How Cables Fail – Debunking the Myths and Reinforcing the Fundamentals to Ensure Long Cable Life

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ABSTRACT

Solid dielectric cable system failure mechanisms are often presumed unknown due to collateral damage at the failure site. On the basis tens of thousands of meter by meter cable profiles, thousands of defect locations, and hundreds of dissection, this paper will provided evidence to debunk three common myths namely, "cables last 40 years", "Water trees fail cable", and "electrical trees have very short lives." A utility case study involving thousands of kilometers of cable systems will be presented showing how effective cable system partial discharge (PD) assessments can be used to direct precise rehabilitation actions and extend the life of cable systems at a significantly lower cost.

KEY WORD

Cable failure, diagnostic testing, life extension, asset management, root cause, water tree, electrical tree, 40 year life, partial discharges (PD), PD testing

INTRODUCTION

Our industry has often treated solid dielectric cable like a 'black box'. Once a failure occurs in the lab or in the field, efforts are made to observe the remaining evidence to determine the root cause. Unfortunately, collateral damage at the fault site most often destroys all or most of the original defect and thus the final failure mechanism is not definitively known. This vacuum of knowledge has led to speculation and inaccurate theories. Today, factory comparable offline 50/60 Hz PD test technology helping to solve many of the 'black box' mysteries by providing meter-by-meter cable system profiles and locating defects before cable failure. Based on tens of thousands of field aged cables and hundreds of dissections of defects, the authors have witnessed firsthand, how a more precise understanding of failure mechanisms can lead to better material selections, system designs, installation techniques, operational practices and asset management decisions extending the operational life well beyond the commonly suggested 40 years.

"Cables last 40 years" is a myth that many utility engineers have taken as truth. Many utilities have 20 to 30 percent of the cable population in the 30 to 40 year old range. These same utilities typically have budgets limiting the rate of replacement such that the oldest cables will likely be over 60 years old before they are replaced. Despite the cables age, utilities are still only seeing a small percentage fail every year. How can this be? As it turns out, most cables operate in an environment that does not severely stress the cable and hence it can last a long time [1]. This assumes the cable is free of defects and its environment is mostly unchanged over its life. One study [1] suggests that under the right conditions, a typical power cable can last more than 100 years. Figure 1 shows the life expectancy of a cable based on the electric stress and the temperature. It shows, that, a cable with normal operating voltages lasts for many years. It is only when there is high electrical stress and high operating temperature that the cable fails sooner. In theory, based on these extrapolated voltage and temperature performance plots, a cable would have an infinite life under the right conditions. Cables are rarely run at emergency current or temperature levels. With proper engineering protocols, they have sufficient overvoltage (arrester) protection. Cables were engineered to exist underground. Hence, with their mild operating conditions, sufficient engineering design protocols and existing in the environment they were engineered for, they can easily last well past the predicted 40 years. This, of course, assumes that they were manufactured correctly, were not damaged during installation or its operation life, have no accessory issues and have no partial discharge sites located along the cable span.

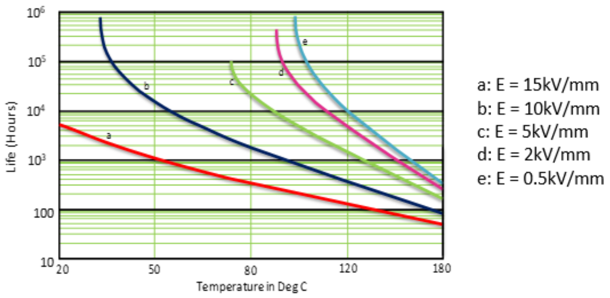

Fig. 1: Electric Stress & Tempereature vs Life Expectancy [1]

"Water trees fail cables" is another myth believed to be propagated by the lack of strong evidence. Water treeing is one of the most widely researched and debated topics associated with early failures of solid dielectric cable insulation. Since the early 1970s, this phenomenon has been the subject of innumerable publications. Electric stress, water, ionic impurities, stress enhancement conditions and aging time are generally accepted as the most important factors contributing to the initiation and development of water trees. Researchers looked at water trees in polyethylene (PE) cables and noticed that the AC breakdown strength (ACBD) was correlated to the length of the water trees. This does not mean that the water tree caused the failure, only that the water tree reduced the dielectric strength of the cable insulation [2]. Figure 2 shows a water tree completely breaching the insulation, yet the cable had not failed prior to location by a factory