# Asset Management Frameworks for Outdoor Composite Insulators

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## ABSTRACT

**Power supply utilities are continuously working to maintain reliable and efficient electrical networks that meet the growing demand for electricity. This is a complex task in which appropriate maintenance, refurbishment and replacement policies for all the assets are critical. Optimising business processes through these constitutes a key challenge of balancing service quality and stakeholder value. Here we present two frameworks that can be used to effectively condition monitor both ethylene propylene diene monomer (EPDM) and silicone rubber (SiR) composite insulators during their lifetime in service. The frameworks are tools to assist asset management decision making. The first framework is derived from a generalized dielectric ageing framework and a more specific one on composite insulators that points out the elements that govern composite insulator materials' ageing on power transmission and distribution lines. The second framework defines four aged states in relation to the risk to failure that a composite insulator has in service before its replacement. Properties of materials that can be measured in order to identify ageing are reviewed. The techniques available as engineering tools for measuring these properties are introduced. These are distinguished as techniques that can be carried out on-line and off-line, and as destructive and non-destructive tests. These techniques are then reviewed in the context of monitoring and maintaining reliable and efficient operation of power networks.**

Index Terms — **Outdoor insulators; Asset management; Ageing; Condition monitoring techniques; silicone rubber; EPDM; composite insulators; Non-ceramic insulators.**

## 1 INTRODUCTION

**MEETING** the continuously increasing demand for power and, at the same time, ensuring a reliable and cost effective transmission and distribution network is a complicated task for the power utilities. One improvement measure has been the adoption of non-ceramic overhead line insulators. The hydrophobic properties of the polymeric insulation [1–4] especially under highly polluted environments [7, 8], their low weight and ease of installation as well as the recent advantages in their design and manufacture are the key features that are driving the replacement of the traditional ceramics [7]. However, limited service experience of polymeric insulation strings and the need to match the excellent performance of the ceramics [8] has led to a great number of papers on the ageing mechanisms [9-19] of

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polymeric insulation as well as diagnostic techniques to evaluate and monitor the insulators' state [20-22]. The value of the diagnostic techniques available to date; whether assessing the ageing of the insulator visually, chemically, electrically or mechanically is indisputable. Nevertheless, a big question arises concerning the potential of these techniques to effectively manage ageing insulators' states within a utility. The answer to this question lies in understanding:

- The ageing processes of polymeric insulations;
- The failure modes that can occur;
- The potential of the diagnostic techniques available;
- The value of the potential diagnostic techniques to utilities.

The five-layer framework presented in [23, 24] is a tool that incorporates the above points by providing asset managers, engineers and scientists with a common platform where these can be discussed and missing "knowledge" can be easily identified. However, the framework presented is a general tool that is not specifically geared to individual plant items or insulation systems. For example it can be applied to cables, transformers, and transmission or distribution line ageing. In this work we are focused on how this general framework can provide a platform of information of ageing mechanisms and monitoring techniques in order to assist asset management of composite insulators. Effective asset management, Figure, of outdoor composite insulators means a good understanding of the ageing process in combination with accurate, focused and cost effective application of monitoring techniques.

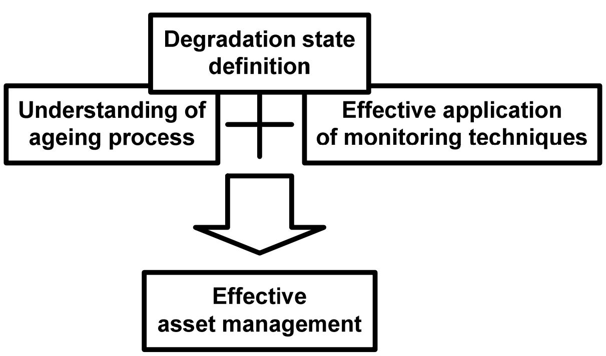


**Figure 1.** Illustration of effective asset management logic.

# 2 AGEING OF COMPOSITE INSULATORS

## 2.1 FAILURE MODES OF COMPOSITE INSULATORS

Outdoor composite insulators are susceptible to two major failure modes. These are:

- Mechanical failure;
- Electrical failure;

Early catastrophic mechanical failure soon after installation is normally attributed to a manufacturing defect. Much improved methods of fitting metal-work to the insulator strength member have reduced such incidences to an acceptable level. In the longer term, mechanical failure can also occur because of severe erosion of the insulation surface, resulting in exposure and stress corrosion cracking of the glass fiber reinforced core. In the latter case, the mechanisms that lead to severe erosion, are normally due to electrical and environmental stresses, i.e. dry-band arcing, or discharge activity.

Less catastrophic but equally important to the electrical system is electrical failure. In practice this means that the likelihood of flashover of an insulator becomes too high, and so interferes with the reliability of the power network. This occurs as a result of increased leakage current, often after a loss of hydrophobicity, with a resultant high occurrence of flashover. Another method of electrical failure is when internal tracking occurs in the interface of the insulation material and the GFR core due to erosion and moisture ingress. This is ultimately seen as a mechanical failure.

Ageing occurs throughout the insulations' service life [10], nevertheless it is not always possible to detect changes in the insulation state. We consider the ageing of composite insulators to occur in two stages [25]. The first stage is when the material ages mainly chemically and the insulation still performs "As New". The first stage is defined from the period from installation and while the insulation retains its initial hydrophobic properties. During the first stage the insulation may age chemically, for example through surface oxidation and migration of the low molecular weight chains from the bulk to the surface that help to retain its hydrophobic properties [6]. The second stage is defined from the time the insulation's hydrophobic properties start to decrease until the failure of the insulation. Historically it has been difficult to identify any quantifiable properties that alter during the early stages of ageing. In this work we introduce the idea of identifying four states of ageing, and argue that it is key for asset managers to identify transitions between these states.

Failure of any insulation which has been type approved for installation, i.e. passed the various short-term electrical and mechanical tests, is unlikely during the first stage. If any such failures are likely to be associated with manufacturing or installation quality issues [7]. Hence the focus of this work lies on the second ageing stage, where observable changes on the properties of the insulation begin to occur and could affect its overall performance. These are outlined below showing how they may progress in time:

- UV Ageing + weathering
- *Decrease of the hydrophobicity*
- Increase of local fields as water droplets grow/merge
- Corona and surface discharges
- Further chemical damage
- Increase of conductivity/ leakage current
- Dry-band arcing
- Increased likelihood of flashover
- Insulation erosion
- Core strength-member exposure
- Mechanical failure