ABSTRACT

Polychlorinated Biphenyls (PCB's) possessing superior electrical and fire resistant properties were used invariably as capacitor impregnants during the past few decades. These PCB's, have been banned throughout the world in the year 1972, as they were found to be harmful for human beings and living organisms. This present project aims at developing new liquid impregnants as substitutes for PCB's and studying the performance of capacitors impregnated with the newly developed liquids. With these aims, the dielectric properties of different vegetable oils were measured. Of all the oils, castor oil was found to have higher dielectric constant ($\varepsilon' = 4.56$) and lesser dissipation factor (tan $\delta = 0.005$), and is available in large quantities in India. Though the dielectric constant of castor oil is very close to that of PCB's the dissipation factor is higher than PCB's. Hence, the improvement of properties of castor oil by mixing it with certain other liquids was thought of. In the present study, transformer oil, having a dielectric constant of 2.2 with a dissipation factor of 0.002 was mixed with castor oil to get the advantages of both the liquids. The physical, chemical and electrical properties of castor oil, transformer oil and mixed oil were measured. Studies were also conducted with organic additives like toluene, ethylene glycol, ethyl acetoacetate and nitrobenzene added to castor oil. Based on the different properties measured on the above oils, it was concluded that both castor oil and mixed oil (castor oil and transformer oil in equal volume proportion) could be used as substitutes for PCB's as capacitor impregnants.
Paper and polypropylene are the solid dielectrics used in capacitors. The dielectric properties of paper and polypropylene under unimpregnated and impregnated conditions were studied and analysed. Next, encapsulated capacitors with paper-polypropylene dielectric impregnated with mixture of castor oil and transformer oil in different volume proportions were fabricated and their dielectric properties were measured. The results of the measurements indicated that an impregnant mixture containing castor oil and transformer oil in equal volume proportion is an optimum one yielding better dielectric properties. Hence for further studies, paper-polypropylene and all-polypropylene capacitors impregnated with castor oil and mixed oil were fabricated. The dielectric properties including partial discharge levels and body temperature rise were measured for all these four types of capacitors. The compatibility of castor oil and mixed oil with paper-polypropylene and all-polypropylene systems were assessed by using infra red spectrography. An analysis of the performance characteristics of the different types of capacitors showed that paper-polypropylene capacitors impregnated with mixed oil are superior to other types of capacitors in many respects.

To make the investigations complete, aging studies under single stress (thermal) and combined stresses (thermal and electrical) were conducted on all the four types of capacitors. Thermal aging studies were conducted at temperatures of 110°C, 130°C and 150°C taking the end point criterion for failure as the reduction in DC breakdown strength to 2 kV. Aging studies under combined stresses were conducted at temperatures of 40°C, 60°C, 80°C and 100°C and at electrical stresses of 50, 60, 70 and 75 V/μm for paper-polypropylene capacitors and 58,
70, 82 and 88 V/µm for all-polypropylene capacitors. Graphical and linear regression methods including Gauss-Markov Techniques were used to analyse the life data obtained during aging experiments. Based on the life data and practical considerations a mathematical model for predicting the life of capacitors under combined thermal and electrical stresses was developed. The accuracies obtained using the proposed model were found to be better when compared to two other models of leading authors. The superiority of the proposed model is that it can take into account any non-linearity in the log life - log electrical stress plot of actual life data.