Research on the influence of pulse parameters on surface charge of epoxy resin

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Abstract. The dynamic characteristic of the surface charge on insulating material is an important electrical characteristic, which can effectively reflect the insulation performance of materials. The phenomenon of surface charge accumulation leads to surface discharge and surface flashover. In this paper, the surface charge accumulation and dissipation of epoxy resin under different pulse parameters were studied. The experimental results showed that the increase of pulse frequency intensified the phenomenon of surface charge accumulation and inhibited the process of charge dissipation. Meanwhile, the increase of the number of pulses led to the increase of surface charge accumulation first and then saturation. At the same time, it inhibited the process of surface charge dissipation.

1. Introduction
In the substation, the operation of circuit breaker, disconnector and node will switch cause very fast transient overvoltage (VFTO)[1]. VFTO has the characteristics of high voltage amplitude, short rising edge, high frequency and multiple pulses. Especially the rising edge can be as short as several nanoseconds. Under the pulse electric field, the surface charges of insulating material will also accumulate electric charge, such as the direct current electric field [2, 3]. The phenomenon of surface charge accumulation will lead to surface discharge and surface flashover.

Many scholars at home and abroad have carried out a lot of researches on surface charge under pulse electric field. Du points out that the surface charge accumulation is affected by the parameters of pulse power supply, and the short rising edge and long pulse width aggravates the phenomenon of surface charge accumulation [4]. Shao states that the increase of pulse frequency reduces the flashover voltage of epoxy resin, and points out that the change of pulse frequency is directly related to the surface charge accumulation [5]. It can be seen from the above research that the impact of pulse parameters on the surface charge and insulation performance has been studied. But at present, the researches lack of systematic. It is not conducive to the formation of a unified understanding of the surface charge accumulation by pulse parameters under different conditions. Thus, the surface charge behavior is not yet clearly understood, and it is necessary to study the pulse parameters effect on surface charge behaviors of EX in pulse power systems.

In order to improve the endurance of insulating materials to VFTO, the effect of pulse parameters on the surface charge of epoxy resin was measured. And the nanosecond pulse power supply was used as corona excitation source.
2. Experimental test system
The typical needle plate electrode structure was used in surface charge test as shown Figure 1. The specific information has been detailed in [6]. The sample used in test is epoxy resin doped with alumina nanoparticles. The ratio of the components of the sample was the same as that of the basin insulator or support insulator in GIS. The sample size was 50 × 50 × 2 mm³. The color was milky white. And the surface roughness was 0.02 μm.

![Figure 1. The diagram of surface charge test system.](image1)

3. Experimental results
3.1. Typical curve
The typical needle-plate electrode was employed to apply voltage to epoxy resin. The applied parameters were as follows: applied voltage of 5 kV, pulse frequency of 1 kHz, pulse number of 1000, pulse rising time of 100 ns, pulse width of 500 ns and falling edge of 200 ns. The typical surface potential decay curve is shown in Figure 2. It can be seen that the surface potential decay curves of epoxy resin showed a double exponential decay. At the initial time of dissipation, the surface potential decreased rapidly. With the increase of dissipation time, the attenuation curve became slow and smooth. It has been proven that surface charges first escaped from shallow traps and then from deep traps [7]. In order to better understand the influence of pulse power supply on surface charge, the influence of pulse parameters on surface charge were studied in following chapter.

![Figure 2. The typical surface charge curve.](image2)
3.2. Effect of pulse frequency on surface charge

In order to analyze the effect of pulse frequency on the surface charge of insulating materials, the frequency of pulse power supply was selected as 1000 Hz, 2000 Hz and 3000 Hz. The other applied parameters were as follows: applied voltage of 5 kV, pulse number of 1000, pulse rising time of 100 ns, pulse width of 500 ns and falling edge of 200 ns.

The curves of epoxy resin surface potential with dissipation time under different pulse frequencies were shown in Figure 3. It can be seen from Figure 3 that the initial surface potential amplitude increased with the increase of pulse frequency. The curves of surface charge attenuation rate at different pulse frequencies were shown in Figure 4. The surface potential of epoxy resin decreased by 55%, 52% and 48% respectively after 1000 s decay time. It showed that the increase of frequency effectively suppressed the dissipation rate of surface charge. It also meant that the increase of frequency led to electric field distortion and promoted the generation of surface discharge. A large number of studies also showed that the insulation performance of epoxy resin decreased with the increase of pulse repetition frequency [4].

The influence of pulse frequency on surface charge could be analyzed from the following aspects. When the positive polarity pulse power supply was applied to the needle electrode, the particles produced by each pulse discharge were injected into the trap on the surface of the material under the action of electric field force. Before the next pulse was applied, the particles generated by the previous pulse would remain on the surface of the material. This phenomenon was defined as "accumulation phenomenon". The increase of pulse frequency meant that the dissipation time from the end of the previous pulse to the beginning of the next pulse was shortened. So, the residual particle density would be higher, and the "accumulation phenomenon" was more serious. With the increase of repetition frequency, the corona intensity tended to increase along the direction of electric field [8].

![Figure 3](image1.png)

**Figure 3.** The surface charge accumulation at different pulse frequencies.

![Figure 4](image2.png)

**Figure 4.** The surface charge attenuation rate at different dissipation time and pulse frequencies.
3.3. Effect of pulse number on surface charge

In order to analyze the effect of pulse number on the surface charge of insulating materials, the number of pulse power supply was selected as 500, 1000, 2000 and 10000. The other applied parameters were as follows: applied voltage of 5 kV, pulse frequency of 1000 Hz, pulse rising time of 100 ns, pulse width of 500 ns and falling edge of 200 ns.

The change curve of surface charge of epoxy resin with dissipation time under different pulse number was shown in Figure 5. With the increase of the number of pulse discharges, the initial surface potential amplitude increased first and then saturated. When the pulse frequency remained constant, the increase of the number of pulses meant the increase of the applied voltage time. But the surface of material has a certain capacity to hold electric charge. Therefore, with the increase of pressure time, the amount of charge trapped on the surface of the material would gradually increase until it is saturated. Ran pointed that with the increase of the number of pulses, corona developed rapidly along the electric field line and the luminous intensity increased obviously [8]. When the number of pulses increased to a certain extent, the corona diffused more towards to the surrounding direction. The decay rate of surface charge under different pulse numbers was shown in Figure 6. The increase of the number of pulses would restrain the decay of the surface charge.

![Figure 5. The surface charge accumulation at different pulse number.](image)

![Figure 6. The surface charge attenuation rate at different dissipation time and pulse frequencies.](image)

4. Conclusions

In this paper, the characteristics of surface charge dispersion under typical pulse voltage were studied. The characteristics of surface charge accumulation and dissipation under different pulse parameters were also studied. The conclusions were as follows:

1) Under pulse voltage, the law of surface charge dispersion was similar to that under DC voltage. The surface charge decay showed a double exponential decay curve.
2) With the increase of pulse frequency, the surface charge accumulation increased and the dissipation rate slowed down.

3) With the increase of the number of pulses, the surface charge accumulation first increased and then saturated, and the dissipation rate slowed down.

5. Perspectives

The following suggestions are put forward for the follow-up study:

1) In order to further confirm the main factors affecting the surface charge accumulation, the characteristics of surface charge dispersion under different rise time, pulse time and falling time need to be systematically studied.

2) Explore the application of new technology, new methods and new materials to realize the regulation of surface charge of solid insulation.

References

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