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High frequency generation mechanism of DC arc and its detection approach

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The DC fault arc in the low voltage DC system threatens the safe operation of the system since it has no zero-crossing point. Therefore, it is of great significance to detect the DC arc. Typically, the approaches for the DC arc most used the high frequency characteristics of the DC arc. However, the reason why the arc generated by DC voltage and current could have high frequency components in the electrical signals remains unclear. This paper analyzes the voltage and current high frequency characteristics and their internal connection of the DC arc and investigates the surface morphology and main elements of the electrodes under different material combinations. The high frequency generation mechanism is revealed. Finally, an DC arc detection approach based on the capacitor current characteristic matrix is proposed.

After the arc is generated, when the current is 2 A, the frequency band distribution density of the characteristic frequency is large in the range of 20-30 kHz and above 70 kHz. However, when the current is greater than 2 A, the frequency bands with concentrated high frequency pulse distribution density of the DC arc are 40-50 kHz and 55-65 kHz. When the combination of the electrode material changes, the frequency band where the high frequency pulse distribution density of the arc current is concentrated does not change, but its amplitude varies. The electrode material has a significant influence on the amplitude of the arc current in the frequency band below 10 kHz. The overall spectral amplitude shows a trend of copper anode and copper cathode>aluminum anode and copper cathode>copper anode and aluminum cathode>aluminum anode and aluminum cathode.

The electrode surface morphology and elemental changes at the microscopic scale were analyzed. When an arc occurs, the random appearance and recombination disappearance of the cathode spots on the electrode surface will lead to random changes in the microscopic morphology of the electrode surface, such as protrusions and depressions. The degree of surface change is related to the current amplitude. When the arc current is large, more dense electrons will be emitted from the cathode and collide with the anode, causing collision ionization. The arc energy is greater, resulting in more severe surface ablation.

From the spectral analysis of different material combinations Al-Cu and Cu-Al, the spectral characteristics at different stages are mainly related to the cathode material responsible for electron emission. In the arc initiation stage, when the material with more active outermost electrons serves as the cathode, its high frequency amplitude is larger. During the arc combustion stage, the material with the outermost electrons being active as the cathode is more likely to maintain a stable conductive channel, and its high frequency amplitude decreases. The influence of electrode material changes on the spectral characteristics at different stages proves that the high frequency characteristics of the arc are essentially caused by the electron migration.

A method for arc fault detection and location by constructing the capacitive current characteristic matrix is proposed. The closer to the location of the arc fault, the greater the amplitude of the high frequency component of the capacitor current spectrum.

References

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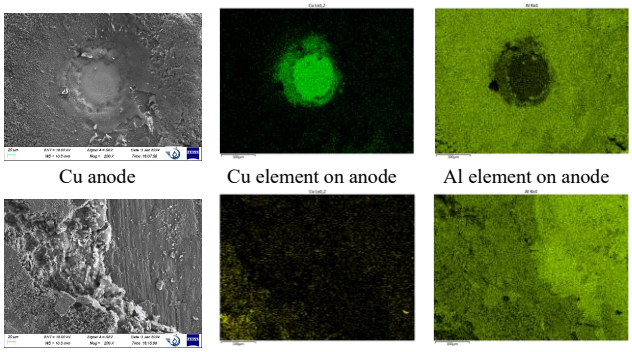
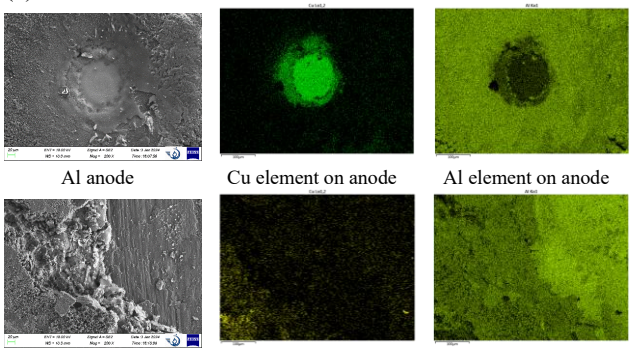


(a) 10 A Cu-Al electrodes



(b) 10 A Al-Cu electrodes

Figure 1 Analysis of the surface morphology and main elements of electrodes under different material combinations.