# A study on the chemical & structural changes of thermally aged XLPE cable insulation by FTIR and thermal analysis techniques

Burjupati Nageshwar **RAO**, K.P. Meena, Tirumurthy, Raja G.K: Central Power Research Institute, Bangalore, India
nagesh@cpri.in


## *ABSTRACT*

Experimental investigations were carried out on aged and unaged XLPE samples in order to study the effect of thermal ageing on the chemical changes which take place during ageing. The structural changes observed are due to the formation of carbonyl groups. The x-ray diffraction spectra did not indicate any changes in the position of the peaks or in their splitting for thermally unaged samples at the ageing temperature and duration investigated. This did not lead to any new crystalline phase in XLPE structure, except variation in the intensity of peaks which indicates that hardly any change percentage of crystallinity of XLPE. The moisture detection in service cable using Dielectric spectroscopy tests could be correlated with FTIR tests. The decomposition temperatures of the specimens though are not that distinct from the normal curves; the derivatives precisely show the peaks at which decomposition is occurring. SEM Pictures showed a significant difference in surface morphology between sound and aged cable XLPE samples.



## *KEYWORDS*

XLPE insulation, FTIR, chemical changes, structural changes.


## INTRODUCTION

Electric Power Systems comprises a large number of power cables which are quite expensive. These cables and their accessories, which are subjected to various kinds of stresses during their service life undergo ageing and deterioration of insulation and hence lead to forced outages. Forced outages are of serious concern and are not economical. Ageing processes are complex in general and take place under different stresses simultaneously or sequentially. Thermal ageing is a chemical process like molecular decomposition and oxidation of organic materials. In extruded polyethylene cables failure due to water trees is most common. A water tree is defined as a diffuse structure in a polymer with an appearance resembling a bush or a fan. The analytical techniques like optical microscopy, visible-light micro spectrometry, FTIR, SEM, Energy dispersive spectrometry, transmission electron microscopy come in handy for determination of water trees.

Over the past a few decades, the progressive deterioration of extruded cable insulation is assessed through nondestructive techniques like measurement of Dissipation factor, Loss angle & capacitance, partial discharge (PD) measurements at power frequency and low frequencies mainly for trend analysis. However, determination of remaining life becomes the most difficult part due to lack of well-defined deterioration models, lack of adequate data, and multiplicity of failure mechanisms. The study of structural and chemical changes that insulation undergoes during ageing is scanty and not fully explored which is absolute necessity to understand the deterioration mechanisms. As suggested by CIGRE Working group 33/15.08 [1] there is a need to apply physical / chemical tools like structural, morphological and spectroscopic procedures which do not appear to be in use for dielectric diagnosis. Such an approach seems to be desirable for understanding the ageing mechanisms in a more comprehensive way and to increase the reliability of measurements. In this paper an attempt has been made to understand the structural and chemical changes that XLPE insulation undergoes during thermal ageing.

### EVALUATION TECHNIQUES

In the present study techniques like Fourier Transform Infrared (FTIR), Differential Scanning Calorimeter (DSC), Thermo Mechanical Analyser (TMA), X-Ray diffractometer and Scanning Electron Microscope (SEM) and dielectric spectroscopy technique were used to understand the chemical and structural changes that cable insulation undergoes during thermal ageing.

#### Fourier Transform Infra Red spectroscopy

Fourier transform infrared (FTIR) spectroscopy is a material analysis technique which is used for identification of organic and many types of inorganic compounds, determination of functional groups like carboxyl groups, carbonyl groups, hydroxyl groups and epoxy groups in XLPE insulation. FTIR spectrometer is normally used to study structural changes and analysis of compositions, functional groups of unstressed & aged XLPE cable samples. Alpha model, Bruker make FTIR was used in the present study.

#### Theory of Infrared (IR) spectroscopy

Infrared radiation spans a section of the electromagnetic spectrum having wave numbers from roughly 13,000 $cm^{-1}$ to 10 $cm^{-1}$, or wavelengths from 0.78 µm to 1000 µm. It is bound by the red end of the visible region at high frequencies and the microwave region at low frequencies. IR absorption positions are generally presented as either wave numbers (ν) or wavelengths (λ).

$$\nu \text{ in } cm^{-1} = [1/\lambda \text{ (in µm)}] \times 10^4$$

IR absorption information is generally presented in the form of a spectrum with wavelength or wave number as the x-axis and absorption intensity or percent transmittance as the y-axis. The transmittance (T) spectra provide better contrast between intensities of strong and weak bands because transmittance ranges from 0 to 100% *T* whereas absorbance ranges from infinity to zero.