Prediction of power cable failure rate based on failure history and operational conditions

Swati **SACHAN** (1), Chengke **ZHOU** (1) Geraint **BEVAN** (1), Babakalli **ALKALI** (1)

1 Glasgow Caledonian University, Cowcaddens Road, Glasgow, United Kingdom, G4 0BA
Swati.sachan@gcu.ac.uk, C.zhou@gcu.ac.uk, Geraint.bevan@gcu.ac.uk, Babakalli.Alkali@gcu.ac.uk

At present a good proportion of power cables are approaching the end of their operational life. Utility companies worldwide are under pressure from regulators and customers to control both cost and reliability. To overcome this challenge utility companies need an improved methodology to identify circuits in critical condition whilst making forecasts of future failures in order to optimize replacement. This paper proposes a methodology to predict the expected failures in the near future based on the stress endured by the cable on a daily basis, due to operational conditions, and at the same time captures the failure trend based on historical failure data. The existing UK regulatory approach of failure prediction is based on an age-based survival model which simulates the failure data. However, this approach ignores the fact that the life of the cable largely depends on the stress which it encounters during service life.

The methodology used to develop the model is:

1. The total failure rate at any point of time is the combined rate of random and aging failures. The random failure occurrences are due to poor workmanship or manufacturing defects which cause intrinsic weakness; aging-related failures result from the accumulation of electro-thermal stress in daily load cycles due to seasonal load demand and ambient temperature. The electrical stress is associated with the electric field due to voltage and thermal stress, from generation of heat within the cable and impedance of heat dissipation to the surroundings due to high ambient temperature.
2. The historical failure data which captures the random failures are modeled using a non-homogeneous Poisson process (*nhpp*) model. This is due to the consideration that the power cable is repairable. Usually when a cable fails, it is repaired by cutting out the piece which has faulted and splicing in a new piece. It is assumed that the condition of the cable after the repair is never “as good as new”. This is in contrast to the case of cable joint failures which are non-repairable.
3. The operational conditions are modelled using a stochastic electro-thermal aging model in which stress accumulates according to cumulative Miner’s rule and which is considered stochastic in nature, following a Gaussian process. The failure rates from both models are combined using Bayesian approach.

A comparative case study is demonstrated in jacketed and unjacketed XLPE cables which have experienced a total of 3541 failures for the years between 1980 and 2009 and for which distribution of the total number of cable failures in each month of year is available. Therefore, it can predict the expected number of failures in each year as well as each month or season of the year by utilizing monthly failure distribution. Results demonstrate that the failure rate model captures the aspects which affect the failure, such as, random failure causes and the combined effect of electrical-thermal stress. This model is applicable to the type of data available with utilities.