic of failure statistics. More specifically, currently used definitions of failure were analyzed.

The core of this brochure is related to the collection, treatment and analysis of the life data of medium & high-voltage components. Life data relates to the part of a population still in service (as opposed to failure data) and is often considered more relevant due to the lack or small number of failure data. Ample attention is given to the influence of maintenance and replacement on failure statistics.

Guidelines for data collection are provided. And as well, guidance is provided to the reader with respect to the approach that should be taken through the presentation of a number of case studies. The different approaches presented are employed for the analysis of the life data of populations of medium and high voltage components.

The international case studies show that the main obstacles and problems related to the analysis of life-data are the limited amount of available data, its censoring and its non-homogeneity. Based on the amount and characteristics of the available life data, the decision about the most suitable tool can be taken. Further application of the statistical approaches presented show that the analysis of imperfect and limited data can yield a sound failure expectancy for the asset manager.