Charge Dissipation Behavior on the Insulating Polyimide Backsheet in Photovoltaic System

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Abstract. Deterioration of electric properties will be generated by the accumulation of surface charge on photovoltaic backsheet in the insulating system of photovoltaic (PV) system. The phenomena of potential induced degradation (PID) could be verified in the insulating Polyimide (PI) backsheet of PV module. In the field of photovoltaic system, PI has been found a special insulating backsheet that work in a mild condition. If the dynamic behaviors of the charge in the insulating backsheet could be understand, unexpected flashover events will be avoided. Thus, the mechanism of surface charge decay of PI should be explored under steady condition. The effect of accumulation of surface charge was explored on PI dielectric under constant ambient temperatures in this paper. The present investigation will contribute greatly toward the early potential induced degradation phenomenon of PV system.

1. Introduction

The insulating PI film has been used in the backsheet of flexible solar cell because of the great electrical insulation and thermal insulation characteristics \cite{1}. But accumulation of surface charge on the insulating Polyimide (PI) will cause the distortion of electrical field which could lead to the deterioration to the insulation system in photovoltaic system. During the decades, numerous researches have been conducted to explore the dynamic charge tendency of surface potential of insulating PI backsheets. The properties of surface potential induced by deposit surface charge are difficult to be explained, because they will vary according to various conditions. A lot of literatures have been tried to explore the affecting factors on the performance of insulating backsheet when surface charge are accumulated, such as surface treatment state, voltage waveform and so on\cite{2-4}. Although the investigation of surface potential decay on the backsheets has been reported for many years, many influence factors are lack of physical understood. The measurement of decay tendency of surface potential has been considered the efficient and practical method in order to evaluate the dissipation of charge and transport characteristic of insulating backsheets after poling due to electron avalanche. In order to obtain dynamic status of charge deposition on whole surface, a stereogram from mapping technique could reflect the exact distribution of surface charge and attenuation trend of insulation layer. Consequently, this technique can evolve into a simple tool for evaluating the dynamic dissipation of surface charge of PI backsheet for photovoltaic module.

In present work, a temperature controlled heater was used to maintain the steady temperature of the PI backsheets during the corona discharge process and the following electrostatic measurement.
Furthermore, for avoiding the influence of residual ion, an ionizing air blower was applied to pretreat the testing sample. What is more, the mechanism studies about the attenuation of surface charge and accumulation was reviewed for having an understanding of surface charge dynamic behaviors and offer theories for promoting the performances of insulating backsheets in this paper.

2. Experimental setup and method

In this experiment, the surface charges on the PI film were acquired by corona discharge system. Charge decay characteristics can be obtained by means of measuring the potential of PI surface that on the PI backsheet. In Figure 1, a system of corona discharge was made up a high-voltage power supply and a needle-plate construction of corona discharge. As shown in Figure 1, the system of electrostatic measurement was composed by an electrostatic voltmeter, a high-speed computer and a grounded copper. PI backsheet was used in this experiment. PI was dealt with corona charging voltages at -10kV for 10 minutes. The size specification of the square backsheet is side length of 40mm and 0.25mm thickness. On the one hand, samples were exposed to constant ambient temperatures. On the other hand, the opposite surfaces of PI were placed on a grounded copper plate of experimental system. The charged area during the experiment should be smaller than the PI sample in order to the free charges could not deposit on the outer parts of the PI backsheets edge. Therefore, a metal needle electrode was used in corona discharge system. The electrode of metal needle was applied on -10000V by a high-voltage amplifier. An interval between the surface centre of PI backsheet and the needle shaped electrode is 10mm. Furthermore, a magnetic stirrer was used in order to keep the sample maintain in a constant temperature during the experiment. Additionally, before the experiment, there is an ionizing draught fan was applied for avoiding the effect of residual ion. What is more, in order to prevent airflow and electrostatic, an insulating canister was used. Thus, the electrostatic effect during the corona discharge could be avoided for the results.

The dissipation situation of PI surface charge was continuous measured through using a system of electrostatic measurement which controlled by a computer. The computer could collect the experimental datum of surface potential, which store the card of data acquisition. The surface charge evacuation behavior will be obtained by electrostatic measurement system with cross table with two directions after corona discharge. The datum will be recorded from 0h, 1h, 2h, 6h, 12h and 24h that have been explored and compared under constant working temperature.

![Figure 1. Corona discharge system and electrostatic measurement system.](image-url)
3. Experimental result and discussions

The tendency of surface potential attenuation are collected and measured, as shown in Figure 2. It can be seen from the result that the numerical value of PI surface potential is 3316V at 0 hour after corona discharge, which is an initial peak value. In 1 hour and 2 hours, the quantitative values of surface potential are obtained for PI samples. The attenuation trend of potential of PI surface can be observed apparently after testing the peak values of 6h, 12h and 24h. Then the apparent values are 3020V, 2230V, 1860V, 1235V and 575V at 1h, 2h, 6h, 12h and 24h after corona discharge respectively. It can be observed from the Figure 2 that the peak values of PI surface potential at 0h, 1h, 2h, 6h, 12h and 24h. A distribution of surface potential like a bell shaped was measured due to the nonuniformity electric field. Finally, the peak values of PI surface potential begin to decay because of the transport of surface charge on the PI samples.

As shown in Figure 3, the attenuation trend of PI surface charges could be influenced by three mechanisms. The mechanisms are the electric transportation through the volume of the backsheet and electrical transportation along the surface of the backsheet as well as the charge neutralization by air molecule, respectively [5-7]. Thus, it could be explained that the distribution of PI surface potential liked bell shape reduce on the whole with increasing the attenuation time. Due to the neutralization with gas ions, charges conduct to the volume of the PI sample, which cause the insulating erosion influenced by atomic oxygen radicals and interface polarization of defects in the specimen. The reactions between the oxygen radicals, oxygen ions as well as the C-H bond cause the surface modifications of PI backsheet [8]. Figure 4 shows the common structural formula of PI. According to the literature review, the disaggregation of C-O-C bond and C-N bond in imide ring resulted in the
chemical structure changes during the corona discharge. This is observable as studied have explored that the weakest part in PI molecular are C-O-C bond and C-N bond, which are decomposition easily by influencing the active oxygen, electron avalanche and heat. In addition, a rapid propagation will be produced easily when the insulating erosion of PI backsheet generate a defect of the cavity or the trap. Thus, the cavity or trap will be generated because of the complex structure in PI sample. The free space charges could be captured by the traps and cavity, which cause more accumulation of charges in the backsheet. This results in the conductivity of PI becomes lower, it also can be observed from the table 1 that the attenuation rate is increasing and attenuation speed is decreasing after adding the measuring time, which could explore a result that a contribution from the gas neutralization becomes more predominant.

Figure 3. Three mechanisms of surface charges attenuation (a) the electric transportation through the volume of the backsheet, (b) electric transportation along the surface of the backsheet, (c) the charge neutralization by air molecule.

Figure 4. Molecular structure of PI.
Table 1. Peak values of PI surface potential.

|                   | 0h  | 1h  | 2h  | 6h  | 12h | 24h |
|-------------------|-----|-----|-----|-----|-----|-----|
| Peak Surface      | 3316| 3020| 2610| 1860| 1235| 575 |
| Potential (V)     |     |     |     |     |     |     |
| Decay Rate (%)    | 8.9 | 13.6| 28.7| 33.6| 53.4|     |
| Decay Speed (V/h) | 296 | 410 | 187.5| 104.2| 55  |     |

4. Conclusion

After corona discharge process, the attenuation of PI surface potential on PI backsheet has been explored by experiment in this paper. It can come to the conclusion that PI placed in constant ambient temperatures, the attenuation rate increases and attenuation speed decreases after adding the measuring time. Based on the results of experiments, the chemical character of PI could influence the surface of PI. Thus, the aromatic structure in backsheet is a significant factor to influence the attenuation trend of PI surface charge. This paper affords a new visual angle in the domain of insulating backsheets.

References

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