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Design and Modelling of a Low Cost Embedded System Based Online DGA Monitor

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ABSTRACT: Dissolved Gas Analysis (DGA) is considered one of the best methods for determining the internal condition of power transformers. The concentrations and the generation rates of the fault characteristic gases dissolved in transformer oil can reflect the internal insulation defects and their developments. This method is to find an accurate way to detect the composition and the content of the mixed gas. The conventional method for obtaining this information requires that an oil sample be pulled into a glass syringe and transported to a lab for analysis using a gas chromatograph (GC). Quite often several hours and in some cases days elapse before the test results are obtained. A new method is proposed in which accurate monitoring is done using embedded system applied in Photo spectroscopic analysis of transformer oil. This method of analysis can be effectively and cost efficiently applied over future DGA systems, thus reducing the cost and complexities in maintenance of transformers.

KEYWORDS: Dissolved Gas Analysis, Fault Analysis, Photo-Acoustic Spectroscopy, Smart Grid

I.INTRODUCTION

Transformers are the most critical assets of electrical transmission and distribution system. Transformer failures could cause power outages, personal and environmental hazards and expensive rerouting or purchase of power from other suppliers. Transformer in-service interruptions and failures usually result from dielectric breakdown, winding distortion caused by short-circuit withstand, winding and magnetic circuit hot spot, electrical disturbances, deterioration of insulation, lightning, inadequate maintenance, loose connections, overloading, failure of accessories such as OLTCs, bushings, etc. Insulating materials within transformers and electrical equipment break down to liberate gases within the unit. The distribution of these gases can be related to the type of electrical fault, and the rate of gas generation can indicate the severity of the fault. The identity of the gases being generated by a particular unit can be very useful information in any preventative maintenance program. A reliable model of online DGA monitor using photoacoustic spectroscopy is presented in this paper.

Historically gas extraction from a sample was performed using a strong vacuum pump called `Toepler pump apparatus'. More recently, a new extraction technique called `Headspace Gas Extraction' became a standard in laboratories due to its convenience, excellent repeatability and perhaps more importantly its inherent suitability for automation. Historically the DGA technique comprised of an extraction process and Gas Chromatography as a quantitative measuring method. The DGA analysis would usually be restricted to once a year, thus the fault development could not be properly predicted. Hence the analysis system met the purpose only to some extent.

II. DISSOLVED GAS ANALYSIS

Dissolved Gas Analysis (DGA) is the industry de-facto standard for transformer main tank and tap changer health assessment. The DGA (Dissolved Gas Analysis) provides the inside view of transformer. By analysing the gases we can observer the inner condition of any transformer. Many faults like arcing, overheating, partial discharge can only be detected by analysing the gases only. Historically the DGA technique comprised of an extraction process (such as the aforementioned headspace) and Gas Chromatography (GC) as a measuring method. The provision for online

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monitoring with GC based equipments was very limited. On-line dissolved gas analysis systems continuously monitor dissolved gas content and relative saturation of moisture, detect developing faults at an early stage, enabling to schedule an outage for maintenance and prevent a catastrophic failure from occurring.

III. PHOTOACOUSTIC SPECTROSOPY

Photo Acoustic Spectroscopy (PAS) works along the following principle: A gas substance absorbs light energy following local heating by an IR light and transforms it into kinetic energy (by the energy exchange process). Regularly interrupting this process causes a series of pressure waves (sound) that can be detected by microphones. By measuring the sound at different wavelengths, the photo acoustic spectrum of a gas sample can be recorded. This spectrum can then be used to identify the absorbing components of the sample (3).

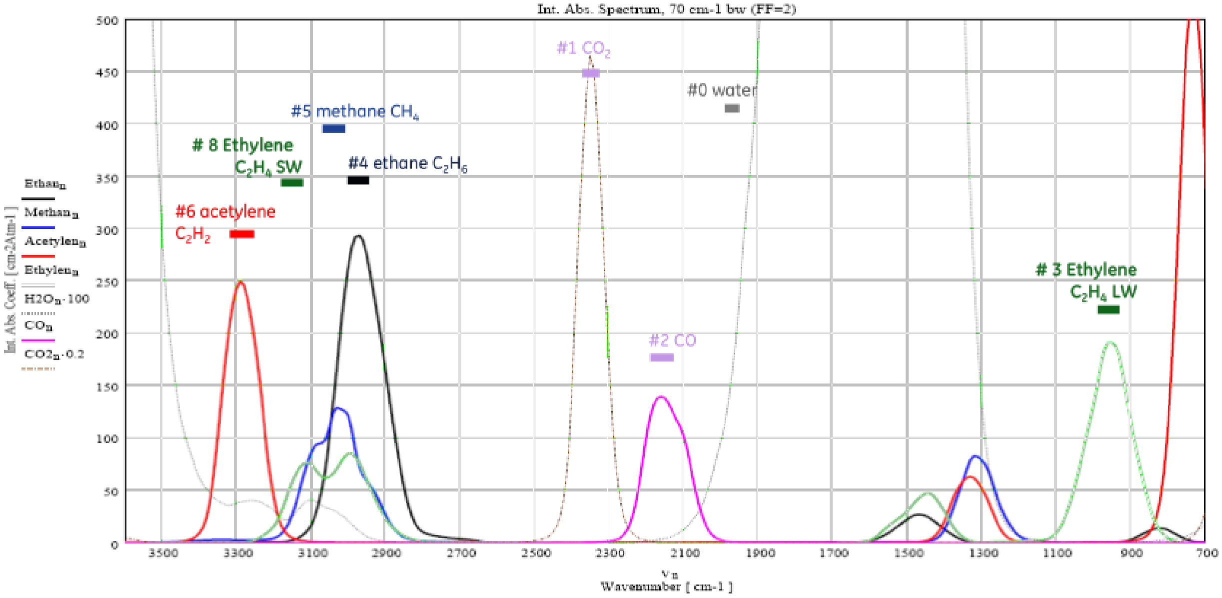

Figure 1. Full spectrum and filter positions for DGA

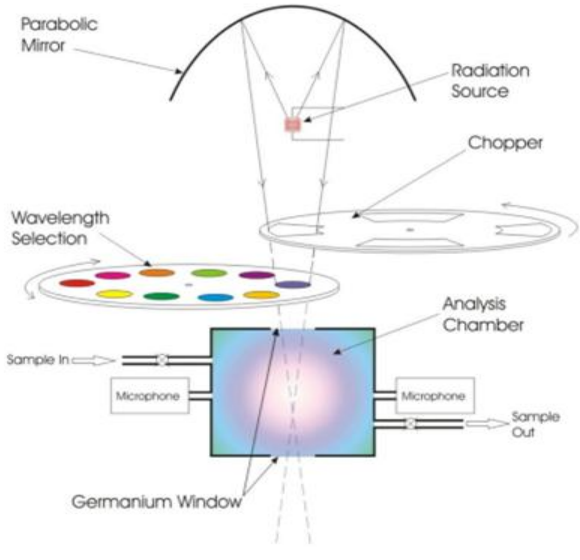

Figure 2. Diagram of a generic photoacoustic analyser.

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The IR energy from the source is focused into the measurement cell, containing a gas sample. The IR energy is pulsed by the action of the rotating chopper wheel and filtered to produce a qualitative and quantitative acoustic signal for a targeted bandwidth.

IV. IMPLEMENTATION

The implementation consists of a microcontroller (Renesas RL78), IR source, filter wheel, stepper motor, microphones, PC, solenoid valve and air pump. Teflon coated magnets contained within the container then proceed to stir the oil which extracts the dissolved gases into the headspace [3]. The gases are then taken from the headspace and are circulated through the sampling loop of the photo acoustic spectroscopy modules. When the gas concentration has reached a stable equilibrium, the IR source is activated. The IR light radiation gets absorbed by the corresponding gas molecules which generate acoustic waves. These waves are collected by the microphones attached to the chamber in which the gas mixture is contained. These collected signals are initially filtered at the RL78 microcontroller, by using a filter wheel which is rotated by a stepper motor. If the signal falls in the required frequency range, the signal is directly passed on to the PC by serial transmission. The signals obtained in the PC are processed by an application developed in Matlab and Simulink. The corresponding fault is displayed on the GUI interface. The working is clearly being illustrated in figures.

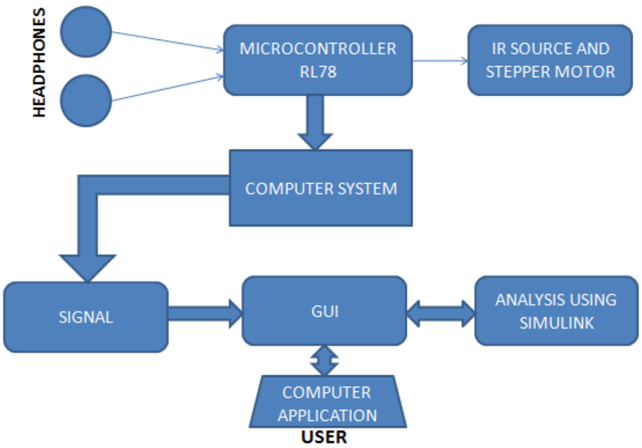

Fig.2 Block diagram of low cost embedded system based online DGA monitor

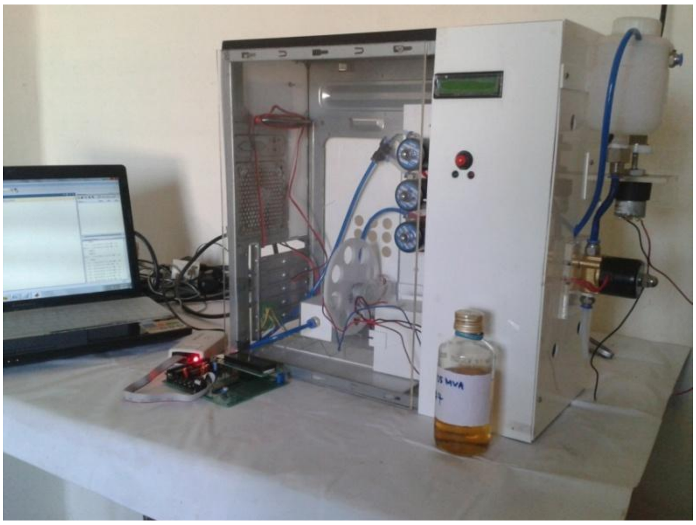

Fig.3 The laboratory model implementation

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V. RESULT AND DISCUSSION

The PAS method of Dissolved Gas Analysis was tested through a laboratory implementation and was found to provide qualitative data regarding the gases dissolved in the transformer oil. The implementation model gave satisfactory results when pure and deteriorated oil samples were tested. Through proper calibration of the equipment, the model application can further be extended to quantitative analysis of samples. The online monitoring of transformers can thus be achieved at reduced cost, compared to the previous methods. The monitoring of all the transformers can be done at the control station real-time, thus paving the way for smart grid.

VI. CONCLUSION

PAS based DGA instruments have been developed with the express purpose of addressing the shortcomings of online GC based instruments. They provide a real alternative to GC by matching their performance and operating successfully in the field. Utilising a technology historically designed for online application, PAS instruments are very stable and repeatable monitoring instruments suited for the tough environmental and operational demands associated with remote transformer monitoring. PAS is the new high-end standard for monitoring critical transformers. The interpretation of gases in the transformer helps in the early detection of the faults in transformer, due to which by taking appropriate action danger of bigger damage can be prevented. A low cost embedded system based DGA monitor is proposed which is able to analyze the transformer health online. Thus transformer faults can be identified at its birth stage and proper remedies can be taken to assure the safety of the transformer.

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