DEVELOPMENT AND APPLICATION OF UHF PD DETECTION SYSTEM FOR SF_6 INSULATED MV SWITCHGEAR

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ABSTRACT

Defects in the SF_6 MV(Medium Voltage) switchgear can result in failure. Therefore it is important to detect defects, such as protrusions and particle, in time and to determine their risk for a possible breakdown. For high voltage apparatus, the UHF(Ultrahigh Frequency) PD(Partial Discharge) detection technology has proven to be a sensitive method. In this contribution the development of UHF PD detection system for the MV switchgear and its application are described. Experimental studies show that the PD detection of the MV switchgear defects is possible

INTRODUCTION

Determining whether SF_6 MV switchgears (Fig. 1) are suffering from dangerous levels of PD is important because failure without warning can result in damage to neighboring equipment, customer dissatisfaction and disruption to economic activity. Detection of PD in MV switchgear can be seen as a means of anticipating imminent MV switchgear failure, thus saving the cost and time. The conventional IEC 60270 method, which can be calibrated, is always applied during quality assurance testing in the factory. However, such low frequency PD detection methods are not suitable for field application as a result of excessive interference from other station apparatus and electromagnetic interference [1-3]. PD pulses in SF_6 produce electromagnetic waves with frequencies that extend well into the UHF range. Therefore, this external noise problem can be overcome through use of the UHF PD detection method in which PD is detected at UHF frequencies (300MHz ~ 3GHz) through use of UHF sensor [4-5].

In this paper UHF detection technique has been used to detect PD activity in the MV switchgear. We developed the UHF PD detection system based on the narrow band system. The narrow band UHF method compared with the broadband method has the advantage that PD signals can be distinguished from external signals in a densely occupied UHF frequency spectrum so that much better S/N ratios can be achieved [6].

To detection of UHF PD signal in MV switchgear, we design and developed internal type UHF PD sensor which was designed based on the spiral antenna theory. The sensors were mounted on the 24kV MV switchgear tank through sensor installation hole, which maintain the gas seal. UHF PD signals from the sensor were amplified using a 20dB gain, 100-2000MHz amplifier and recorded using a commercial spectrum analyzer (Anritsu MS2721A). After a PD data measurement complete, analysis based on the phase resolved PD pattern was processed to distinguish the PD sources (protrusion, free moving particle, floating electrode, insulator defect and noise).

Nevertheless it is not possible with those techniques to establish a direct relation between the apparent charge in pC and the output level of the sensors expressed in dBm, the results clearly indicate that UHF PD detection and analysis of MV switchgear is an excellent tool to assess its dielectric condition.

Fig. 1. A photo of SF_6 MV switchgear

UHF PD DETECTION SYSTEM

To detect PD in the 22.9kV SF6 MV switchgear the UHF detection method has been used. To pick up the electromagnetic waves excited somewhere inside the MV switchgear, the internal type UHF PD sensor was used (Fig. 2). This sensor was designed using the two armed

Archimedean spiral antenna theory and the frequency range is 300MHz~1500MHz [7].

Fig. 2. The internal type UHF PD sensor

The internal type UHF PD sensor was mounted on the back side of the switchgear tank. The output port of the sensor directly connected to the spectrum analyzer (Anritsu, MS2721A). Using this spectrum analyzer, the detected PD signals were analyzed in frequency domain, to obtain a frequency spectrum up to 1500MHz and in the time domain (Zero span mode), which were described in the following section. The analysis software which was installed on the notebook computer has been used for data acquisition, save, spectrum analyzer control and analysis of the measuring data.

The basic structure of the UHF PD detection system is shown in Fig. 3. It contains:

1) A internal type UHF PD sensor
2) A coaxial cable
3) A spectrum analyzer
4) A note computer (with the analysis software)

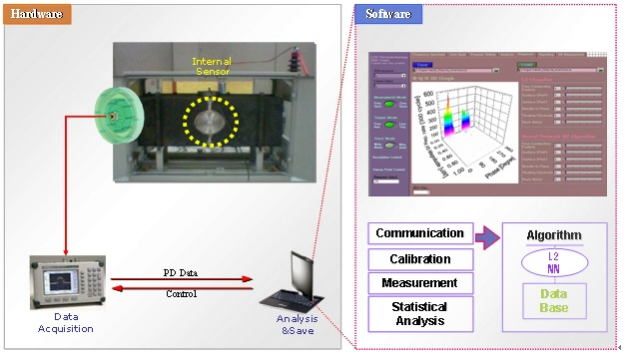


Fig. 3. Structure of the UHF PD detection system for MV switchgear

PD DETECTION EXPERIMENT

Measuring process

First step: In order to avoid background noise (TV station, radar, mobile phone etc) a measurement starts with detection of the background noise frequency spectrum with a spectrum analyzer and sensor. In this case a sensor is installed around the MV switchgear.
Second step: The incoming noise spectrum from outside of the MV switchgear is measured. In this case a sensor is installed on the switchgear.
Third step: In order to find the best frequency band for PD detection, a measurement is capturing the PD frequency spectrum with spectrum analyzer and sensor which was mounted on the MV switchgear. PD pulses are generated using artificial defects which can be frequently generated in the aged switchgear. Based on this measured spectrum, a certain center frequency which represents PD activity with the highest signal-to-noise ratio is selected.
Forth step: A spectrum analyzer can also analyze can also analyze the sensor's output signal in the time domain, resulting in similar phase-resolved PD patterns that are obtained with a standardized measuring system.

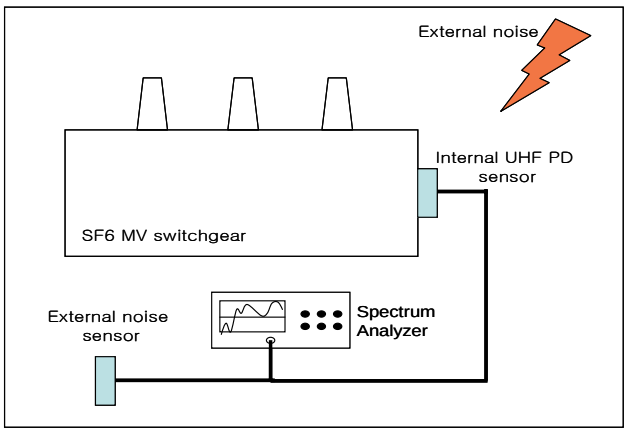


Fig. 4. Block diagram of noise measurement

External noise measurement

The external noise spectrum was measured at four sites with spectrum analyzer, preamp (gain: 20dB) and sensor as shown in Fig. 4. These four sites obtained the external noise spectrum were the downtown area where the MV switchgears were serviced in Korea (Fig. 5).

Fig. 5. The external noise measurement at site

The detection frequency of this test is in range of 100 ~ 2,000MHz. The measurement was made in "max-hold" mode over period of about fifteen minutes. Fig. 6 shows

the measured spectrum. In this figure, noise spectrum is different depending on the site, anyway UHF range is fairly densely occupied and quite high level noise is existed. The following frequencies were the importance commercial bands: UHF television transmission (470~750MHz), the mobile phone services Cellular (820~880MHz) and PCS (1.8~1.9GHz), airplane communication (1.22~1.26GHz), wireless microphone (740MHz).

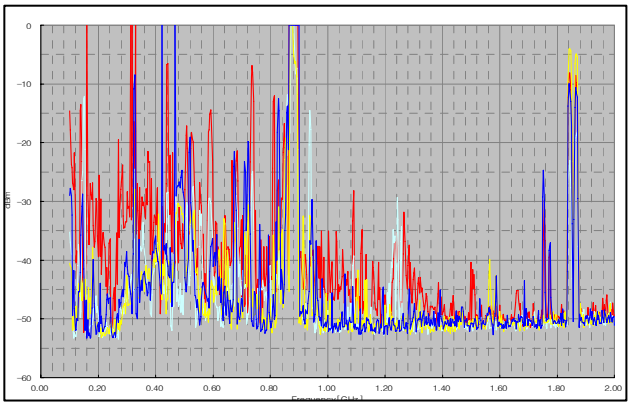
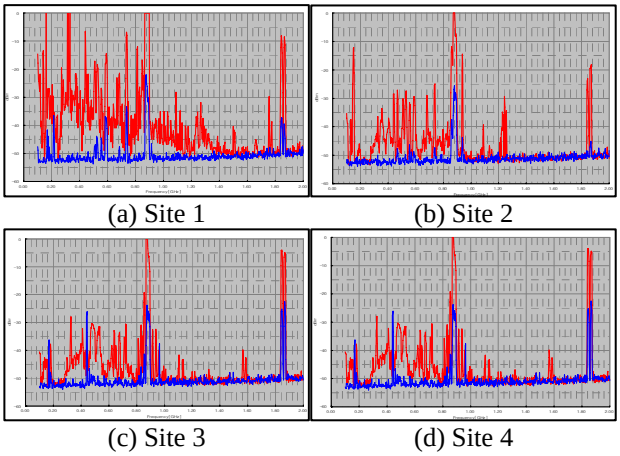


Fig. 6. The external noise spectrum

Incoming noise measurement inside switchgear

The incoming noise spectrum inside the MV switchgear was measured at same sites with spectrum analyzer, preamp (gain: 20dB) and internal sensor. The measured spectrum at each site is shown in Fig. 7. In these results, owing to the shield effect of switchgear steel tank incoming noise amplitude was attenuated more than 20 dB. However, we can see that some noise region which has high amplitude level can not be eliminated.



(a) Site 1 (b) Site 2

(c) Site 3 (d) Site 4

Fig. 7. The comparison between external noise spectrums and incoming noise spectrum
(Red line: external noise, blue line: incoming noise)

PD measurement in the laboratory

The main in a SF_6 MV switchgear that may cause breakdown and can be detected by PD measurements are a free moving particle, a floating electrode, a protrusion and an insulator defect. Artificial defects reproducing these conditions have been made, and used in the shielded room to measure the frequency spectrum of each artificial defect. The artificial defects were placed in the mock-up MV switchgear with the internal UHF PD sensor, and test voltage was applied using the noise free transformer. The apparent PD magnitude have been measured using the commercial PD detector (Robinson) and UHF PD spectrum have been measured using the spectrum analyzer. This test setup is shown in Fig. 8.

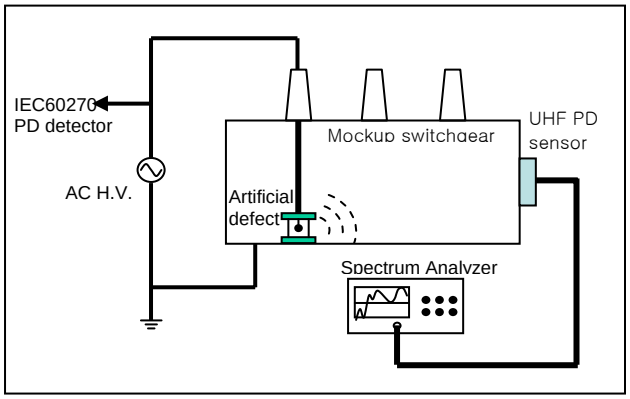


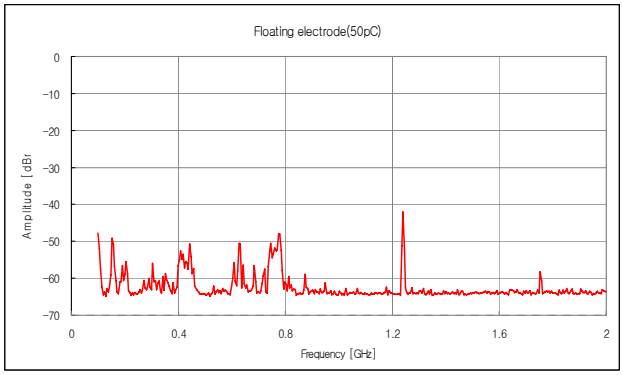
Fig. 8. Block diagram of UHF PD detection experiment

Fig. 9 shows examples of frequency spectra detected for each defect. The measuring frequency was in range of 100 ~ 2,000MHz and the measurement was made in “max-hold” mode over period of about fifteen minutes. The background noise floor was -65dBm. The spectrum of the floating electrode defect is shown in Fig. 9(a), the spectrum of the free moving particle is shown in Fig. 9(b), the spectrum of the protrusion is shown in Fig. 9(c) and the spectrum of the insulator defect is shown in Fig. 9(d). In each case, the apparent PD values were 50pC. All the sources were easily detected, however frequency spectrum pattern has different shape. In these results, we can observe that the free moving particle defect generate wide and large UHF signal compare to the other defects.

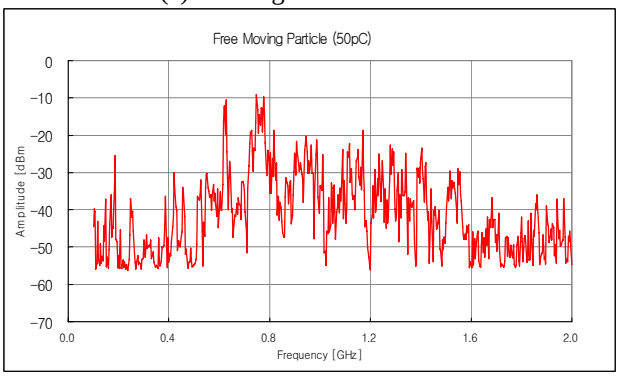
On-site application

In order to verify the reliability of the internal type UHF PD sensor, the MV switchgear with the sensor was installed at July 2006 on the distribution network. For the present we can not find any problem.

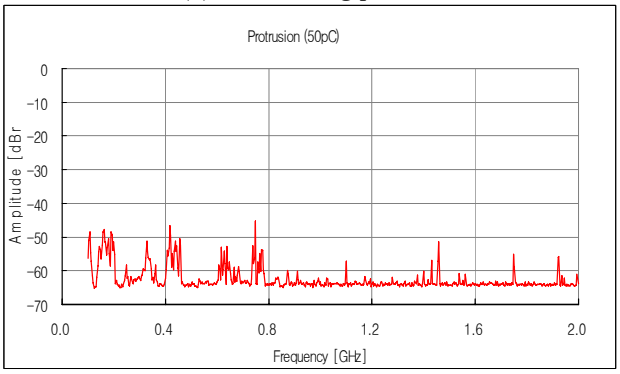
The goal of PD monitoring is to predict failures before they occur. To perform a risk assessment, it is essential to research about relation between PD trend and aging process. For this purpose, this switchgear has small insulator defect so small PDs are generated. Using the portable UHF PD detection system, the periodic PD signal measurement has been performed.



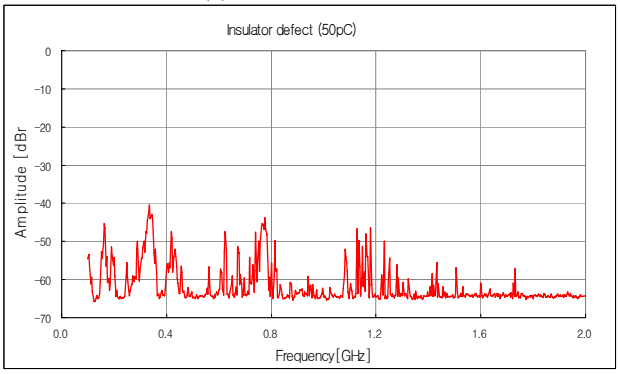
(a) Floating electrode defect



(b) Free moving particle



(c) Protrusion defect



(d) Insulator defect

Fig. 9. PD spectrum for each artificial defect

CONCLUSIONS

In this study the development of UHF PD detection system and its application are described. The following conclusions can be made on the base of this study.

- The portable PD detection system for SF_6 MV switchgear using UHF method was developed.
- The external noise spectrum (100 ~ 2,000MHz) and incoming noise to MV switchgear were measured.
- Using this system the PD detection of the MV switchgear defects is possible. In accordance with the defect type PD spectrum shows the different pattern.
- The PD detection system is useful and supporting the reliable operation of MV switchgear.

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