Modeling of Early Stage Partial Discharge and Overheating Degradation of Paper-oil Insulation

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ABSTRACT

The power transformer is one of the most important equipment in the electrical power system due to its cost and potential failure's consequences. To ensure a continuous energy supply, it is needed to assess abnormal condition such as thermal and electrical behavior. From this viewpoint, dissolved gas analysis (DGA) is very useful in detecting internal defects in oil-filled electrical equipment. A system has been developed that allows to simulate partial discharge and overheating in transformer's insulation. By using this system, we have studied on DGA under low temperature overheating in mineral oil and vegetable oil.

Index Terms — **Transformer, partial discharge, overheating, mineral oil, natural ester oil, dissolved gas analysis.**

1 INTRODUCTION

THE power transformer is the essential energy transferring equipment of the high voltage power system. To supply the electric power energy continuously, the soundness of the power transformer is important. To prevent the failure of the power transformer and undesirable electricity delivery interruption, it is needed to assess abnormal condition such as thermal and electrical behavior.

The structure of power transformer is very complicated, it is composed with strucural or supporting system, electrical and magnetic system and insulating system. Among these systems, the insulating system of power transformers consists of oil and cellulose. Both materials generally change their dielectric properties during the life of the transformer.

Recently, the number of transformers which have been operated more than 30 years increases rapidly. On the other hand, existing equipment is required to be used up to or near the limit of the design lifetime to save capital investment. Therefore, the transformer insulation diagnosis technique becomes extremely important to maintain reliability and expect residual life. Specially, detecting faults in transformers such as partial discharge (PD) and low temperature overheating at early stage is useful to use transformer long time.

Dissolved gas analysis (DGA) is used as high sensitivity and efficient insulation diagnosis technique [1-4]. And recently natural oil has been used in many transformers and the study of DGA was stated [5-7]. This study aims to examine the relation between transformer internal abnormality and concentration of dissolved gases, and to evaluate the applicability of DGA method. We have developed a system that allows to simulate partial discharge and overheating in transformers. We have studied DGA under various PD and overheating conditions. This paper deals with the PD fundamental characteristics measurement and the low temperature overheating.

2 DEVELOPMENT OF APPARATUS

In Figure 1 and Figure 2 the developed diagnostic system of transformer which consists of PD part, overheating part and DGA part are illustrated. It has the following five functions [7].

- removing moisture and gas in insulating oil
- generation and measurement of PD in insulating oil
- local overheating in insulating oil
- control of heating temperature and time automatically
- extraction and analysis of combustible gases

In Figure 3 the main chamber to generate PD and overheating in insulating oil is shown. The main chamber consists of a needle –plane electrode system to generate the partial discharges, two ceramic heaters to generate overheating, a glass filter to separate oil mist, moisture and air. After separating, moisture and air are removed by a vacuum pump. The upper space of chamber above oil is replaced by 0.1 MPa argon gas. Two thermocouples are used to measure heater temperature and insulating oil temperature.

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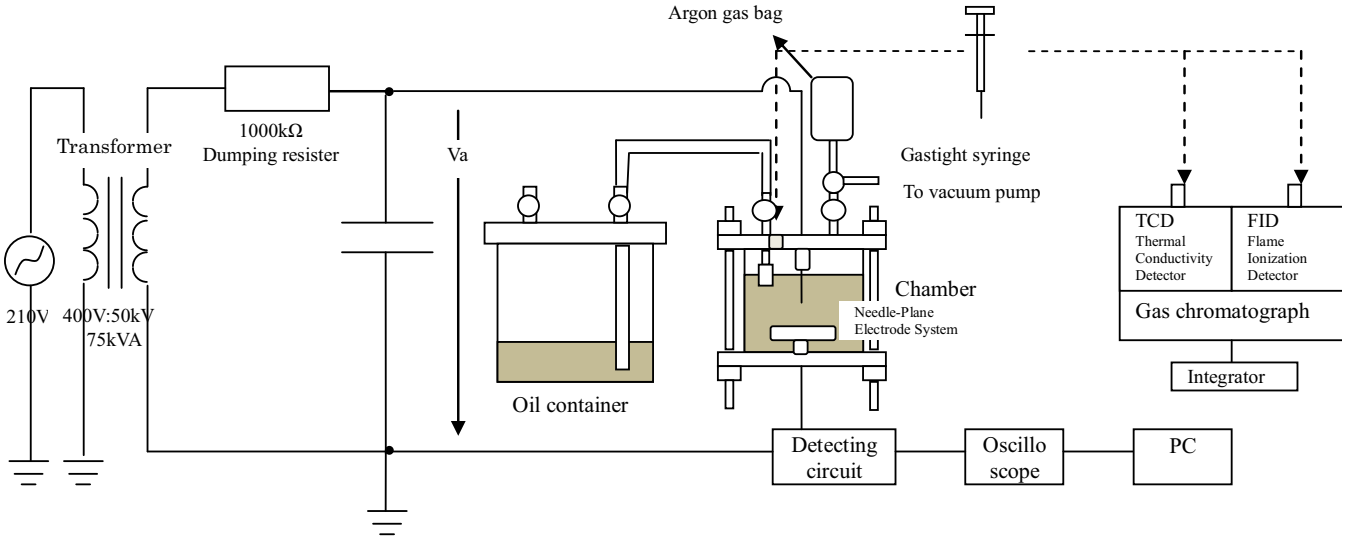

Figure 1. Diagnostic system to generate and measure PD [7].

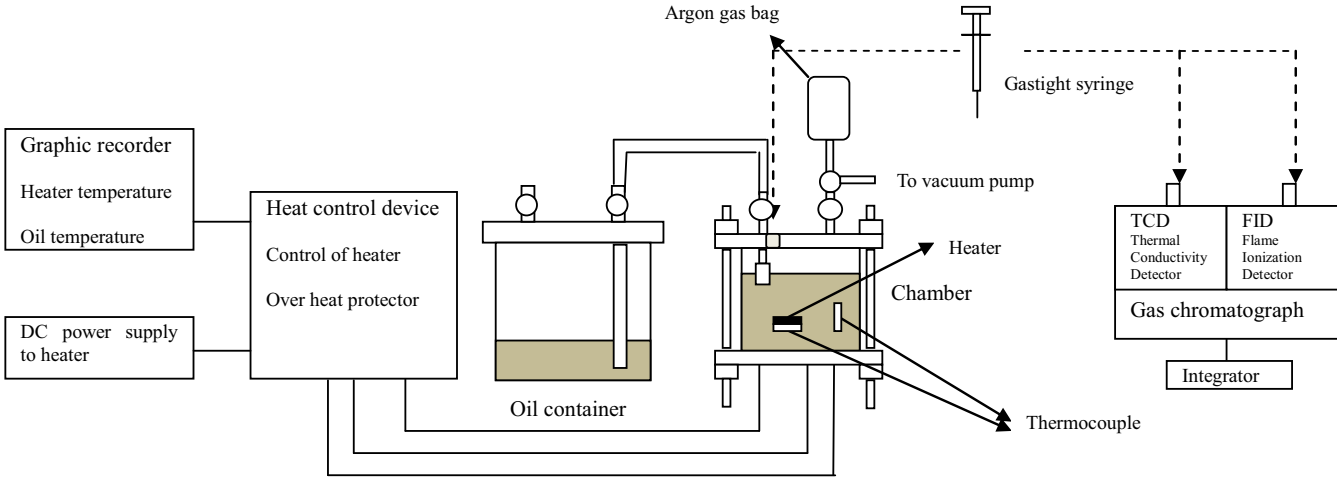

Figure 2. Diagnostic system to generate and measure overheating.

Figure 3. Photograph of main chamber.

The combustible gases were measured both from oil sample and from gas space above oil sample each other. And the total combustible gases were calculated as the sum of two parts.

The combustible gases on oil surface are extracted with a syringe, and analyzed with a gas chromatograph (Shimadzu, model GC-2014). This system has the advantage such as preventing the influence of external factors and shortening measurement time because all the processes can be made in a single chamber.

Every experiments and measurements were carried out at 20 ^{o}C.

3 PD BASIC CHARACTERISTICS MEASUREMENT

3.1 EXPERIMENT

In Figure 4 an experimental configuration of a needle-to-plane electrode system is depicted. A needle electrode having a point radius of 10 μm was utilized to investigate PD