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Review of Partial Discharge Signal Monitoring In Power Transformer Using Chromatic Approach

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Graphical abstract

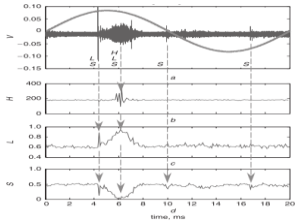

Figure 2 shows HLS results for chromatic processing of RF

Abstract

In partial discharge (PD) phenomenon energy is emitted as electromagnetic emission, acoustic emission and chemical reactions as ozone formation and nitrous oxide gases. One of the continuous conditions monitoring process is done in high voltage equipments such as power transformer. This paper deals with a short review on PD detection methods regarding high-voltage equipments such as electrical detection, chemical detection, acoustic detection and optical detection. Also, new technique for PD signal monitoring in power transformer call as chromatic in the present. The chromatic approach shows the ability to quantifying information content of PD signal by chromatic parameters hue (H), saturation (S) and lightness (L), which can be related to characteristics of PD signal. The chromatic approach shows the ability to yielding new patterns, which monitoring indications of the discharges signals with high accurac and without noise.

Keywords: Partial discharge; power transformer; chromatic approach

Abstrak

Dalam fenomena discas separa (PD), tenaga dipancarkm sebagai panc:tran elektromagnet, pancafimakustik dan tindak balas kimia sebagai pembentukan ozon dan gaI nitrus oksida. PD adalah merupakansalah satu syarat proses pemantauan berterusan dilakukan dalam peralatan voltan tinggi seperti pengubahkuasa. Kertas kaja ini mernbincangkan kajian ringkas menganai kaedah pengesaaaa PD terhadapperalatan bervoltan tinggi seperti pengesanan elektrik, pengesanan kimia, pengesanan akustik dan pengesanan optik. Ia juga membincangkan teknik banr untuk pemantauar isyarat PD dalam pengubah kuasa pengubah yang dikenali sebagai kromatik. Pendekatao kromatik menunjukkan keupayaan untuk mengukur kandurgan maHumat isyarat PD oleh parameter wama kromatik (H), keteuan (S) dan keringanan (L) yang boleh dikaitkan dengan ciri-ciri isyarat PD. Pendekatan kromatik menunjukkan keupayaan unnrk menghasilkan corak baru yang memantau tanda-tanda isyarat dilepaskan dengan ketepatan yang tinggi dan tanpa bunyi.

Kata kunci: Pelepasan separa; pengubah kuasa; pendekatan kromatik

1.0 INTRODUCTION

High-voltage power equipment is critical and costly components. The failure of this equipment without warning, results in fires and damage to equipment. Insulation breakdown is the main type of power transformer breakdown. PD is a main cause of insulation breakdown. PD in transformer can lead to corrosion in solid insulating materials and thus cause a breakdown of concerned operating component in the long term. PD is electrical discharges that do not completely bridge; they are localized to small area within insulation medium. PD can occur when electric field strength exceed the breakdown strength of insulation after that the insulation is unable to withstand the electrical stress and lead to flashover. Studying and monitoring of PD are done to detect insulation problems. Over 50 years, a conventional method has evolved to detect PD activity in cables, transformers, GIS systems and other HV equipment. Generally; some approaches can be used to detect partial discharges in high-voltage power equipment. Some examples of these approaches in high-voltage equipment are electrical method, chemical method, acoustic method and optical method. The existing method of PD signal analysis does not give the right indication of the equipment condition due to disturbances and interferences of noise during detection. Therefore it is vital to have a new method of PD signal analysis in order to give the correct value of PD signals. This paper presents overview of PD detection methods and the application of new method of PD signal analysis in power transformer using chromatic technique.

2.0 CURRENT METHODS OF PD DETECTION

The electrical detection can give good recording of PD signals in the inside laboratory and precision measurements, but very difficult to apply on-site (in-service transformer), due to various disturbance and interference which results in high environmental noise level. The electrical detection includes two methods: ultra high frequency (UHF) method and capacitive coupler method. The UHF method based on electrical resonance at frequency range up to 1.5 GHz due to PD excitation which is used in detection and location of PD source [1,2]. UHF method has some advantages such as low noise levels due to shielding effect of the transformer and very low signal attenuation. The coupler capacitive method can gets the apparent charge by detecting the PD current in detecting coil, impedance, and earth line [3]. The chemical detection used to detect PD in high voltage transformer is done by taking samples such as oil or gas. Chemical detection includes two methods: high performance liquid chromatography (HPLC) and the dissolve gas analysis (DGA). The HPLC gives information of PD signal by products such as degraded forms of glucose induced by degradation of insulation [4, 5]. While the DGA gives information of PD signal in term of volume of gas produced. The disadvantages of this method is that there may be long time delay between enough gas evolution and initiation of PD source to be detectable, which means that the real time cannot be used for online monitoring. Both chemical and electrical approaches are not able to limit the exact location of the detection of PD sources. The acoustic detection can detect and locate the site of PD by studying the amplitude attenuation or phase delay of the acoustic waves. The principle of acoustic method of PD detection is propagation of mechanical wave from discharge site to around medium. The mechanical wave (acoustic wave) induced by explosion of mechanical energy due to vaporization of material inside transformer tank in form of pressure field [6, 7, 8, 9, 10]. The main advantage of acoustic method over electrical and chemical methods is the acoustic system has position information using sensors at multiple locations. The drawback of acoustic method is the requirement of sensitivity. Optical method using optical fiber sensor can measure a wide range of chemical and physical parameters due to its small size, high sensitivity, light weight, high frequency response and immune electromagnetic interference [11, 12, 13]. Usually, optical detection technique is based on fiber optic intrinsic interferometers such as Michelson interferometers, Mach–Zehnder interferometers, multimode fiber and fiber optic extrinsic such as Fabry–Perot interferometric sensors. The Michelson interferometers, Mach–Zehnder interferometers sensors were suffer from the fringe fading problems due to random polarization rotation. Fabry–Perot interferometric sensors are compact in size compared to Michelson and Mach–Zehnder fiber sensors, and therefore achieve virtually single-point measurement. But until now, using an optical method in PD detection has limitation due to measurements sensitivity of sensors are not enough for PD detection. The detection methods such as electrical detection, chemical detection, acoustic detection and optical detection are revisited here. Some advantages and drawbacks of each method have been explored have been discussed.

3.0 CHROMATIC MODULATION METHOD

3.1 Chromatic Modulation Theory

Chromatic monitoring systems have been use in many applications where accuracy and cost effectiveness are important. The chromatic approaches have been under development at University of Liverpool for over ten years. The chromatic modulation is employment of polychromatic light for sensing changes in a physical system. It based on detection of changes in spectral profile of optical signal. The detection of chromatic changes in measurand by monitoring the sum of contributions of relative changes at all wavelengths within a spectral power distribution. Chromatic changes can be monitoring by three photo detectors with over lapping spectral response. The output of each detector expressed as

$$V= \int P(\lambda)\, R(\lambda)\, d(\lambda) \quad (1)$$

Where $P(\lambda)$ is spectral power distribution of optical signal $R(\lambda)$ is wavelength responsively of detector and λ is the wavelength [14].The output of three photo detectors can be referred to as red, green and blue (R, G and B). By algorithm, the (R, G and B) can transform from color science into other representations such as H dominant frequency, S effect signal bandwidth and L nominal signal strength representations.
The chromatic parameters H, S and L are defined as follows:

$$H = 60\ (G-B)/\ \max(R, G, B)-\min(R, G, B) \text{ if } R=\max \quad (2)$$
$$H = 60\ [2+ (B-R)/\ \max(R, G, B)-\min(R, G, B)] \text{ if } G=\max \quad (3)$$
$$H = 60\ [4+(R-G)/\ \max(R, G, B)-\min(R, G, B) \text{ if } B=\max \quad (4)$$

$$L = [\max (R, G, B) +\min (R, G, B)]/2 \quad (5)$$

$$S = [\max (R, G, B) - \min (R, G, B)]/ [\max (R, G, B) + \min (R, G, B)] \quad \text{if } L \leq 0.5 \quad (6)$$

$$S= [\max (R, G, B) - \min (R, G, B)]/ [2-\max (R, G, B) - \min (R, G, B)] \quad \text{otherwise} \quad (7)$$

Where R, G and B output of photodetectors. The chromatic methodology may be briefly by Figure 1. The chromatic processing based on Fast Fourier Transform (FFT) techniques has been shown in Figure 1. The Figure 1 (a) signal to be processed, the output of three detectors transfer from time domain to frequency domain. Figure 1 (b) chromatic processing of each time window by a set of three Gaussian detectors Figure 1 (c) conversion to HLS system or any other chromatic representation system by using algorithm method as shown in equations (2-7) . The chromatic monitoring has advantages such as high optical detection efficiency due to integrative wavelength detection involved, effectively broadband systems, which respond very well to changes distributed throughout a spectrum and insensitive to light intensity changes across the entire spectral.

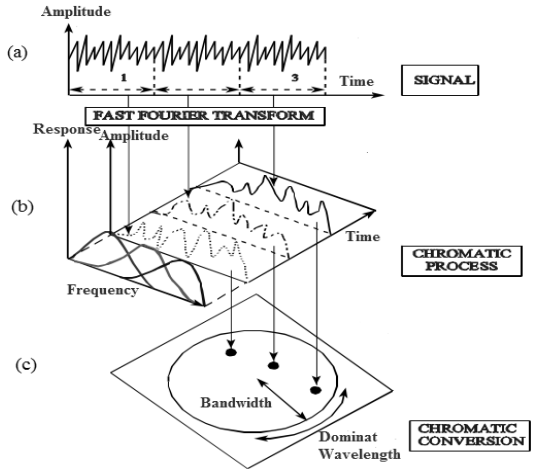

Figure 1 (a) Signal to be processed. (b) Chromatic processing of each time window by a set of three Gaussian detectors. (c) Conversion to HLS system or any other chromatic representation system [14]

3.2 Application of Chromatic Processing of Radio-Frequency Produced by PD in Power Transformer

The PD signal emitted energy as electromagnetic emission such as radio-frequency (RF) and ultra high frequency (UHF). The RF use to detection PD inside oil tank of high voltage power transformer. The transformer was used in this investigation is 500 MVA, 400/275/33 kV unit, which had failure over the last 38 years [15]. The chromatic approach use to PD signal. The chromatic technique using tristimulus deployment is applied to RF induced by PD in oil tank. The methodology of chromatic processing is shown in Figure 1. The results of chromatic processing are shown in Figure 2.

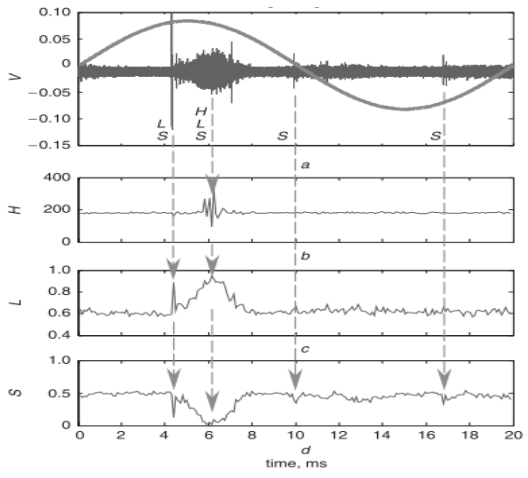

Figure 2 HLS results for chromatic processing of RF [14]

Figure 2 (a) shows orthogonal plot of PD signal detected by RF in power transformer. The PD signal has been processed by passing three filters (R, G and B). The output from filters (R, G and B) are have mathematically processing by algorithm method as shown in equations (2-7) to give three signals defending parameters (H, L and S). The Figure 2 (b) shows The L chromatic parameter which discriminates between strong and weak features of the raw time-varying of PD signal in Figure 2 (a). The Figure 2 (c) shows the sensitivity of S chromatic parameter to some types of pulses. The Figure 2 (d) shows high accuracy level of discrimination of H chromatic parameter. The results of chromatic process show the ability to yielding new patterns, which monitoring indications of the discharges signals with free noise signal.

4.0 CONCLUSION

Although the PD detection has employed conventional methods, recently some alternative methods have been introduced in power transformer. Due to these alternative methods, it is now possible to put suitable method into power transformer using chromatic approach. The chromatic approach shows the ability to quantifying information content of PD signal by chromatic parameters H, S and L, which can be related to characteristics of PD signal. The chromatic approach shows the ability to yielding new patterns, which monitoring indications of the discharges signals with high accuracy.

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