CONDITION AND LIFE ASSESSMENT OF LAMINAR DIELECTRIC CABLE SYSTEMS THROUGH DISSOLVED GAS ANALYSIS BASED ON FIELD TRIALS AND EXTENSIVE FIELD DATA

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ABSTRACT

DGA is being increasingly applied to laminar dielectric cable systems in the US, with promising results. The merits and shortcomings of DGA are discussed. DGA behaviour of cables is quite different from that of transformers, and it depends on the type of cable involved and its accessories.

This paper covers the application of DGA to taped cables in the US and France, including the main DGA differences observed in the two countries. Several successful cases showing the extent of insulation damage from minor to severe revealed by DGA-prompted cable system openings are presented. The DGA application to extruded cable terminations has been included.

KEYWORDS

Dissolved-gas-analysis, field-data, taped- and –extruded-cable, reveal-damage, underground-transmission-cable

INTRODUCTION

The extruded cable systems have been gaining increasing acceptance worldwide at higher transmission voltages, and 400 kV underground transmission became a reality in the early-to-mid 1990s. However, enormous quantities of laminar dielectric cable systems are still in service, particularly in the United States where the installed taped cables constitute approximately 18% of world's underground transmission system. A major proportion of the taped transmission cable systems in the world are approaching, or have exceeded their estimated lifespan of 40 years, and decisions have to be made regarding the continued use of these taped transmission cables, including replacements. This places focus on diagnostic methods to perform condition and life assessment on the aging laminar dielectric cable systems, which represent considerable utility investment (e.g., tens of billions of dollars in the US).

The taped cable systems are comprised of three types of cables, namely, high pressure fluid-filled (HPFF), self contained fluid-filled (SCFF), and high pressure gas-filled (HPGF), with minor installations of fluted cables at 69 kV, a cross between SCFF and PILC (paper-insulated lead-covered) cables. While the HPFF cable systems are mostly employed in the US and to a limited extent in France and Mexico, the SCFF cable systems are still in service in many European and Asian countries, although the deployment of the latter is dwindling and removals are on the increase.

Following the successful application of dissolved gas analysis (DGA) to power transformers, the DGA technique is drawing increasing attention for taped transmission cable systems. While the transformer DGA experience is quite useful, particular attention to cable DGA with respect to sampling, analysis and interpretation has to be paid due to inherent differences in the design, materials and operating conditions relating to the two types of equipment. These differences include type of fluids and their viscosities, cellulosic materials, electrical and thermal stresses, marked differences in the degree of insulation tightness and oil movement, as well as operating pressures. The DGA behavior of cables should not be confused with that of transformers, where DGA long predates that of cables and has come to be well understood due the accumulation of massive DGA data worldwide over several decades – the transformer guidelines will call for the shutdown of many otherwise acceptably operating cables. Accordingly, the DGA behavior of cables is radically different from that of transformers and this also holds amongst various types of cables and their accessories.

The US utilities started applying DGA to the taped cable systems in the early 1980s and this pace has accelerated since the mid-1990s; this is generally true for the large French utility (EdF) as well. The majority of the North American DGA data relates understandably to HPFF cable systems, as this type of cable constitutes about 80% of the US underground transmission, and was first installed in the mid-1930s, starting at 138 kV. All the French DGA data discussed in this paper are based on HPFF cable systems, at 225 kV. The data generated on non-HPFF cable (HPGF and SCFF) systems also have been discussed in the paper. While there are several DGA methods described in ASTM (American Standard Test Methods) 3612 such as vacuum extraction, stripper column extraction and head space, depending on the way gases are extracted from the sampled insulating fluid before gas chromatographic analysis, the present investigations are based on EDOSS (EPRI Disposable Oil Sampling System). Unlike other available methods, it is the only known one in which the field sampling and subsequent laboratory analysis are performed in the same very cell, minimizing handling. In addition, EDOSS lends to ready automation, light weight and inexpensive glass disposable sampling vial, long shelf life and ease of shipment of vials in bulk. The small sample size, probably the lowest known in the industry, renders EDOSS most suitable for low fluid volume apparatus, such as extruded cables terminations and transformer bushings. The DGA generated by EDOSS on 138 kV and 230 KV extruded cable terminations that cannot much spare the fluid like laminar dielectric cable systems, have been included.