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가스절연기기 내부의 금속 이물질에 의한 초고속 부분방전량 및 전류 측정

Ultra-fast meseurement of pariatl discharge current due to conducting particle in Gas-insulated System (GIS)

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Abstract

A special discharge cell containing a free conducting particle was used to generate the discharges in SF_6. The analog bandwidth of the measurement system exceeded 5 GHz. The measured signals were processed to compensate for the response of the measurement system. The discharge current rise time was in the range of 70 ps, while its full-width half-maximum was 120 ps. Single and double current pulses of positive and negative polarities were measured. Likewise, these pulses were compared with the measurement obtained using a conventional partial discharge detector of the IEC60270 type

Key Words : Partial discharge, Ultra-high Frequency, Ultra-wideband (UWB), Current pulse, GIS)

1. Introduction[1)]

Partial discharges (PDs) in the SF_6 gas-insulated switchgears (GIS) usually generate ultra-fast rise current pulses that generate ultra-wideband (UWB) radiation in the ultra-high frequency (UHF) range [1, 2]. These ultra fast rises of current pulses are of interest because they generate broad-band UHF signals that can be used to detect and locate PDs caused by internal GIS defects. Current pulses caused by PDs in the pressurized SF_6 gas have rise times and pulse widths that are known to lie in the sub-nanosecond range [3-5]. The ultra-fast nature of the discharge current pulses in the GIS requires measurement using a high-bandwidth equipment. To investigate the shapes of the current waveforms, a high bandwidth measuring system was assembled. Likewise, a special discharge cell containing a free-moving metallic particle was used to simplify the measurement of current pulses caused by discharges in SF_6. Although an aluminum ball was used to simulate the particle that is hard to locate in the real GIS, the current pulses from the discharge caused by the rolling-ball type Al particle simulate those pulses from the particles of various shapes may found in the real GIS.

2. Experimental Set-up

To achieve maximum possible bandwidth of the current measurement a special discharge cell was used to generate PDs [4]. The discharge cell, insulated by SF_6 at 0.5 MPa, contained an aluminum ball of 1.5-mm in diameter, as shown

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in Fig. 1. The upper part of the cell was fabricated to produce a rather even electric field between the electrodes. Likewise, the central region of the lower part was insulated to form a 50-Ohm coaxial transmission line that emerged at the bottom of the cell through a hermetically sealed SMA connector. A 32-dB attenuator with a specified bandwidth of DC-18 GHz was attached to the SMA connector to form a shunt resistor. The lower part of the cell and the shunt resistor were then grounded together to form a return path for the discharge current. The output of the attenuator was fed into the oscilloscope. To maintain a traceable calibration of measured voltage versus current flowing into the shunt resistor a noncontact ultra-wide bandwidth current transformer that was calibrated up to 2 GHz was employed. The output of a regulating transformer was fed into a PD-free exciting transformer to produce an adjustable 0-100 kV AC supply (Fig. 1). This voltage was applied to the upper part of the cell through a high frequency choke and a series resistor that limits the flashover current.

When the electric field inside the cell is sufficiently high, the particle begins to move around in the bottom part of the cell. When the particle hits the center conductor of the coaxial line, a partial discharge may take place. Thus, a pulse of current may flow into the shunt resistor, then ground. In addition, a conventional IEC60270-type PD detection system was simultaneously attached to the cell to compare measurements using the oscilloscope.

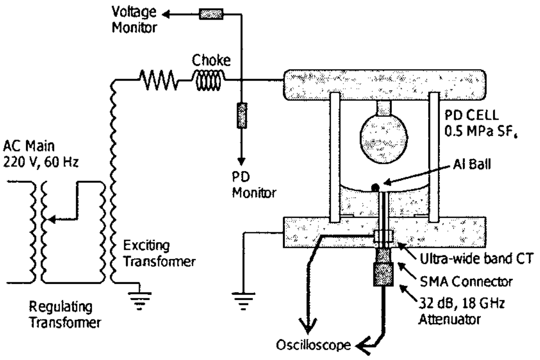

Fig. 1. Experimental set-up for PD generation. The PD cell was filled with SF_6 gas at 0.5 MPa and a 1.5 mm, in diameter, aluminum ball was used as a particle (See text for details).

3. Measurement System Response

To verify the bandwidth and the rise time of the measurement system, a known pulse from a pulse generator was applied at the input of the system as shown in Fig. 2.

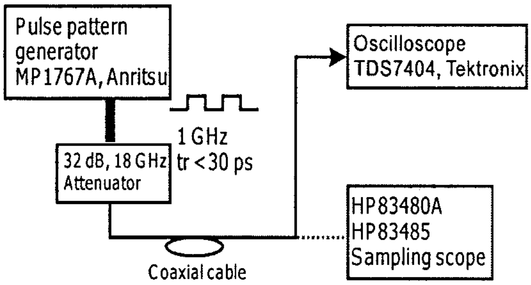

Fig. 2. Measurement system bandwidth and rise time verification set up. The SMA type connections and phase stable cable was used.

The measurement system is composed of an attenuator, coaxial transmission line, and an oscilloscope. Pulses with risetimes of 28 ps from the pulse generator (Anritsu, MP1767A) were fed into the input of the shunt resistor. Pulses were then fed into the oscilloscope (Tektronix, TDS-7404) through a low-loss transmission line. The output of the pulse generator was then verified using a sampling scope (HP, 83480A, 83485, tr = 17.5 ps). The measured voltage waveform of the pulse train is shown in Fig. 3. The recorded risetime (10% - 90%) of the pulse is 103 ps. Therefore, the calculated measurement system risetime ($tr_{system}^2 = tr_{measured}^2 - tr_{pulse}^2$) is 99 ps. This information was used to compensate for the measured waveforms. The analog bandwidth of the measurement system exceeded 5 GHz.

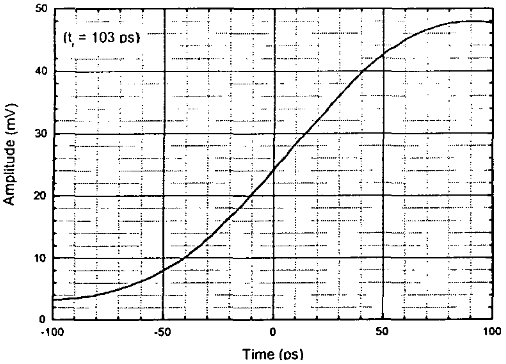

Fig. 3. Measured voltage waveform of the pulse train from the pulse generator. The measured risetime of the pulse is 103 ps.

4. PD-induced Current Pulses in GIS

At about 11 kV of applied voltage the Al ball in the cell moves around and generates current pulses due to partial discharges. The 1.5-mm Al ball produced various current amplitude ranging from 0.2 to 0.6 A. Current pulses with both positive and negative polarities were measured, as shown in Figs. 5 and 6. The width of a few of those pulses is rather wider than others, revealing double peaks or superposition of multiple peaks, as shown in Fig. 6. Although, several hundreds pulses were measured, the shapes of the pulses changed only slightly. None of the pulses measured had a risetime that exceeded ~300 ps.

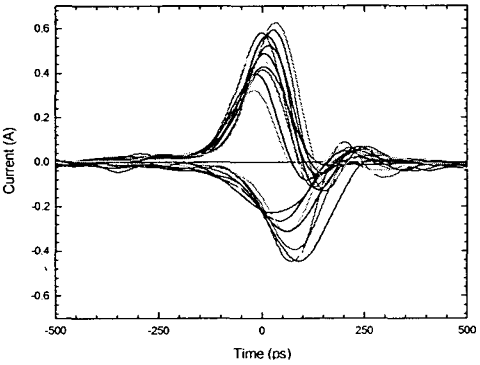

Fig. 4. Typical single current pulses of positive and negative polarity.

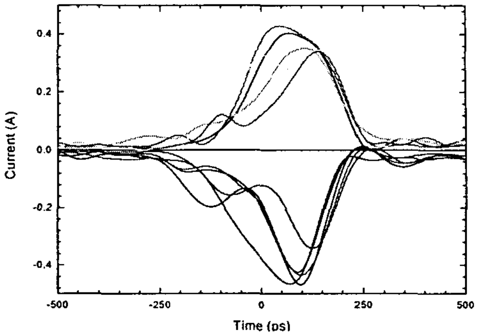

Fig. 5. Typical double and broad current pulses of positive and negative polarity.

The measured current pulses in Fig. 4 were further processed to compensate for the bandwidth of the measurement system, as discussed in Sec. 3. The bandwidth data shown in Fig. 3 was used to deconvolve the measured pulse [6]. Fig. 6 shows typical measured (dotted-line) and deconvolved (solid-line) single positive pulse current waveforms. The risetime of the compensated pulse is ~70 ps, while its full-width at half-maximum is ~120 ps. Such results are consistent with previously reported values [4].

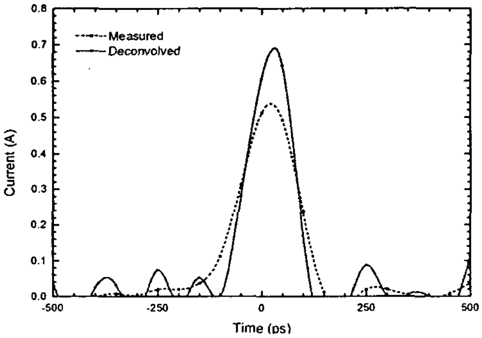

Fig. 6. Typical measured (dotted) and deconvolved (solid) current waveform due to partial discharge in the PD cell shown in Fig. 1.

To compare these ultra-fast measurements of PD with measurement using regular PD detectors, a conventional IEC60270-type PD detector (Robinson, DDX 7000) was simultaneously connected to the PD cell (Fig. 1). The PD detector was calibrated by using an internal calibrator. The PD detector was triggered by the current pulses and its output was recorded simultaneously at another oscilloscope. The actual charge values were determined by integrating those current pulses shown in Figs. 4 and 5.

Fig. 7 shows discrepancy between the discharge values measured using the PD detector and the corresponding values determined from the discharge current pulses. Due to the limited bandwidth of the PD detector and calibration error, the apparent discharges measured with a conventional PD detector were about 10 times smaller than those values calculated from current waveforms. The 1 pC offset of the apparent discharge in Fig. 7 was originated from the DC offset and the uncertainty of the PD detector output. Conventional PD measurement systems obviously cannot follow the ultra-fast rise of current discharges in SF_6. Therefore, they must be extended and calibrated for ultra-fast discharges in gas [7, 8].

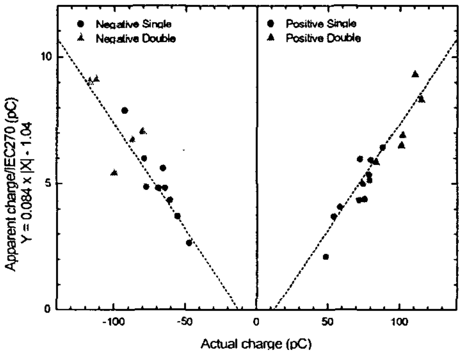

Fig. 7. Ultra-fast measurement versus conventional measurement of partial discharges due to a particle in SF_6.

5. Conclusions

We have measured ultra-fast current pulses of partial discharges caused by a particle in the pressurized SF_6 insulated system. A special PD cell was developed to measure accurate waveform of discharge currents. Likewise, the system response of the experimental set-up was verified. At about 11 kV of applied voltage, both single and double current pulses of positive and negative polarities were observed. The fastest risetime of the measured current was ~70 ps, while its full-width at half-maximum was ~120 ps. This ultra-fast nature of the discharge current indicates that UWB UHF PD detection techniques must be applied in GIS. The conventional IEC60270-type PD measurement system cannot follow the ultra-fast rise of the discharge current in SF_6. Therefore, a special calibration is needed for the ultra-fast partial discharges in pressurized gas system.

[References]

[1] Kijun Park, Sun-geun Goo, and Jin Yeol Yoon, "GIS partial discharge detection research - 2nd year report, "M98PJ04 .M2001.166, KEPRI, Apr., 2001.

[2] Kijun Park, Sun-geun Goo, and Jin Yeol Yoon, "Detection of partial discharge due to particle movement in the 362 kV gas-insulated switchgear using the UHF sensor, " Proc. KIEE, pp.516-518, Nov., 2000.

[3] G. Wanninger, "Discharge currents of free moving particles in GIS," 10th Int. symposium on high voltage Eng., 1997.

[4] M. D. Judd and O. Farish, "High bandwidth measurement of partial discharge current pulses," IEEE Int. Symp. on Electrical Insulation, Washington, U.S.A, 1998.

[5] S. M. Neuhold, H. R. Benedickter, M. L. Schmatz, "A 300V Mercury switch Pulse Generator with 70 psec risetime for investigation of UHF PD signal transmission," IEE Int. Symp. on High-Voltage Eng., 1999.

[6] M. S. Roden, Analog and Digital Communication Systems, Prentice-Hall, Englewood Cliffs, N.J. U.S.A., 1991.
[7] IEC-Publ. 60270, Partial discharge measurements, IEC, Dec., 2000.
[8] G. Wanninger, "Apparent Charge Measurement in GIS by Diagnostic Methods," ETEP Vol. 7, No. 4, pp251-255, 1997.