Propagation Characteristics of GIS PD Signals by Dual UHF Band Method (2)

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Abstract - It is widely known that the ultra high frequency (UHF) method that detects the electromagnetic wave of the PD pulses in the gas insulated space is one of the most competitive methods for its high sensitivity. From the above point of view, this paper describes the propagation characteristics of GIS PD signals measured with ultra wide band (UWB) GIS PD detecting system in which PD signals are detected into the dual UHF band. The UWB PD detection system consists of the UWB UHF coupler, the UWB low noise amplifier (LNA) and the oscilloscope. The dual bands for PD signals are 0.5-2GHz(full band) and 1-2GHz(high band). As results, propagation characteristics of GIS PD signals were measured in the mock-up GIS bus and it was found that the propagation characteristics of the high band showed a better result in accordance with the internal configuration of the GIS bus than those of the full band.

1. Introduction

The scales of the electric power facilities in South Korea as well as other countries in the world are being enlarged due to an increase in the electric power demand. Gas-insulated substations (GIS) have been adopted due to greater compactness, security and reliability than the conventional substations. While the GIS has numerous advantages as shown above, there are some difficulties related to observing its inside condition, as well as measurement of failure and repair. Under these circumstances, when failure occurs in the electric power facilities, it takes a great deal of time and enormous financial cost to perform repairs. Therefore, it is essential to develop a technology detecting and analysing partial discharge (PD), which can be generated as a precursor before flashover if the insulation of power apparatus deteriorates. Thereby, the insulation characteristics in the SF_6 gas-insulated apparatus can be diagnosed in advance.

A number of PD detection methods using the various PD phenomena such as light, sound, vibration and electromagnetic waves have been proposed [1-4]. It is widely known that the ultra high frequency (UHF) method that detects the electromagnetic wave of the PD pulses in the gas insulated space is one of the most competitive methods for its high sensitivity and robustness to noises [5,6]. However, there have been few studies concerning the ultra wide band (UWB) UHF detection system in the field of GIS PD detection [7], due to difficulties in the design of the UWB coupler, matching circuits and UWB low noise amplifier (LNA) as well as onerous digital signal post-processing.

In this paper, the authors have introduced the developed UWB PD detection system and the propagation characteristics of GIS PD signals in the mock-up GIS chamber.

2. Experimental setup and method

The developed UWB PD detection system consists of the UWB UHF coupler, the UWB LNA and the oscilloscope. Fig. 1 shows the UWB UHF coupler whose bandwidth is from 0.5 GHz to 2.0 GHz. The log-periodic geometry was adopted for the coupler and the tapered balun was used for matching as shown in the figure. Fig. 2 shows the schematic diagram of the UWB LNA that has two output bands. The two bands for PD signals are Full band (0.5-2GHz) and High band (1-2GHz). Other specifications of the LNA are 45 dB in gain and 2.5 dB in noise figure. PD signals from the UWB UHF coupler is amplified and then divided into two bands in the UWB LNA.

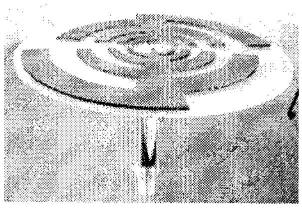


Fig. 1 Developed UWB UHF coupler

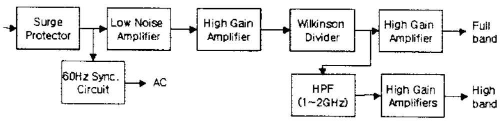


Fig. 2 - Schematic diagram of UWB LNA

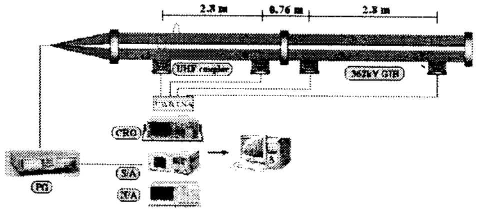
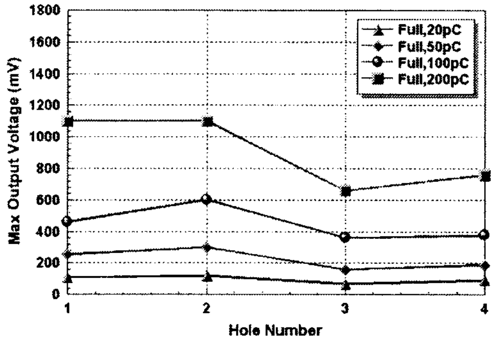


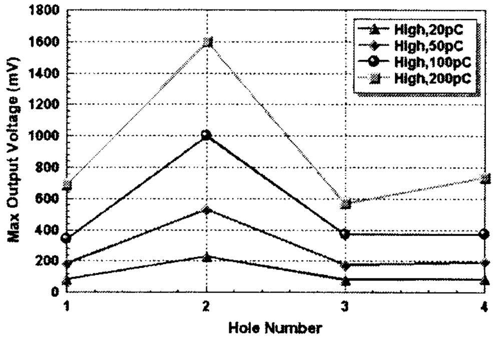
Fig. 3 Experimental setup for measuring propagation characteristics of GIS PD signal

The UWB coupler and UWB LNA are very important components in the diagnostic system using the UHF method because it should be able to catch those pulses having a rise time shorter than one nanosecond [8], which means it should be of ultra wide band with the bandwidth ranging from hundreds of MHz to several GHz. Therefore, a UWB system is more desirable for the detection of the PD pulses in GIS because the UWB characteristics of the detected PD signals have plenty of information for verifying the type and the location of the defect in the GIS.

The experiments for the propagation characteristics of GIS PD signals with the developed UWB PD detection system were carried out using the 362 kV mock-up gas-insulated bus (GIB, 120/500 mmϕ) as shown in Fig. 3. The pulse generator (PG) emits pulses of 0.5 ns rise time through the conical coaxial bus for matching into the GIB. The signals detected by the UWB UHF coupler in the hand hole were amplified by the UWB LNA and analyzed by measuring instruments such as an oscilloscope (LeCroy, wavePro 960, 2 GHz / 16 GS/s, 16 Mpts), spectrum analyzer (Advantest, R3131A, 9 kHz 3 GHz) and network analyzer (HP, 8753D, 30 kHz 3 GHz)



(a) Full band



(b) High band

Fig. 4 - Propagation characteristics of GIS PD signals in the 362 kV mock-up GIS

3. Experimental Results

The maximum output voltage characteristics of various input charges, that is, the propagation characteristics in the GIB were investigated as a function of the hole number, that is, coupler position in Fig. 3 and the result is shown in Fig. 4. Fig. 4 (a) and (b) show the propagation characteristics of Full band and High band respectively. In Fig. 4 (a), it has to be noted that a great deal of signal attenuation occurs between hole 2 and hole 3 due to the conical spacer that is placed between those holes. From the above attenuation, it is evident that the conical spacer plays an important role in attenuation of the signal. It is also worth noting that the signals hardly attenuate between hole 1 and hole 2, and between hole 3 and hole 4. It can be thought that some reflection in the GIB contributes to the maintenance or the slight increase of the level of the signal. The contribution due to the reflection can be identified remarkably by observing Fig. 4 (b), the propagation characteristics of High band.

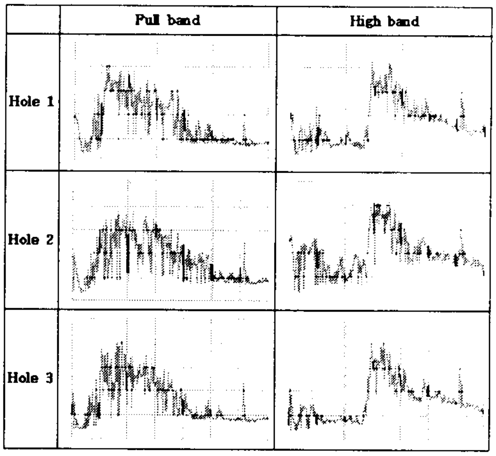


Fig. 5 Spectra of the dual band from the holes (i nput pulse : 200 pC, ver. : 10 dB/div, hori. : 0. 3 GHz/div)

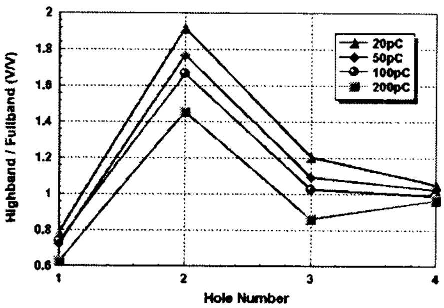


Fig. 6 Ratios of High band to Full band

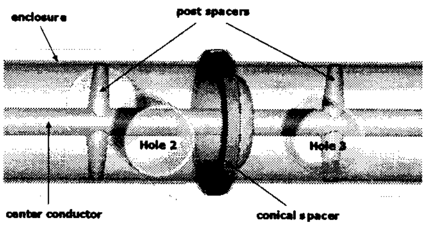
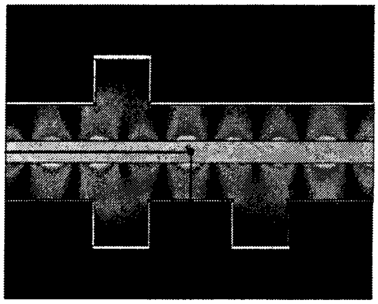
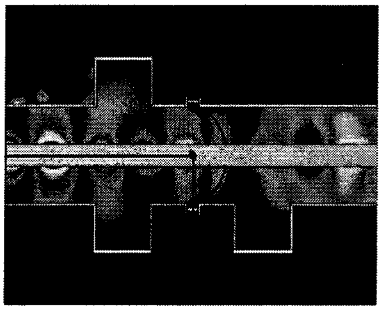


Fig. 7 Configuration of the spacers and the holes

Fig. 5 shows the spectra of the dual band from the each hole in case of 200 pC input pulse and explains the results of Fig. 4. It can be seen that the spectrum of Hole 2 is highest in both Full band and High band due to the reflection from the spacers.

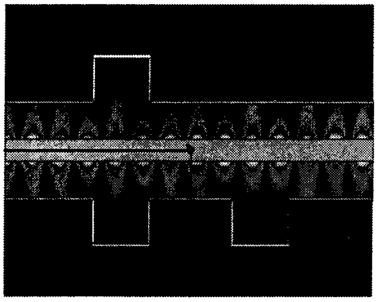


(a) without the spacer

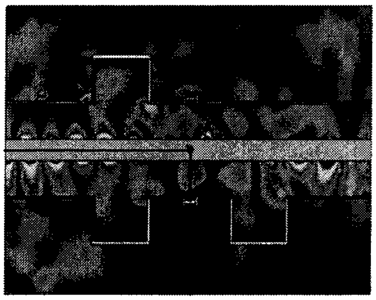


(b) with the spacer

Fig. 8 Field distribution in the GIB at 600 MHz



(a) without the spacer



(b) with the spacer

Fig. 9 Field distribution in the GIB at 1,000 MHz

4. Discussions

The propagation characteristics can be observed better by introducing a new index, Ratio of High band to Full band for each hole as shown in Fig. 6. In Fig. 6, the ratios of High band to Full band for Hole 1 are much lower than those of the others. This is due to the facts that (1) the lower frequency components below 1,000 MHz were filtered out in High band, (2) the geometry of the bus from the pulse generator to Hole 1 is of simple coaxial cylinder and could scarcely generate reflection of the wave and (3) The UHF coupler mounted in each hole is more sensitive to higher order modes because of its geometry.

The sudden increase of the ratio at Hole 2 means the generation of reflection due to the spacers under the configuration as shown in Fig. 7. In more detail, the drastic increase is due to reflection from both the post spacer in front of hole 2 and the conical spacer in back of hole 2, and sudden attenuation between hole 2 and hole 3 is due to both absorption and reflection of the conical spacer as shown in Fig. 7. In addition, the slight increase between hole 3 and hole 4 explains reflection from the conical spacer in back of hole 4.

Furthermore, in order to investigate the effect of the spacer in the GIB, the field distributions in the GIB at 600 MHz and 1,000 MHz were calculated as shown in Fig. 8 and Fig. 9. It can be seen that the field distribution become more complex when the spacer exists. The sudden increase of the ratio at Hole 2 of Fig. 6 can be explained by this spacer effect. In addition, it can be seen that the field distribution at 1,000 MHz is more complex than that at 600 MHz. This fact implies that the output of High band can give closer information about the GIB configuration than that of Full band.

5.Conclusion

UWB PD detection system using dual UHF band method was developed to investigate the propagation characteristics of GIS PD signals. The developed UWB PD detection system consists of the UWB UHF coupler, the UWB LNA and the oscilloscope.

It was found that the propagation characteristics of High band showed a better result in accordance with the internal configuration of the GIB than those of Full band and it was verified that the dual UHF band method is valid for the investigation of the propagation characteristics of GIS PD signals.

Now that the UWB PD detection system has been developed, hereafter, the construction of PD database according to the defects in GIS is needed.

References

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