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The estimation of electrical performance from highly censored test data

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Sommaire

L'analyse des essais de vieillissement accéléré effectúes sur des câbles de transport d'électricité est souvent difficile, du fait que les données sont en nombres très limités; en effet le taux de défaillance a été trés faible, voire nul. La solution technique préférée consiste à poursuivre les expériences en vue d'obtenir un plus grand nombre de défaillances; or, souvent, ceci n'est pas possible en raison des limitations de temps et de ressources d'essais. Par conséquent, il est essentiel d'analyser les ensembles de données en nombres très limités, car ces données représentent des investissements considérables. Ce rapport décrit et illustre une méthode servant á analyser ces ensembles de données en nombres trés limités, et à tirer profit des résultats d'essais.

Abstract

The analysis of accelerated ageing tests on electrical power cables often prove difficult as the data are highly censored: very few, or often no, failures have occurred. The technically preferred solution is to continue the experiments to give more failures; this is often not possible due to constraints on test resources and time. Thus analysis of highly censored data sets is essential as they represent considerable investments. This paper describes & illustrates a method to analyse these highly censored data and capitalise on the test data.

Introduction

Electrical endurance tests for power cables commonly use elevated temperatures and voltages to accelerate the ageing mechanisms that can occur in service [1, 2]. Analysis of these results then allow the estimation of the possible life of the cable. The standard method for the analysis of endurance data is the Weibull distribution. However endurance tests at stresses close to operational levels often result in very few, or often no, failures: these surviving data are said to be highly censored. In this case the standard Weibull method cannot be easily applied.

The technically preferred solution is to continue the experimentation to gain more failures and reduce the censoring. Often this is impractical given the constraints of test resources and time. Therefore analysis of these highly censored data sets is essential as they represent very considerable investments in time and money. In addition they provide valuable design data on the performance of cables.

Weibull Analysis

The standard method for analysing endurance data (electrical and mechanical) is the Weibull distribution [3 - 5]. The probability (P_f) of a failure at any given time (t) is given by

$$P_f = 1 - \exp\left(\frac{t}{\alpha}\right)^{-\beta} \qquad (1)$$

The time (t) can be expressed in hours, days or cycles. The functionality of the distribution is defined by the scale (α) and shape (β) parameters. The scale parameter (α) represents the time by which 63% of the samples have failed.

To gain highly accurate estimates of the scale and shape parameters large numbers (>100) of test data are required. However for most engineering studies practically useful estimates of performance can be made with as little as 10 test data. Under some experimental test protocols even 10 data are difficult to achieve and often tests are terminated without failure data. In this case we refer to the data set as being highly censored: a censored datum is a unit that has been tested but has not failed. These tests represent considerable investments and some form of analysis is required to quantify the endurance performance of the product. Unfortunately the standard Weibull methods cannot provide good parameter estimates of these highly censored data.