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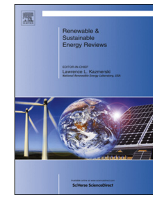

A review of monitoring methods for predictive maintenance of electric power transformers based on dissolved gas analysis

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ABSTRACT

Electric power transformers are the link between the generators of a power system and the transmission lines and between lines of different voltage levels. Power transformers undergo changes in their operational life expectancy and reliability over the years. Currently, several tools for diagnosis and assessment of their operational condition are available, including diagnostic techniques based on dissolved gas analysis in the insulating oil. Through monitoring of dissolved gases in oil, it is possible to perform detailed data analysis, seeking systemic failure prediction. The adoption of new technologies for maintenance of power transformers can induce substantial changes in the reliability of such equipment in view of the existence of a global trend to decrease operational costs, predict maintenances and control substations in a centralized way. This paper describes the main factors that lead to lifetime reduction in transformers and reviews the main methods used for predictive maintenance based on dissolved gas analysis. The advantages and disadvantages of each one are outlined and some future directions for research are proposed.

Contents

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1. Introduction

Electric power transformers are robust and efficient electric equipment that play a fundamental role in supplying electric energy at adequate voltage levels to consumers. Nevertheless, power transformers undergo changes in their reliability and operational lifetime over the years. This is mainly due to the heavy loading of the equipment, driven by the need to achieve increased profits and the related reluctance to invest in new facilities by the power companies in a competitive market environment [1]. Due to improved monitoring and maintenance methods which emerged with technological advances, their lifespan have increased.

Since power transformers have a high cost and are very important to the availability of electrical power systems, several tools for diagnosis and assessment of their operational condition are available. Some diagnostic techniques can be based on the analysis of dissolved gases in oil [2–6], on the monitoring of liquid and solid insulation from the physical–chemical analysis of the insulating oil and analysis of lifetime from the definition of the degree of polymerization of insulating paper, among others [7]. Studies in the past decades have proved that the dissolved gases in transformer oil are related closely to incipient faults [4]. If an incipient failure of a transformer is detected before it leads to a catastrophic failure, predictive maintenance can be deployed to minimize the risk of failures and further prevent loss of services [10]. Therefore, online monitoring and offline testing are vital for assessing power transformer conditions [11].

Methods of diagnosis of potential faults concealed inside power transformers have attracted much research interest [5]. Dissolved gas analysis (DGA) is a common practice for incipient fault diagnosis and preventive maintenance of power transformers. These methods test and sample the insulation oil of transformers periodically to obtain the constituent gases in the oil due to breakdown of the insulating materials inside the equipment [6–12]. When there is any kind of fault, such as overheating or discharge fault inside the transformer, it will produce a corresponding characteristic amount of gases in the transformer oil [9]. Through the analysis of the concentrations of dissolved gases, their gassing rates, and the ratios of certain gases, the DGA method can determine the fault type. As study results indicate, corona, overheating and arcing are the three main causes for insulation degradation in power transformers [6]. In DGA, the fault related gases commonly used are hydrogen (H_2), methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4), ethane (C_2H_6), carbon monoxide (CO), and carbon dioxide (CO_2). Therefore, if we forecast these dissolved gases content in power transformer oil according to the recent historical data, incipient failures of power transformer and its development trend will be found out early, minimizing the probability of a transformer loss [5].

It is possible to monitor various parameters of a transformer, enabling early identification of failures, so that they can be treated predictively. Various types of sensors can be installed on the transformer to measure variables such as the temperature of the oil and the windings, the dissolved gases and moisture content of the oil, the capacitances and power factor of the bushings and the contact wear on load tap changers. The data obtained by these sensors can be analyzed and the results used to indicate if the equipment is under some kind of fault or close to one. A risk analysis can also be performed on the data to calculate important indicators such as the probability of failure of a transformer operating at a certain condition.

2. Electric power transformers and maintenance

2.1. Constructive aspects

Transformers applications are diverse and they are widely used by the industry and distribution and transmission systems. In these installations the transformer is commonly used to lower or raise the system voltage level [13].

The lifetime of a transformer is mainly determined by its insulation system, such as the type of material used and how it was manufactured [14].

The insulation system is designed based on factors determined by the shape and characteristics of the active part (set comprised of core and windings of a transformer) and the gradients of temperature specified. Among the various materials that make up the cooling system we can highlight the radiators (the main component of this system), fans, pumps and insulating oil, used as a refrigerant. The heat load to which the internal components of transformers are exposed to is severe so that the cooling system is essential for its proper functioning, emphasizing the fact that these systems vary according to the operational context (conditions and environment) and the power capacity of the transformer.

2.2. Maintenance methods for electrical equipment

Maintenance is considered a strategic activity that ensures operation reliability of equipments and industrial processes. Maintenance should seek the intervention in equipment through a strategy of reducing the intervention time, leaving the system unavailable for the shortest time possible [7].

Among the various forms of maintenance we can highlight four main types which are:

- Corrective maintenance;
- preventive maintenance;
- predictive maintenance; and
- proactive maintenance.

2.2.1. Corrective maintenance

Corrective maintenance fixes flaws and performance indexes through system restoration. This form of maintenance can be divided into two types, namely:

- Unplanned corrective maintenance: failure is corrected randomly, without an intervention plan.
- Planned corrective maintenance: correction of fault and/or performance occurs in a planned manner, due to flaw detection through preventive and/or predictive maintenance, ensuring reduced costs and implementation time.