

Aging Detection of Glass Disc Insulator by Using Infrared Camera

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Abstract

Suitable diagnostic techniques for outdoor glass insulators are important for ensuring the reliability and stability of power system. The possibility of insulator flash-over increases, especially when the insulator is covered by pollution layers or has an internal defect. In this paper, a new technique to detect the pollution level and invisible damage by measuring the surface temperature of glass disc insulators is proposed. A high definition camera had been used to determine the surface temperatures of four glass insulators. The effects of applied voltage on the surface temperature and its distribution were studied. The results show the possibility of using the infrared camera to detect the aging level and invisible damages of the glass insulators.

Keywords: glass insulator, thermal surface, pollution, invisible damage, infrared camera

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1. Introduction

The health of disc insulators may pose a serious threat on the efficiency and reliability of a high voltage power system [1, 2]. The long term performance of disc insulators can be affected by many factors such as the surface pollution and damages [1-6]. The glass insulators are subjected to surface pollution because of the atmospheric contamination [1, 2]. The pollution accumulation at the surface of the glass insulators may lead to flash-over across the insulators, which may then cause disruptions in power supply [2-6]. The outdoor insulators can also be damaged because of vandalism, for example, as a result of stones thrown at insulators. The insulator may be damaged or cracked [7, 8].

The main target of a condition monitoring is to obtain relevant data about the state of the glass insulator and help to make right decision on a further action [7-10]. Several researchers have studied the insulator aging using different techniques to monitor the disc outdoor insulators [3, 11, 12, 21-30]. Most of these used the offline monitoring of the glass insulator aging. The pollution layer's shape and thickness had been measured by many researchers using several indicators, such as the equivalent salt deposit density (ESDD), the non-soluble deposit density (NSDD), and the pollution index (PI) [31-34].

In previous research, there is little attention given to new or more reliable and effective techniques to detect the invisible damages in the glass insulators [35]. The existence of defects inside the glass insulators may lead to terrible consequences to power systems. The main disadvantage of previous techniques is that they have to be implemented offline. The more effective way to detect failure of insulation in a power system is by an online technique.

In this paper, the surface temperature of randomly chosen glass insulators had been measured and analyzed. The main target of this study is to estimate the relationship between the surface temperature and the degradation levels of the glass insulators for various applied voltages. The study proposes the use of the infrared camera to detect pollution level and any invisible damage by measuring the surface temperature of the glass insulators.

2. Methodology

It is noted that leakage current flows through the surface of the glass insulator due to the pollution layer [1, 36-38]. Heat is generated on the surface due to the leakage current

passing through the pollution and due to the electric field intensity once high-voltage was applied [1], [37, 38]. The magnitude of the applied voltage is known to have direct relationship with the leakage current [39]. The leakage current is also known to have direct relationship with the pollution thickness and type [39]. The glass insulators were previously under service in the TNB system and were randomly selected. The pollution layers accumulated on the glass insulator was non-uniform as shown in Figure 1. Supply voltage was made using a high-voltage transformer which was connected to a voltage regulator. The thermal images were captured by NEC H2640D_NS9500PRO infrared thermal camera. Figure 2 shows a photo of the measurement setup.



Figure 1. Glass insulator samples used in the experimental



Figure 2. Experimental setup showing the thermal camera positioning

3. Results and Discussion

Four glass insulators had been tested. Each sample of the glass insulators werestressed with three different voltages (10, 15, and 20kV) for five continuous hours. All plotted results were adjusted or normalized to an initial temperature of 30.6 °C.

3.1. Effect of Applied Voltage

Figure 3 shows the maximum temperature of the glass insulator surface, and it is seen to drastically increase with time during the first hour. The average and minimum temperature behaviors follow the same trend. The average and minimum temperature increments from an ambient temperature through the first hour are shown in Figures 3 (b) and (c).

The surface of the glass insulator heated up due to the applied high voltage across the insulator. After a certain time, it reached the steady-state condition. The larger the applied voltage, the larger would be the steady state temperature. In addition, the average and minimum temperatures, which are also plotted on the same respective graphs, were affected by the level and distribution of the maximum temperatures (appeared as hot spots when using infrared camera).

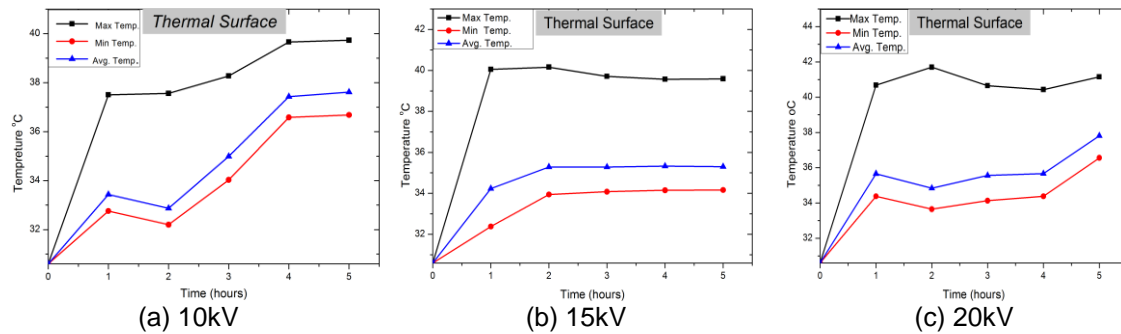


Figure 3. Thermal profile over five-hour period of the insulator surface for sample D, (a) 10 kV, (b) 15kV, and (c) 20kV

Figure 4 shows the effect of the applied voltage on the temperatures of the insulator surface. Sample Chad been stressed with various voltages (10, 15, 20 kV) for five hours. The behaviors of the maximum temperatures with time are almost similar for different voltages. The surface temperatures were seen to increase significantly with the applied voltage. The influence of the time period on the thermal surface was also seen to be affected by the applied voltage. Figure 5 shows the maximum temperatures after five-hours for sample B. The behavior is almost similar with previous results but the maximum temperature is a bit higher in this case.

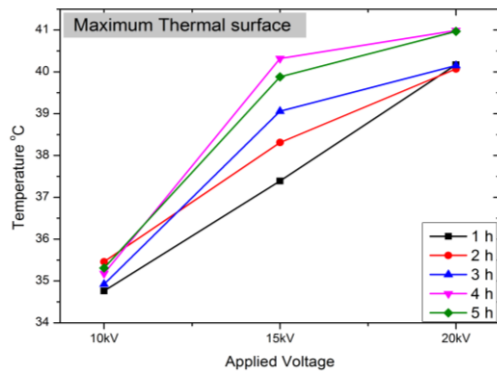


Figure 4. The effect of the applied voltage on the maximum temperature for sample C (for varying stress time periods)

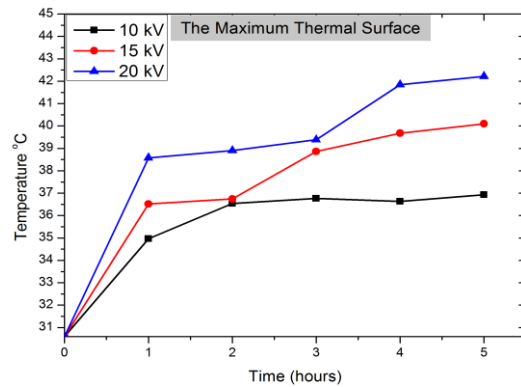


Figure 5. The effect of stress time on the maximum temperature for sample B (for varying applied stress level)

Figure 6 shows the influence of the maximum temperatures of surface with different samples, when applied 10kV, 15kV and 20 kV. The behavior of the surface temperatures effected by the magnitude of the voltage applied. The increment of applied voltage has similar influence with the four samples of the glass insulators that is the surface temperatures are raised up. In spite of, the four samples have different rate of the thermal rise when the voltage increased regularly.

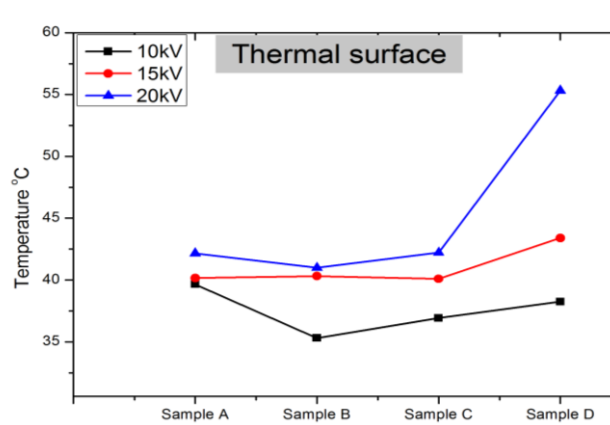


Figure 6. The maximum temperatures for various samples at varying applied voltages (stress time was 5 hours)

3.2. Distribution of the Surface Temperature

Figure 7 shows the thermal images representing the surface temperatures distributed over the surface of the insulator for various applied voltages (10kV, 15 kV and 20 kV) for sample C. The infrared camera shows higher temperatures were concentrated around the pin and gradually spreading and decreasing toward outer diameter of the glass insulator. The glass insulator surface was seen to have a hot spot. The hot spot becomes more intensified with the applied voltage. Figure 8 shows the histogram of the temperatures distribution on the surface of the insulator, for applied voltage of 10kV, 15 kV and 20 kV on sample B. The histogram analysed the thermal images by grouping the image pixels according to their temperature. The histogram is another way to show the temperature distribution of the glass surface. A higher applied voltage led to raised minimum limit of the surface temperatures, and hence the range of temperatures across the glass insulator became wider.

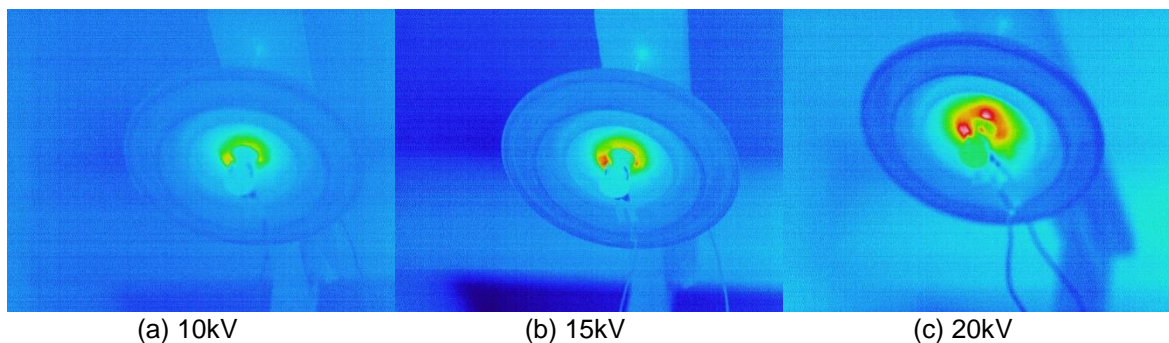


Figure 7. The thermal images of sample B for various applied voltages; (a)10kV, (b) 15 kV, and (c) 20 kV

Figure 9 shows thermal images for sample A after five hours, when various voltages were applied. The invisible damage can be indicated in the thermal image as a hot spot, where it can be seen that the hot spot brightness increases with the applied voltage.

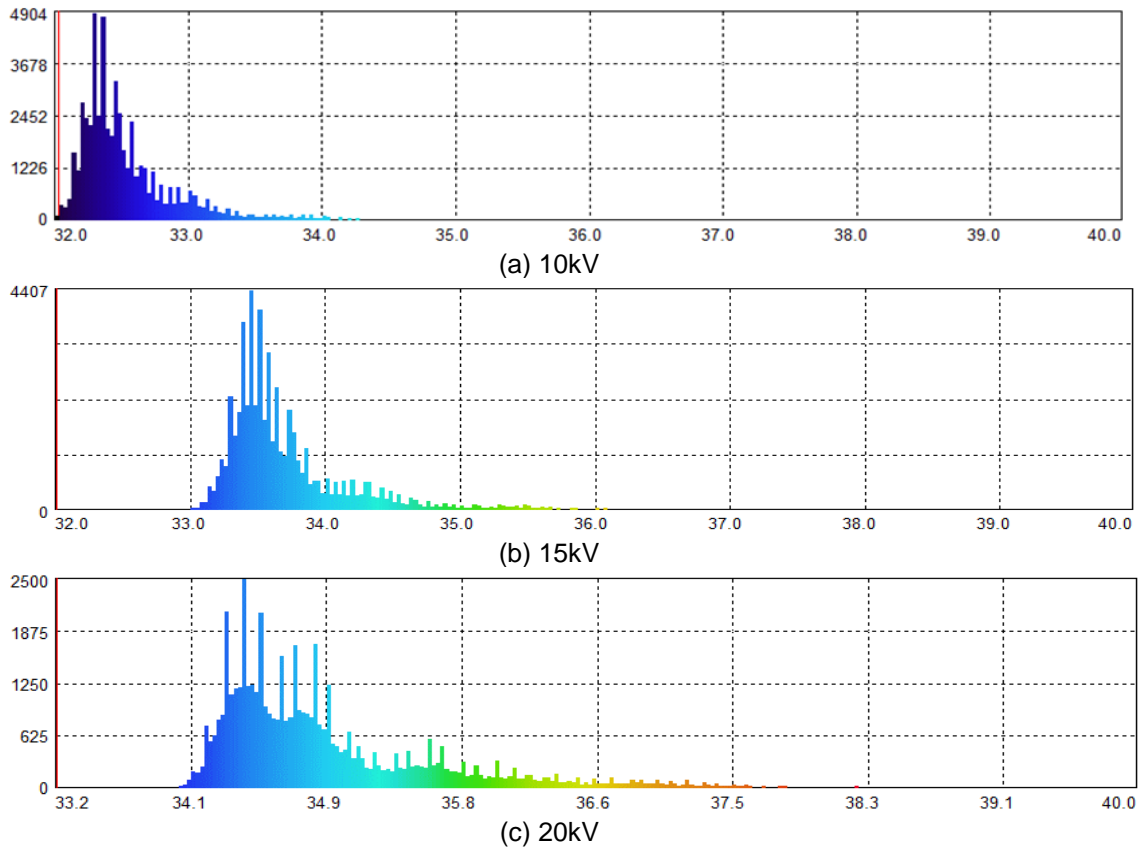


Figure 8. The histogram of the temperature distribution along the insulator B surface, for various applied volatges; (a) 10kV, (b) 15 kV, and (c) 20 kV

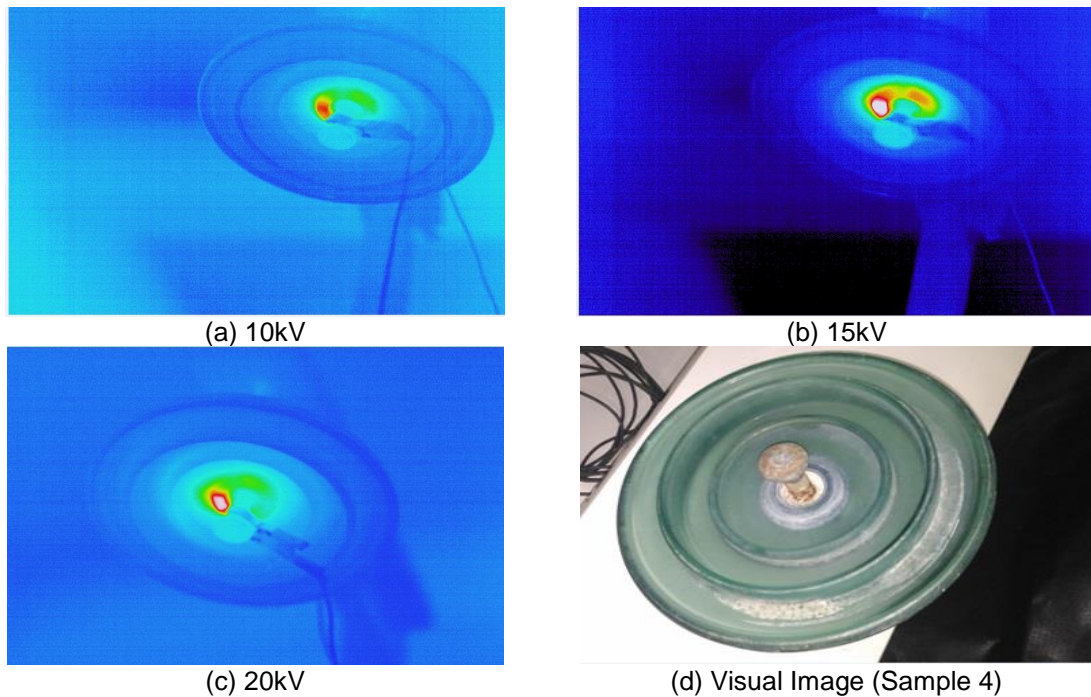


Figure 9. Thermal images of sample A after 5 hours, when applied with various voltages; (a) 10kV, (b) 15kV, and (c) 20 kV; and (d) Visual image of the insulator

4. Conclusion

A new technique using an infrared camera was implemented to measure and depict the surface temperature of the glass insulators as well as to detect glass insulator health. The range of surface temperature depended on the voltage magnitude and pollution level. The leakage current increases when the applied voltage increases which then leads to more heat along the insulators surface. The stress duration is important for the insulator since the initial stress duration will be used to heat the insulator to the steady state condition. The behavior of the applied voltage effect was similar for different samples. The surface temperatures were distributed non uniformly along the glass surface and increased with time. The infrared camera measured the surface temperatures of glass insulators. The thermal distribution can help to detect the pattern of pollution layers on the glass insulators. The applied voltages played a main role to increase the leakage current which leads to the thermal increase on the insulators surfaces. The infrared camera is able to detect the glass insulator internal and external damage as hot spot, and is also able to demonstrate the pollution effects. The aging level of the glass insulators can be evaluated according to the amount of leakage current passing through the insulators surfaces.

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