Detecting High Resistance Grounding Faults in DC Electric Railways Using High Frequency Current Injection

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It is difficult to distinguish the current that flows through the DC feeding circuit during a high-resistance grounding fault having a resistance of several ohms from the electric car current. Detecting it has long been a problem.

Recently we developed a method of detecting a high-resistance grounding fault. In this method, a high frequency current is injected into the DC feeding circuit to distinguish between the electric car current and the high-resistance grounding fault current. This paper describes the principle of detection and provides an outline of the detector.

Principle of detection

When a micro high-frequency voltage is applied to the DC feeding voltage at the substation, the impedance as viewed from the substation differs between the electric car current and the high-resistance grounding fault current. In principle, therefore, it is possible to distinguish between them (Fig. 1).

In Fig. 1, assuming the impedance as viewed from the substation when frequency f_1 (angular frequency ω_1) is injected as $Z(\omega_1)$, the following equation holds true. The resistance of the feeding circuit is assumed to have a characteristic proportional to the frequency, and is expressed as $\omega_1 r_F$.

$$Z(\omega_1) = (j\omega_1 L_F + \omega_1 r_F)l + (R + j\omega_1 L) \quad \text{.........} \ (1)$$

In the above equation, $j\omega_1 L_F + \omega_1 r_F$ denotes the impedance per unit length of the feeding circuit, and l denotes the distance from the substation to the electric car or high-resistance grounding fault point. $R + j\omega_1 L$ is the electric car impedance or the resistance of the high-resistance grounding fault. Observing the resistance component and reactance component of $Z(\omega_1)$, the value of $l\omega_1 r_F$ in the resistance component, $l\omega_1 r_F + R$, is larger than the value of R due to the skin effect (Fig. 2) and hence it is difficult to distinguish between them. In order to detect R separately, we consider injecting an angular frequency, ω_2, which is relatively close to ω_1. In this case, the impedance can be expressed by the following equation.

$$Z(\omega_2) = (j\omega_2 L_F + \omega_2 r_F)l + (R + j\omega_2 L) \quad \text{.........} \ (2)$$

From the above equations (1) and (2), R can be obtained as follows.

$$R = \frac{\omega_2 Z(\omega_1) - \omega_1 Z(\omega_2)}{\omega_2 - \omega_1}$$

Thus, by injecting two different frequencies, it is possible to reduce the error in calculation of R due to the skin effect on the feeding circuit.

High-resistance grounding fault detector

The high-resistance grounding fault detector, developed on the principle of detection mentioned above, consists of an inverter unit and an injection unit. It detects the impedance and R of the feeding circuit from the amplitudes and phases of the injected voltage and injected current (Fig. 3).

Considering the influence of the detector on the track circuit (signal), we inserted a filter into the inverter unit and injection unit. In addition, we adopted a frequency of the harmonics generated by the rectifier ±10 Hz as the injection frequency, so that it does not affect the signal track circuit and is free from the influence of harmonics generated by the rectifier (Fig. 4).

According to the test results obtained by the detector, the frequency-dependent component of R during a high-resistance grounding fault is eliminated, making it possible to detect the resistance component (Fig. 5). This result suggests the possibility to detect a high-resistance grounding fault.

From the test results obtained by our high-resistance grounding fault detector, it was made clear that the detector is capable of detecting a high-resistance grounding fault without adversely affecting the track circuit. However, in order to put the detector into practical use, it is necessary to provide measures against the variation of R due to sudden changes in electric car load and verify a method of distinguishing between the electric car load and high-resistance grounding fault when they occur at the same time.

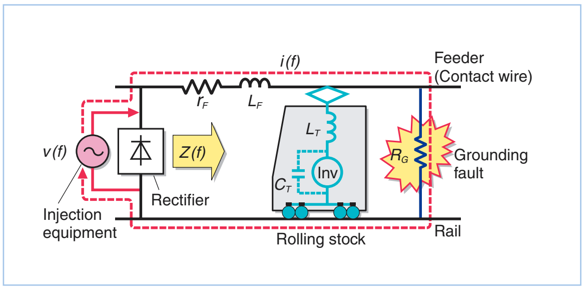

Figure 1. Principle of grounding fault detection.

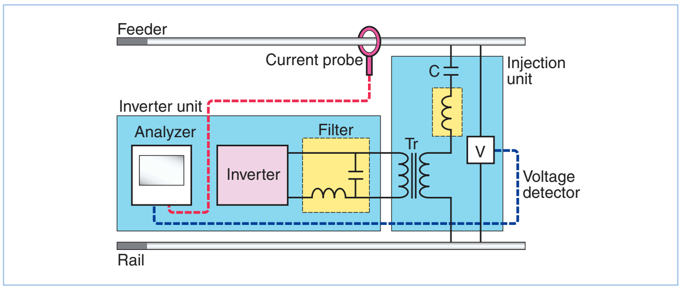

Figure 3. Configuration of high-resistance grounding fault detector.

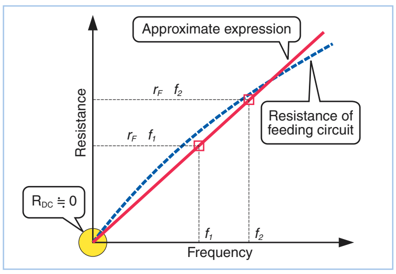

Figure 2. Skin effect.

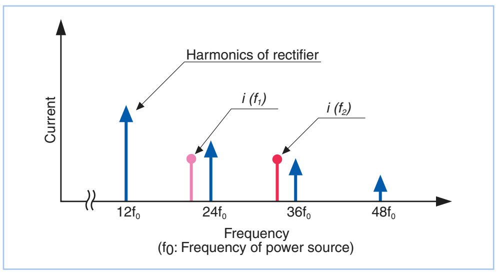

Figure 4. Injection frequencies.

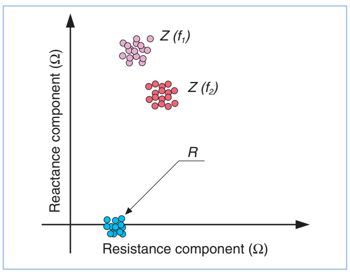

Figure 5. Measurement result of R at high-resistance grounding fault.