

# Partial discharge signal detection using ultra high frequency method in high voltage power equipments: a review

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**Abstract**— Partial discharge (PD) can be detected using ultra high frequency (UHF) method to increase the detection threshold and to improve the performance of on-line measurement of PD in noise environment. The PD emitted energy as electromagnetic emission, acoustic emission and ozone and nitrous oxide gases. We can use this emitted energy to detected PD signal. The best method to detect PD in gas insulate substation, power cable and transformer is by using UHF electromagnetic wave. UHF method have advantages such as high sensitivity, a good signal –to- noise ratio (SNR). On the other hand, there are still some issues to be solved in the UHF methods, such as a clear understanding of the propagation characteristics of electromagnetic waves arising from the structure of the equipment, optimization of antenna design and calibration of charge. Furthermore, in on-site measurements and laboratory experiments it has been that UHF method gives avery moderate signal attenuations. In this paper, a review on UHF PD sensor connected at extra high voltage-termination of cables, UHF PD signals in a 132 kV gas insulated substation (GIS) transformer are described. Results from the measurement show that this method can give the precise value of PD signal.

**Index Terms**—partial discharge, ultra-high frequency method, gas insulation substation, transformer and power cable

## 1 INTRODUCTION

HIGH voltage equipments are considered as one of the essential elements in electrical network. Any failure in these equipments directly reduces network reliability and increases maintenance costs [1]. PD detection is a technique widely used for high voltage equipment insulation condition monitoring and assessment. In such applications, an understanding of PD mechanisms, characteristics and development processes is important[2]. The insulation system has high risk for dielectric stability when PD occurs. Therefore, measurement of PD is important to prevent high-voltage equipment from damage. PD is an electrical discharge or spark that bridge small part of insulating between two conducting electrodes. PD can occur when electric field strength exceeds the breakdown strength of insulation, and can lead to flashover. The measuring techniques of PD detection are using different physical properties of phenomena such as electromagnetic emission (in form of radio wave, light and heat), acoustic emission (in audible and ultra sonic rages), ozone and nitrous oxide gases [3]. The ultra-high frequency (UHF) generated by PD can be detected by using sensors [2]. The range of frequency between 300MHz-3GHz can be called as UHF range. The UHF signal generated by PD occurred within time-scale of nanosecond (ns). PD signals detected can be used as diagnosis of insulation condition for transformer and GIS. PD detection method by using UHF in GIS has some advantage

such as

wide detection range, high sensitivity and reduce external disturbance [4,5,6]. UHF method to detect of PD is very important in the application of GIS because utilities and manufacturers recognize the suitability of this sensitivity method for monitoring of insulation safety [7,8,9,10]. The major reason to the success of UHF method in GIS is the PD current pulse has short rise time (<100 ps) in SF<sub>6</sub> [11,12]. PD signal can be detected by using UHF sensor installed at the drain/oil valve. For on-line measurements disc shaped and cone shaped sensors are used but measurement conducted in the laboratory uses cone shaped, disc shaped and monopole sensors. The transformer has conventional research on advance detection of PD, The method in transformer has active research been carried out in UHF method application [13,14,15,16,17,18,19,20]. PD detection using UHF method have some advantages such as low noise levels due to shielding effect of the transformer and very low signal attenuation. UHF method can also avoid local interference due to the frequency band is under 100 MHz while the band of UHF method is between 300 MHz-1500Hz. UHF method also has immunity of external noise due to UHF sensor is connected inside the transformer. The connection between UHF sensor and power transformer is non-electrical, so that UHF method is reliable for power secondary and safe.

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## 2 UHF SENSORS FOR LABORATORY TESTS

UHF technique has some application in high-voltage equipments such as GIS, power transformer and cable. Recently the application of UHF for PD detection in power transformer has been increasing area of interest with a more precise results

[21,22]. Locating and detecting of PD in power transformer is vital both in industries and utilities to avoid damage of high-voltage equipments [23,24]. In the laboratory, application of UHF sensors can give excellent results due to minimum of noise generated as compared to on-site measurement.

Some examples of UHF PD sensors in high-voltage equipments for laboratory tests and on-site PD are showed. Fig.1 shows UHF sensor to detect PD in GIS. This type of sensor has well been proven not only for laboratory test but also for on-site PD. The main advantage of the sensor has detection sensitivity very low as few apparent charges. Fig. 2 shows UHF sensor for PD detection in a cable joint, this type of sensor known direction coupler UHF sensor. The sensor has advantageously applicable for checking the right assembling work in power cable accessories. Fig. 3 shows UHF sensor for power transformer for usage DN 50/DN80 gate valve. The sensor can give alternative possibility to measure PD signal, this method known bushing-tap for galvanic connected decoupling. Fig.4 shows inductive UHF sensor for power cable termination. The sensor can give very low detection sensitivity as few PC

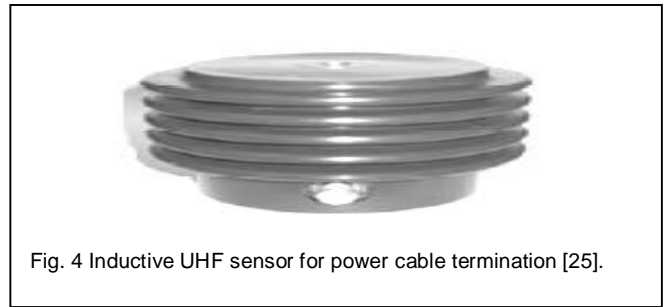


Fig. 4 Inductive UHF sensor for power cable termination [25].

### 3 APPLICATION OF UHF TECHNIQUE IN HIGH-VOLTAGE EQUIPMENT

#### 3.1 UHF PD Detection in Power Cable:

While the cable is in normal operation, the constraint allowing sensitive measurements on plug-in cable connectors can be overcome by using on-line UHF test technique. The principle of UHF diagnosing on plug-in cable termination is shown in Fig.5. The capacitive sensor (electric component) and inductive sensors (magnetic component) detected transient electromagnetic field emitted by PD. The capacitive sensor is copper disc with diameter 2 cm. The inductive sensor is two winding coil. The pulses emitted by PD are pre-amplified, filtered and processed with a computer-based oscilloscope.

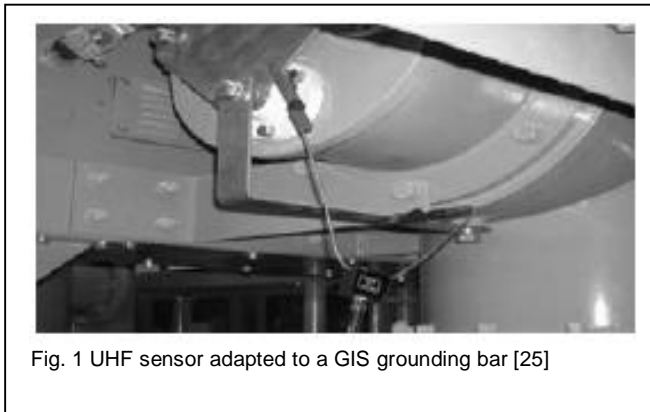


Fig. 1 UHF sensor adapted to a GIS grounding bar [25]

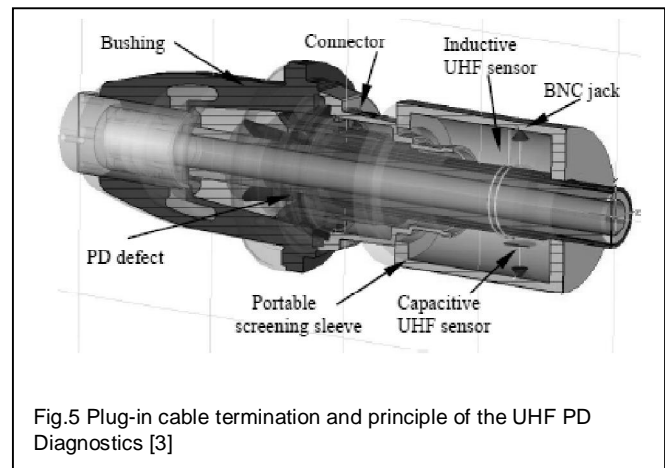


Fig.5 Plug-in cable termination and principle of the UHF PD Diagnostics [3]

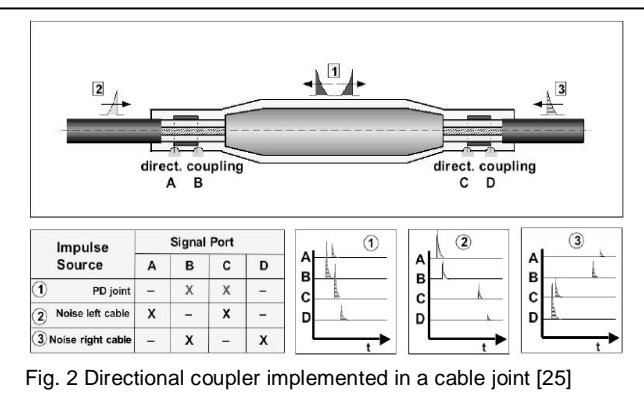


Fig. 2 Directional coupler implemented in a cable joint [25]

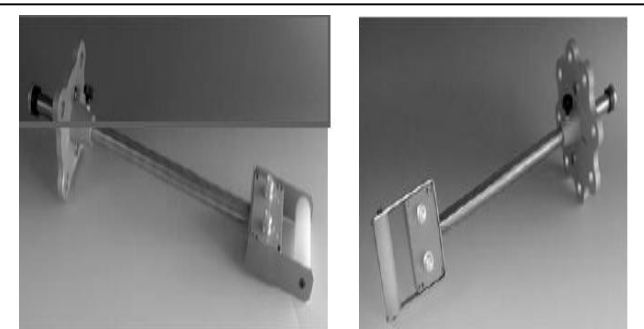


Fig. 3 Oil valve sensor for power transformer reactor e.g. a) for usage on DN 50 gate valve b) for DN 80 gate valve [25]

The results of PD tests are not qualified due to SNR. This is major caused via limitation of measurement frequency less than 500 kHz. We can improve SNR by increasing the measurement frequency more than 500 kHz and by selecting either ultra wide band signal. When the signals travel inside the long power cable, it seems obvious that this technology works selectively due to strong attenuation of PD pulses within a high-frequency spectrum. Therefore, UHF technique is a perfect method to check accessories of power cable such as terminations and joints. The acceptance level of PD in power cable the apparent charge must be less than 10 pc.

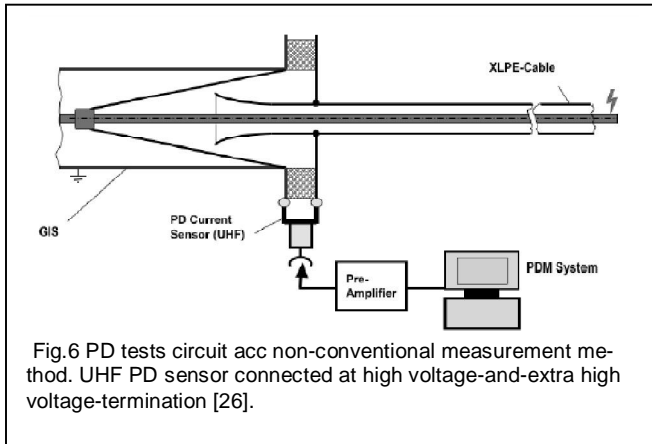


Figure 6 shows schematic diagram of the UHF PD measurement system in power cable. The system consists of UHF PD sensor, pre-amplifier and PD measurement. The UHF PD sensor is connected to GIS-cable termination and the output of this sensor is connected to high-pass filter by coaxial cable to limit range frequency within 300 MHz. It is also connected to a pre-amplifier to increase the SNR. The output of a pre-amplifier connected to PD measurement to PD pulse processing.

**3.2 UHF PD Detection in GIS:**

PD pulse current has short rise time less than a nanosecond (ns) in SF6 gas which is used as insulating gas. The frequency component in UHF band is available in electromagnetic wave generated by PD signal. In the GIS tank, the electromagnetic wave emitted by PD signal can propagate over long distance with very less attenuation so that UHF signals can be detected by using antenna or sensor. There is no influence of different noise arising from broadcast wave or telecommunication signals with very high frequency. UHF method of PD signals has quick response, which detected SF6 decomposition species. In GIS, risk assessment of breakdown is easy to determine due to information on PD phenomena in SF6 gas [27]. There is another method to improve the accuracy of PD localization and enhance the maintenance efficiency in GIS based on UHF combined with acoustic technique[28].

The main reason for attenuation of wave in GIS is power dissipation in metallic enclosure. Very low attenuation coefficient of 2dB/km is present with theoretical result values of about 1-2dB/Km [29,30]. As an example we can take a flat disc to study the effect of a spacer in GIS. It can compute the reflection lossless dielectric disc by using model of a transmission line. To compute transmission coefficient of Transversal Electric Magnetic mode (TEM) is shown in Fig.7 and to compare a coefficient of Transversal Electric (TE), Transversal Magnetic(TM) mode in transmission line with cut-off frequency about 500MHz are shown in Fig.8. We can see transmission coefficient approach zero for both TM and TE mode in some frequency band that showing for every mode available series frequencies are not attenuate.

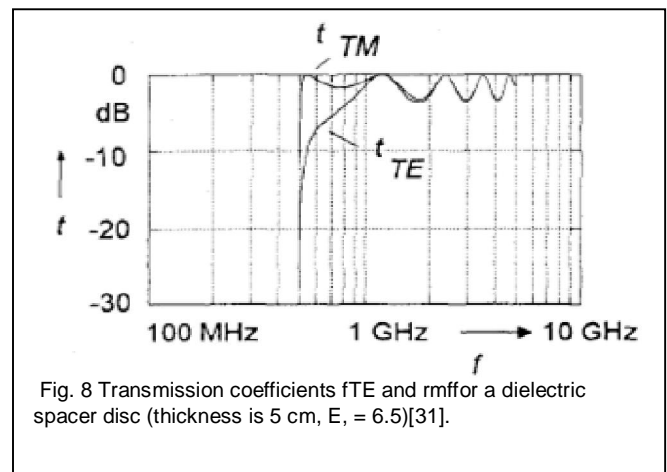
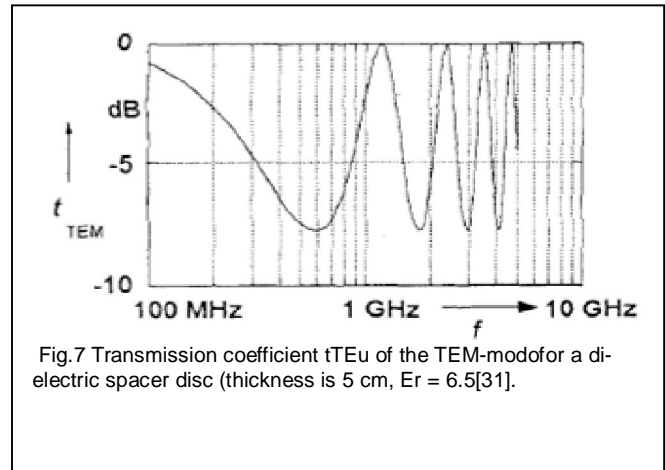
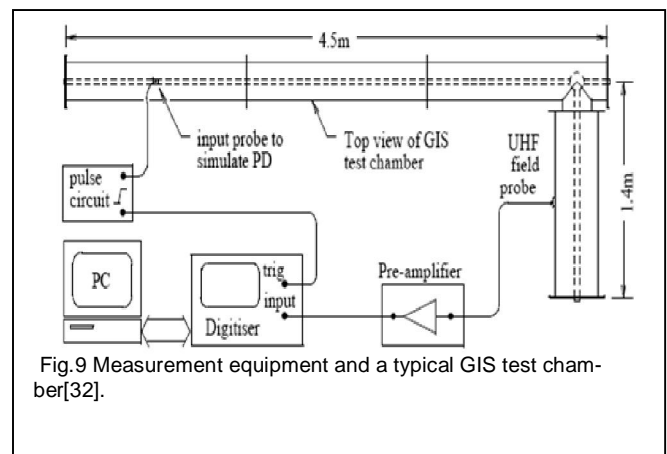


Fig. 9 shows typical measurement arrangements. The system consists of UHF field probe sensor, pre-amplifier, digitizer and personal computer. We can see the signal coming from a sensor; goes go to a pre-amplifier with 25dB gain and bandwidth 1GHz. The maximum record 20ns caught using digitizer, where in each arrangement the first UHF signal was collected via five recorded by the trigger delay (20ns in each step).



### 3.3 UHF PD Detection in Transformer:

UHF PD detection in transformer has been widely used. Some of the advantages of using UHF technique in transformer is low noise level due to shielding, low signal attenuation of oil insulation and sensitive measurement with noise on-site condition due to complete structures.

The laboratory set up of PD measurement in transformer consists of half closed metallic tank with dimensions (1.0 m, 0.5 m, 0.5 m) with a needle sphere PD source, with two similar disc – sensors. The bandwidth of transient record was 3 GHz and no additional amplification is used. Furthermore, there is a metallic wall inside closed half tank to divide tank into two sections, every section has one sensor as shown in the Fig.(10,11). It is also called as “2-path-arrangement”. We can analyze different types of structures and materials in the “2-path-arrangements”. In oil-oil test the pulse energy attenuation was 4.27% -0.19 dB with apparent charge 1.8-3.7 pc. While in solid insulation materials the apparent charge is 2.7 pc. Fig.12 shows comparison between attenuated and unattenuated signals.

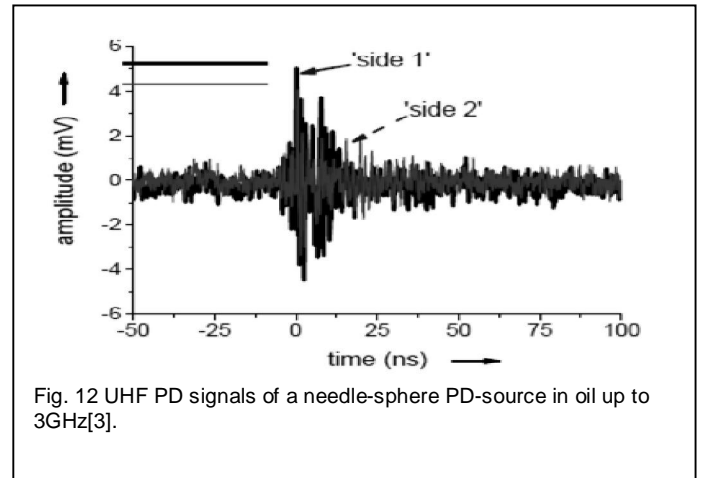


Fig. 12 UHF PD signals of a needle-sphere PD-source in oil up to 3GHz[3].

Figure 13 shows typical UHF monitoring system. The system consists of UHF sensor, amplifier, detector, data acquisition and computer. The UHF sensor is inserted inside the tank of the transformer. The output signal of UHF sensor is connected to the amplifier which will be filtered and detected.

Finally, the signal data will be monitored and stored in a computer. Patterns of these data can be recognized by using intelligent software [33].

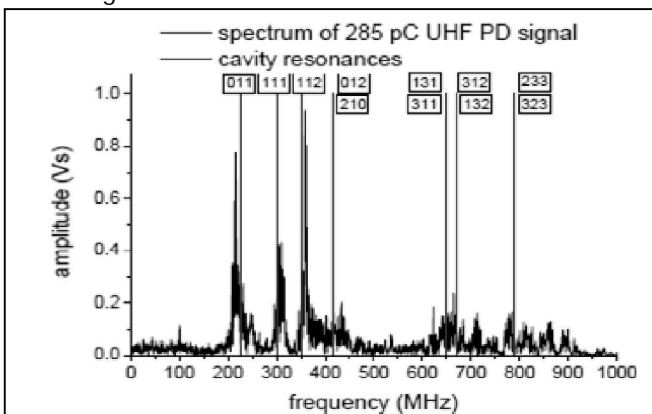


Fig. 10 UHF PD spectrum of a rod-plane PD source (apparent charge 285 pc) with some dominant cavity resonances [3].

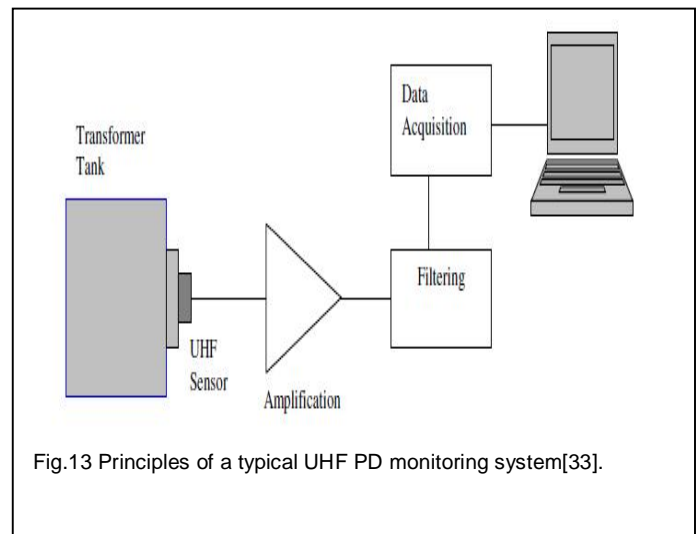


Fig.13 Principles of a typical UHF PD monitoring system[33].

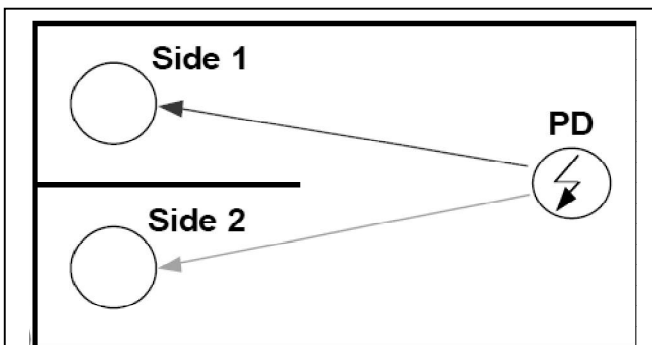


Fig. 11 Schematics of the 2-path test setup: top view of the two sided experimental setup with half-closed test tank (1.0x0.5x0.5) m3, two disc-sensors and needle-sphere [3].

## 4 CONCLUSION

This article deals with UHF PD measurement in high-voltage equipment such as cable, GIS and transformer. UHF method of PD measurement can be used to perform diagnosis of insulation of the effective power apparatus. The laboratory experiment and on-line UHF measurements gave a low-noise level with a very high sensitivity. Due to this reasons, this method of PD detection and measurement can be considered as future technique which will give a more precise PD values.

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