A Study on Synthetic Failure-finding Method for Electrical and Thermal Degradation of Polymer Insulator by Surface Discharge

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Polymer insulators are used widely in variable fields for high voltage insulation and separating people from high voltage charging parts for safety and also supporting overhead power line in electric railway. But it may be broken down by tracking path resulting from continuous surface discharge. This paper has investigated synthetically both the characteristics of electrical aging using precision CT(current transformer) and the thermal aging using thermography method. Electrical aging was analyzed for time-frequency region and thermal aging was illustrated by image processing method. This synthetic method may be an appropriate one to evaluate the surface degradation of polymer insulator.

Keywords : Polymer insulator, Thermography

1. INTRODUCTION

Polymer insulators play a very important role in serving supporting the HV facility and protecting electronic equipments from unexpected hazard by touching it in electric railway system. Therefore, they need to be taken continual inspection and replacement [1-3]. But the degradation of them is not easy to know because of being proceeded very slowly and very weakly. The degradation may be caused by corona discharges and repeated breakdown on the surface of polymer insulator. Corona discharges can be a significant threat to the integrity of polymer insulator due to the organic nature of the housing material[4]. Corona can be a problem not only in contaminated but in clean environments as well. On polymer, corona can be present locally for long periods of time due to inadequate hardware design, damaged hardware, contamination of surface by diesel locomotive etc. and more corona discharge may cause surface breakdown. Its characteristics of ceramic or polymer insulators have continued to receive attention, primarily due to the fact that the surface breakdown strength of an electrical insulator is lower than that of its intrinsic withstanding capability[5,6]. For preventing these corona discharge and surface breakdown, there is a necessity to periodically inspect polymer insulator and replace degraded insulators in a timely manner as mentioned before. The currently used by the utilities to inspect in-service polymer insulator are acoustic emission, radio interference voltage measurement, infrared thermography, visual observation etc. Both, acoustic emission and radio interference voltage measurement methods are sensitive to background noise. They cannot be used to determine the precise location of the discharge on the insulator. It is significant drawback as discharges on insulator hardware cannot always be avoided and may not need immediate replacement, while discharges on housing can be a harbinger to serious prob lems in future[7]. This paper have investigated the method using precision CT(current transformer) to measure PD on the polymer insulator surface which may cause some breakdown and the applicability of thermal inspection(thermography method) for the surface temperature rise when the flashover occurs. Data obtained by precision CT are processed to show the results of measurement in time and frequency region. And also the picture of temperature distributions by thermography method are shown after image processing.

2. EXPERIMENTAL SETUP

This paper are prepared for polymer insulator used in supporting the overhead electrical train line. The gap length of electrodes(aluminum thin plate with glue) to form surface discharge on insulator was 15mm, which was separation between upper and lower sheds. Puncture tester(0~30 kVac) are used to apply voltages cross two electrodes. Firstly, Corona discharge current are picked up by pearson precision CT(model 2877, 300 Hz~200 MHz). CT was connected with digital oscillocope (Tektronics 750, 500 MHz, 2 GS/s) displaying and storing the current pulse passing through the surface of polymer insulator. CT was immerged into the sillicon oil to prevent from unexpected corona discharges between CT and wire penetrating through CT. And also Air breakdown between electrodes was observed into a naked eyes and pictured by thermal tracer TH3100 (0~300 ℃) for investigating the temperature effects on surface of insulator when it happens. Thermal tracer were located in 50 cm distant from test specimen. Thermal tracer have the limit to resolve the thermal image into pixel. However, determination of surface temperature by IR thermography when surface breakdown happened are successful.

3. RESULTS AND DISCUSSION

Corona discharge inception voltage on the surface of insulator was 5.07 kV as shown in Fig. 1. Corona discharge was firstly initiated from positive voltage range at applied AC voltage, which are supposed to be resulted from the electron emission of polymer insulator surface nearby the positive electrode not cut with correct round because of human error. Current pulses picked up by CT were coming from charge variation under corona discharge The amplitude of CT output pulses are increased in accordance with increasing the applied voltage between two electrodes. Figure 2 is illustrating the waveform and frequency distributions of CT output pulse acquired by Digital oscilloscope in 9 kV applied.

The waveform of CT outputs have very fast rising time(about <60 ns) and the regularly oscillating tail with decreasing almost exponentially. The pulse duration of CT output was about 340 ns in crossing the zero voltage both rising and falling. Frequency distributions in Fig. 2(b) have two peaks in 11 MHz and 19 M over 5 MHz which are related with rising(<60 ns) and falling time(<280 ns) with respective. Pulse amplitudes of CT output are going on with increasing the applied voltage(Increasing rate : 1 kV/s). Finally, there was surface flashover at applied voltage 12.1 kV as shown in Fig. 3, in which have some missing time(about 2 sec) because of triggering problem, which was coming from the switching interference occurring when dielectric puncture tester switch off and down to 0 V very sharply.

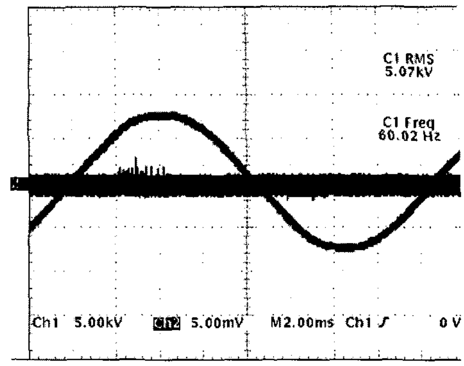
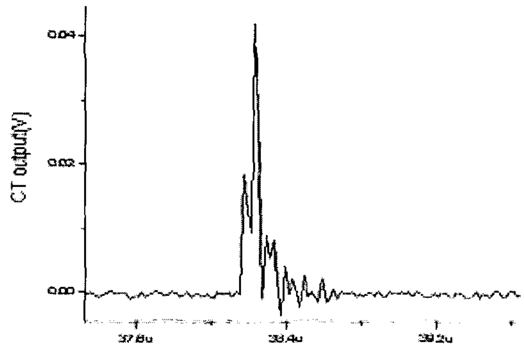
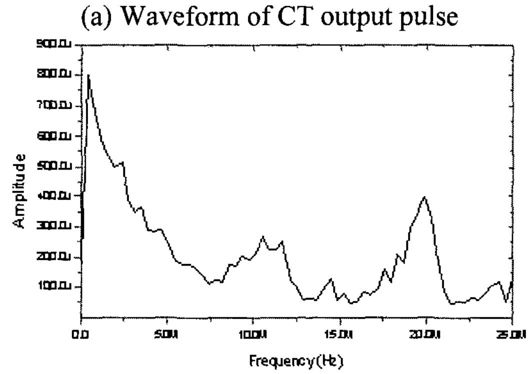


Fig. 1. Inception voltage of corona discharge.



(a) Waveform of CT output pulse



(b) Frequency reponse of CT output pulse

Fig. 2. Waveform and frequency reponse of CT output pulse.

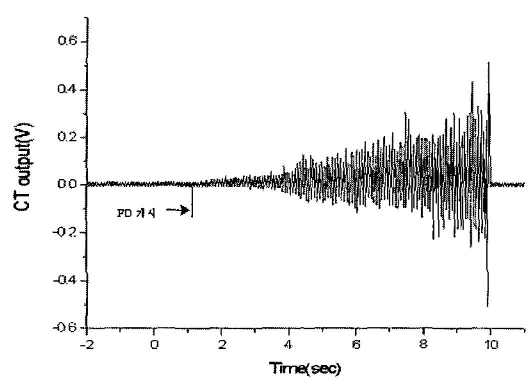


Fig. 3. Variations of CT output pulse according to uprising voltage with time(1 kV/s).

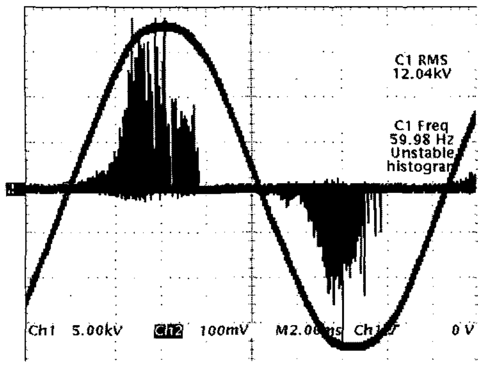


Fig. 4. Cumulative CT output pulse during 100 periods.

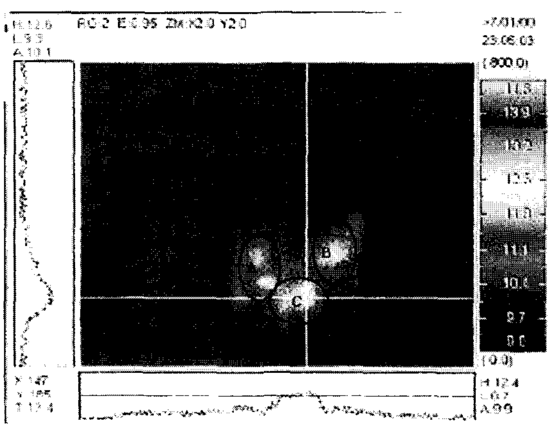


Fig. 5. Thermal picture during surface flashover.

Uprising voltage with 1 kV/s represent almost linearly increasing of corona discharge intensity on insulator surface. After corona discharge inception, corona discharge was occurred mainly in positive voltage at 5~8 kV applied and also in both positive and negative voltage over 8 kV applied. On the verge of surface flashover, the cumulative CT outputs during 100 periods(1/60 Hz per 1 period) have shown almost the same shape in both positive and negative voltage(Fig. 4).

The surface flashover give an serious effect on the degradation of insulator surface. This paper investigated the temperature rising effect made by the surface flashover using thermal tracer TH3100. Figure 5 have illustrated the flashover thermal picture and the waveform of abscissa and ordinate section in flashover point. There are Three parts which consist of two electrode parts(A:negative electrode, B:positive electrode) and a flashover part(C) in Fig. 5. Two electrode parts reflect the infrared light into thermal tracer and are seen as thermal generation but not real generation of heat. Highest and lowest Temperature value for the thermal picture was 12.4 ℃ and 8.7 ℃ respectively. There was temperature rise of 3.7 ℃ due to the surface flashover. This is to meager too invoke the serious damage at one time flashover. But the continuously repeated flashover may inflict some damage to the insulator surface. Abscissa waveform in Fig. 5 have shown little higher left side(high voltage) than right side(ground) but could not know which side was positive or negative voltage because measurement of both applied voltage and thermal picture was not done at the same time. IR is related with the light emission closely. According to[8], 1. visible light of low intensity originates at the cathode ; 2. the illumination(originated at cathode) propagates towards the anode; 3. as soon as the light(from cathode) reaches the anode a very bright region starts at the anode and extends towards the cathode. Therefore, right side may be anode, that is to say, positive part.

4. CONCLUSION

This paper have investigated both the electrical corona discharge current and the thermal effect of surface flashover on polymer insulator. corona discharge inception voltage was 5.07 kVac(60 Hz) and the pulse amplitudes of CT output have almost linearly increased with increasing the applied voltage(1 kV/s). Under 8 kV, corona discharge occurred mainly in positive voltage and then both in positive and negative voltage. On the verge of surface flashover, the cumulative CT outputs during 100 periods have shown almost the same shape in both positive and negative voltage. Using thermal tracer, thermal picture have shown a difference of 3.7 ℃ at a point of time in surface flashover.

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