DEVELOPMENT AND APPLICATION OF UHF PD DETECTION SYSTEM FOR SF₆ INSULATED MV SWITCHGEAR

Young-Geun KIM  
LS Industrial Systems – Korea  
youngk@lsis.biz

Do-Hoon LEE  
LS Industrial Systems – Korea  
dhlee@lsis.biz

Won-Jong KANG  
LS Industrial Systems – Korea  
wjkang@lsis.biz

Yang-Sop SHIN  
LS Industrial Systems – Korea  
yssin@lsis.biz

Dong-Myung KIM  
KEPRI – Korea  
kimdmmg@kepri.re.kr

Kee-Joe LIM  
Chungbuk Univ. – Korea  
kjlim@chungbuk.ac.kr

ABSTRACT
Defects in the SF₆ 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 SF₆ 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 SF₆ 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 SF₆ 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].

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)

**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.

**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).
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](image)

**Incoming noise measurement inside switchgear**
The incoming noise spectrum inside the MV switchgear
was measured at same sites with spectrum analyzer,
preamplifier (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.

![Fig. 7. The comparison between external noise spectrums
and incoming noise spectrum](image)

**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
temperature 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](image)

**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.
CONCLUSIONS

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

- The portable PD detection system for SF₆ MV switchgear using UHF method was developed.
- The external noise spectrum (100 ~ 2,000 MHz) 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.

REFERENCES


Fig. 9. PD spectrum for each artificial defect