Research the Instrument of Karl Fischer Titration How to Detect the Moisture Content from Transformer Insulating Oil

Original Research Article

ABSTRACT

This article focuses on the monitoring and control of the moisture content from the transformer insulating oil. When its moisture content exceeds the standard value, it will endanger the normal operation of the equipment and cause accidents. Research on how the moisture content penetrates into the insulating oil of the transformer. How to diagnose the moisture content is an important issue under the premise of affecting hidden worries about the quality of power supply？ Currently, there are three types of moisture content detecting: "visual", "calcium carbide method" and "liquid chromatography." This article will use the most accurate and effective "liquid chromatography", also referred to as "Karl Fischer coulometric titration" or "ASTM D6304-20", as the vertical axis and "monitoring and control" as the horizontal axis to analyze and discuss the moisture of generation in transformer insulating oil and detection methods to compose throughout them for an article. When the detecting oil sample has measured without contamination under normal procedures which has 30 to 35 ppm of moisture content, it is judged as a passing standard by ASTM D6304-20. If it exceeds standard level, the transformer equipment must be shut down for being deal with. To pay more attention on the item for detection of moisture content in insulating oil, so be doing that the transformer - related electrical accident failure which will be what It will not happen again similar accidents caused by moisture content. In addition to being a reference for maintenance technicians of substation equipment, this article can effectively monitor the moisture content inside the transformer to ensure the safe operation of the equipment.

Detection Method: the principle of the Karl Fisher Titration detection method is to employ the reaction of chemical between iodine (I_2) and sulfur dioxide (SO_2), and then absorb all the water ($2H_2O$) from the insulating oil, while the chemical reaction produces sulfuric acid (H_2SO_4) and hydrogen iodide (2HI), so by doing to diagnose the moisture content in parts per million (ppm) of the oil sample.

Detection Purpose: To explain " the Instrument of Karl Fischer Titration How to Detect the Moisture Content from Transformer Insulating Oil."

Detection Effectiveness: The most accurate and effective method of liquid chromatography, also known as Karl Fisher Titration which is employed for power companies.

Keywords: Transformer Insulating Oil, Power Transformers, ASTM D6304-20, Moisture Content.

1. INTRODUCTION

Power transformers play the role of important equipment in the power system, and daily inspection, maintenance and monitoring are extremely important task. Because the inside of the transformer is soaked with a large amount of insulating oil, it can insulate the internal components, extinguish the arc, and cool the temperature generated by the coil passing through the load and provide each dissolved gas content analysis. However, its internal moisture has great harm to the insulating medium characteristics of the transformer, because it can reduce the breakdown voltage of the oil and also promote the corrosion of related metal materials to produce saponified substances which deteriorate the dielectric coefficient of transformer oil. [1] [2] And increase the moisture absorption of oil, accelerate oxidation, lead to aging of insulating paper and shorten the life of equipment. Based on the author's many years of experience in serving power companies, the detection of the moisture content from the insulating oil is very important to the operation of the transformer. Based on the author's many years of experience in serving power companies, the detection of the moisture content from the insulating oil is very important to the operation of the transformer. Therefore, this article proposes how employs the most accurate and effective method to monitoring and controlling what the moisture content of the transformer operate.

2. LITERATURE REVIEW

First of all, select a few related articles from many historical documents, and describe the characteristics as follows. [1] [2] This test method is intended for use with commercially available coulometric Karl Fischer reagents and for the determination of water in additives, lube oils, base oils, automatic transmission fluids, hydrocarbon solvents, and other petroleum products. [3] Transformer insulation is subjected to various kinds of stresses such as thermal, electrical, mechanical; ambient that reduces its useful life. Especially, moisture is the major culprit for degradation of transformer insulation. [4] Moisture measurements and absolute moisture content determination by Karl Fisher titration method were performed under controlled laboratory conditions to investigate solubility models of different types and conditions of transformer oils. [5] The moisture content of the ceria Nano fluids has been measured by Karl Fisher titration, which is important for the breakdown strength of transformer oil. [6] Transformer insulating oil is dissolved and analyzed to produce normal and abnormal gases. Afterwards, 1000 normal and 100 abnormal data were collected respectively; those data were obtained from the maintenance records of Taiwan Power Company. Using correlation coefficient of theory to calculate a diagnostic "threshold value," Then applying the traditional estimation and detection theory, by minimizing the maintenance cost of the transformer. A new fault diagnosis method for oil-immersed power transformers was developed. [7] This article analyzes the variation trend of moisture content in insulating oil and paper board. Under the experimental conditions of temperature of 35°C, 50°C, 70°C correspond to the humidity of 20%, 40%, 60%, and 80% separately, the relationship of the insulating oil and paper in equilibrium are proved. [8] Moisture and temperature bring a great harm on the transformer insulation. This article focuses on the research of the relationship between moisture, temperature and dielectric properties of transformer oil with the help of IDAX300 measurement system. [9] The internal desiccant of the transformer oil pillow respirator can reduce the oily moisture of the transformer insulation and improve the oily insulation performance of the transformer. The replacement of desiccant is not only time-consuming, but also has the risk of direct contact between oil and air of transformer.

Based on the characteristics of the above documents and the author's years of experience in serving the power company, it is consolidated into an article to explain "Relationship between moisture content in insulating oil and transformer life."

3. FORMATION OF MOISTURE

When it comes to the moisture in the transformer insulating oil, the author starts with how it is formed along with other substances and the relationship between the various components inside the transformer. The moisture content in the insulating oil comes from the moisture of the atmosphere or the cracking of the fiber insulation material, which leads to the change of the insulation properties of the oil. The solubility of moisture content in oil is related to temperature, acid value and polar substance content. When the temperature is higher or the acid value is higher, the ability of insulating oil to dissolve moisture content is relatively improved. [7] The moisture absorption of the insulation oil increases linearity and

the relative humidity and oil temperature. If the temperature is fixed at 60 ° C, the moisture content is 80 ppm when the relative humidity is 40 %, and the moisture content is 200 ppm when the relative humidity is 80 %. Moisture is distributed between insulating oil and insulating paper, and most of the moisture content is distributed in fibrous insulating materials (such as insulating paper, spacers plate...), oil temperature will affect the moisture content in insulating oil, as far as the insulating paper is concerned, the moisture content does not change much, but it will cycle repeatedly between the winding and the insulating oil as the load of the transformer changes and the temperature changes. Therefore, by measuring the moisture content in the insulating oil, the moisture content of the insulating paper can be estimated. If the moisture content in the insulating paper exceeds the specified value, it will accelerate the cracking of the insulating paper and cause internal failure of the transformer. Moisture content exists in insulating oil has three forms: soluble, emulsified, and free water. Generally, the high moisture content may be caused by the failure of the desiccant from the respirator or the incomplete airtightness of the transformer, those cases may be the transformer respirator fails to inhale moisture from the air (more common), as well as the insulating material in the transformer is aging (less common). [8] It can be known from the above that the correlation between the moisture content of the insulating oil and the withstand voltage will be presented in a graph as shown in Fig.1.

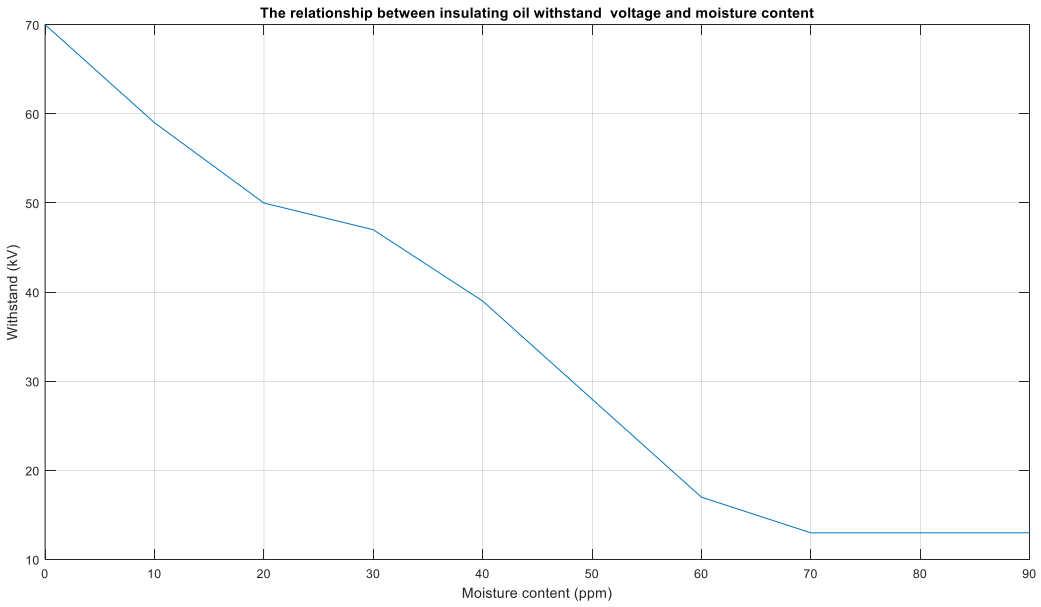

Fig.1 the correlation between the moisture content and the withstand voltage

4. MOISTURE CONTENT DENTENT

Continuing from the above description, the author knows that the moisture content in the insulating oil greatly affects the normal operation of the transformer. In order to ensure accurate detection of equipment maintenance, this paragraph will describe how to detect it. There are currently three detection methods for moisture content in insulating oil: visual inspection, calcium carbide method, and liquid chromatography (Fischer), the most accurate and effective method of liquid chromatography, also known as Karl Fisher Titration which is employed for power companies. [3][4] Every year, the maintenance staff regularly arranged to take oil samples from the insulating oil of the transformer in operation to analyze what the content of dissolved gases, voltage withstand, and moisture from ones. [5]

4.1 Karl Fischer titration

Karl Fischer titration is a titration method that employs volumetric or coulometric titration to detect the amount of moisture content present in a given analyte. This method for quantitative chemical analysis was developed by German chemist Karl Fischer in 1935, and today specialized titrators, known as Karl Fischer titrators, are employ to perform such titrations.[2]

As for the principle of the Karl Fisher Titration detection method is to employ the reaction of chemical between iodine (I_2) and sulfur dioxide (SO_2), and then absorb all the water ($2H_2O$) from the insulating oil, while the chemical reaction produces sulfuric acid (H_2SO_4) and hydrogen iodide (2HI), so by doing to diagnose the moisture content in parts per million (ppm) of the oil sample. First of all, which uses the KF oven method to heat the oil sample in the oven until the moisture content inside the oil sample is released into water vapor and then transferred it to the titration container for measurement.

This precious instrument is expensive, it must be operated by professional technician (with qualification certificates), so the detection accuracy is high.

4.2 Advantages and disadvantages of Karl Fischer titration

Advantages: It is suitable for detection the moisture content in gases, liquids and solids, it is helpful to detect free water, dissolved water and emulsified water, it is a fast detection process and only requires a small amount of insulating oil samples and has high accuracy degree method.

Disadvantages: It is a destructive technique; the detection solvent consumption is high and the solvent volume is refilled every measurement. It is only suitable for insulating oil samples containing a small amount of water, and the test results will take a long time to confirm.

In order to deepen the impression of the equipment, the physical photo of the equipment is shown in Fig.2 [10].

The chemical reaction program between the chemical substances in the detection process is shown in Formula (1).

$$I_2 + 2H_2O + SO_2 = H_2SO_4 + 2HI \quad (1)$$

FIG. 2 Karl Fisher Titration of the instrument [10]

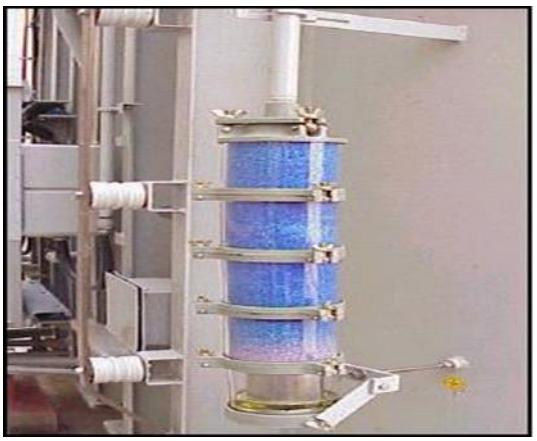

FIG. 3 the transformer respirator [11]

As shown in Fig. 2, only a brief introduction to the structure and principle of the instrument is given. There are many types of such instruments in the market. I am afraid that it will involve commercial activities, so the new instruments of the manufacturer are not shown in this article.

5. TEST PROCESSING

Actual detection steps: The maintenance technicians of the substation regularly take the insulating oil of the transformers in service every year, but this task depends on the weather, and it will be postponed in case of heavy rain or high humidity. To take the insulating oil sample according to the normal standard operating procedure and put the oil sample in a dedicated container. Properly packaged and sent to the professional and technical personnel of the testing department (those who has qualified testing certificates) for testing.

The amount of moisture content in the insulating oil has a great detrimental effect on the characteristics of the insulation properties of the transformer, in addition to reducing breakdown voltage; it will also corrode metal materials, increase moisture absorption and accelerate oxidation, resulting in aging of insulating paper to shortening life of transformer. Therefore, when the oil sample is detected by the Karl Fisher Titration instrument , if the moisture content exceeds the standard by 30 to 35 ppm, the transformer should be shut down to deal with immediately .

6. MAINTEANCE SUGGESTIONS

Looking at the descriptions of the above paragraphs, this paragraph puts forward the matters that should be paid attention to in the daily maintenance of transformer equipment, as follows:

- When filling new insulating oil, to prevent the oil from being polluted by moisture. In addition to testing the oil quality, being must also pay attention to whether the atmospheric humidity is within the standard range.
- When the transformer needs to be opened cover for inspection and maintenance, it should be avoided in rainy days; in case of emergency, it must be properly protected and covered.
- When the desiccant in the transformer respirator changes color (blue to white) because the desiccant inhaled into the moisture from the insulating oil in inside of transformer, it should be replaced immediately to avoid in danger, the equipment photo shown in Fig.3.[11]
- When the transformer oil sample is taken for inspection, the valve is opened and closed to avoid with contamination or moisture.

7. CONCLUSION

For the monitoring and control of the moisture content from the transformer insulating oil, to avoid due to moisture content cause electrical fault. After reading many references, the instrument of Karl Fischer Titration is recommended to use because it is the most accurate and effective presently. Meantime, this article discusses the pollution sources of transformer insulating oil on the power system in service. Then it introduces the detection principle of instrument and the abnormal treatment guidelines. As well as a description of the precautions for daily maintenance, in order to improve the operating life of the equipment and reduce the contribution of maintenance expenditures. To pay more attention on the item for detection of moisture content in insulating oil, so be doing that the transformer - related electrical accident failure which will be what It will not happen again similar accidents caused by moisture content. So, the author hopes it is published on *Journal of Engineering Research and Reports* to share with colleagues in the industry.

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