# VERIFICATION OF DC GROUND FAULT DETECTOR FOR THE SIGNAL EQUIPMENT ROOM

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ABSTRACT
The feeder circuit protection system of the DC substation is protected by the DC overcurrent device, DC fault selective relay and ground fault overvoltage relay. The DC overcurrent device detects an accident when a current exceeds the set value, and the feeder fault selective relay detects a sudden change in the current during the fluctuation time. In addition, the ground fault overvoltage relay detects an accident when the potential between the rail and the ground of the substation mesh earth exceeds the set value and continues for a certain period of time. However, high-resistance ground faults flow only several hundred amperes. Therefore, the high-resistance ground faults cannot be detected by the DC overcurrent device and feeder fault selection relay installed in the substation. In addition, the rail potential is too small to be detected by ground fault overvoltage relay. If the high resistance ground fault continues, the signal equipment will burn out and transport disorder will occur. There was no way to protect the signal equipment room from high-resistance ground faults. Therefore, we have developed a DC ground fault detector with the aim of protecting the signal equipment room from high-resistance ground faults and preventing defect in transport. This time, a field test was conducted to determine the protection set value of the DC ground fault detector and evaluate the weather resistance. In conclusion, it was confirmed that the developed DC ground fault detector for the signal equipment room was no malfunction. Also, considering that the operating voltage of the signal protector operates at 470V DC ± 20%, the major fault setting value was set to 350V DC so that the ground fault current can be cut off due to a serious fault before the protector operates.
*Keywords: high-resistance ground fault, DC ground fault detection method, rail potential, signal equipment room.*

## 1 INTRODUCTION

The high-resistance ground fault that could not be detected by the protection system of the substation occurred in the electrical equipment inside the station in the JR East, and the ground fault current flowed from the 1,500V DC feeder circuit to the signal equipment and burned out. It is difficult to distinguish between the load current of a train (several hundred to several thousand amperes) and the high resistance ground fault current (several hundred amps) at a substation in the electric power system using 1,500 V DC [1]. There was no way to protect the signal equipment room from high-resistance ground faults. Therefore, we have developed a DC ground fault detection relay with the aim of protecting the signal equipment room from high-resistance ground faults and preventing large-scale transport disorder.

This time, a field test was performed using this DC ground fault detector to confirm protection settings and weather resistance.

## 2 SUBSTATION PROTECTION SYSTEM

The DC substation's power circuit protection system is protected by DC overcurrent device, DC fault selective device and voltage detection method using the ground fault overvoltage relay. DC overcurrent device detects an accident when a current exceeds the set value. DC fault selective relay detects an accident when a steep change ($\Delta I$) occur in the current during the fluctuation time ($\Delta t$). In addition, ground fault overvoltage relay detects an accident when

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the potential between the rail and the substation mesh grounding (rail potential) exceeds the set value and continues for a certain period of time. However, high-resistance ground faults cannot be detected by the DC overcurrent device and instantaneous rate of rise relay installed in substations because only a ground fault current of several hundred amps flows. In addition, the rail potential too small to be detected by ground fault overvoltage relay. If a high resistance ground fault cannot be detected, dielectric breakdown in protective device will occur due to the potential difference between the signal equipment room and the ground. And ground fault current flows, leads to burning. Detection of high resistance ground fault accidents in DC feeder circuits has been a long-standing issue (Fig. 1).

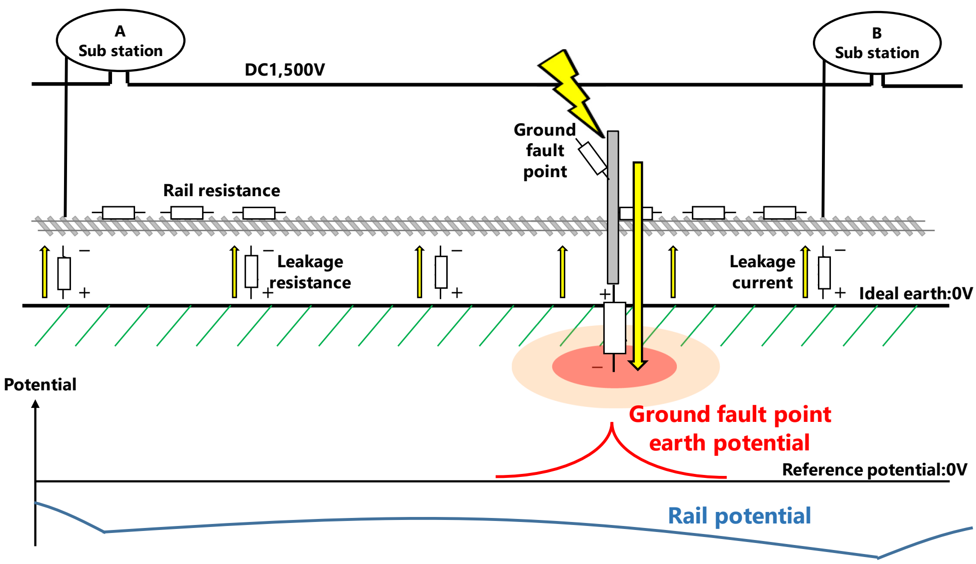


Figure 1: Rail potential at ground fault.

## 3 HIGH RESISTANCE GROUND FAULT DETECTION PRINCIPLE AND OUTLINE OF DETECTION DEVICE

In order to protect the signal equipment room from high-resistance ground faults, we select the method to detect the ground surface potential rise around the signal equipment room when high resistance ground fault occur and to open the DC high speed circuit breaker of the substation. This method uses ground fault overvoltage relay to detect the rail potential and the potential difference between the grounds near the signal equipment room. There are two types of detection, minor fault and major fault. For minor faults, the operating voltage is 100V/150V DC, and the operating time is variable from 0 to 30 s. For serious fault, a 50V DC step selection system with an operating voltage of 250 to 500V DC was used, and the operating time limit was a fixed value of 15 ms. In addition, polarity discrimination function is provided for the operating voltage. The reason for this is that at the time of a high-resistance ground fault, the rail potential is always negative with respect to the ground. When a high-resistance ground fault is detected by this detector, a signal that detects a high-resistance ground fault is transmitted by transmitting a cut-off signal from the power command to the DC high-speed circuit breaker of the substation via a communication facility provided separately. Stop feeding in the equipment room section (Fig. 2).

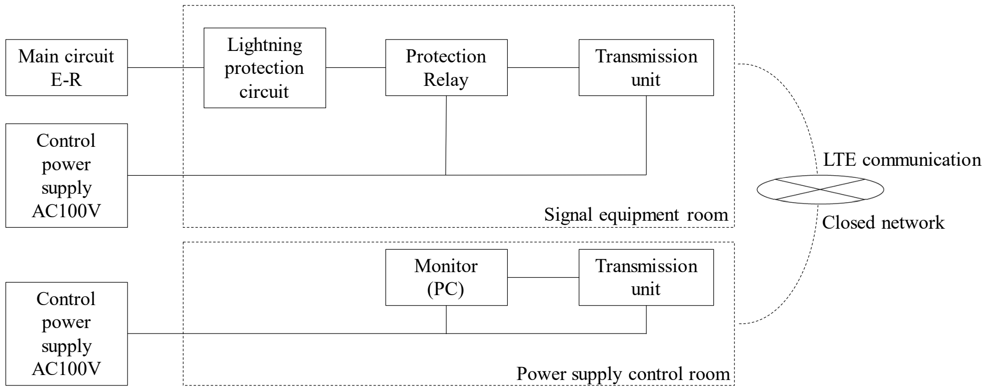


Figure 2: Detection device configuration.

# 4 FIELD TEST

## 4.1 Test environment

The DC ground fault detection device was installed near the signal equipment room at Shiraoka Station on the Tohoku Main Line, and ground of 10 ohm or less was placed near the signal equipment room to measure the potential difference between the rail potential and the ground in the signal equipment room. The shape of the detector has been reduced in size and weight so that it can be installed on a utility pole, and has length of 890 mm, width of 500 mm, depth of 565 mm, and weight of 70 kg.

## 4.2 Weather ability measurement

The temperature and humidity inside the DC ground fault detector were measured from 21 April to 4 November 2020. In order to prevent the temperature inside the panel from rising, the housing of this detection device has a double structure and has a light-shielding property. As a result, the maximum ambient temperature was 3°C, the maximum temperature inside the detector was 45°C, and the maximum humidity was 62%, and the results were good. In the factory, the test was conducted at an ambient temperature of –20 to 60°C. As a results, weather ability measurement was got good results. (Fig. 3).

## 4.3 Rail potential measurement

The rail potential due to the train load current was measured by sampling 1 s from 30 May to 4 November 2020. The reason is to confirm that the rail potential due to the train load current is equal to or less than the minor fault settling value of this detection device. As a result, the maximum negative rail potential was 69.5V DC and the duration of 60V DC was 0.8 s, so the minor fault settling value was 100V DC or less and the operating time was 10 s or less. Therefore, it was confirmed that there is no risk of malfunction due to rail potential fluctuation due to train load current (Fig. 4).

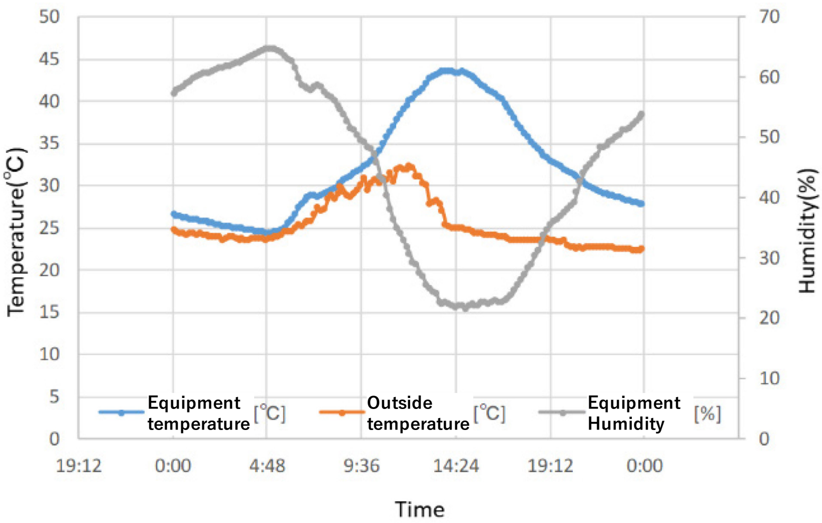


Figure 3: Temperature and humidity measurement results.

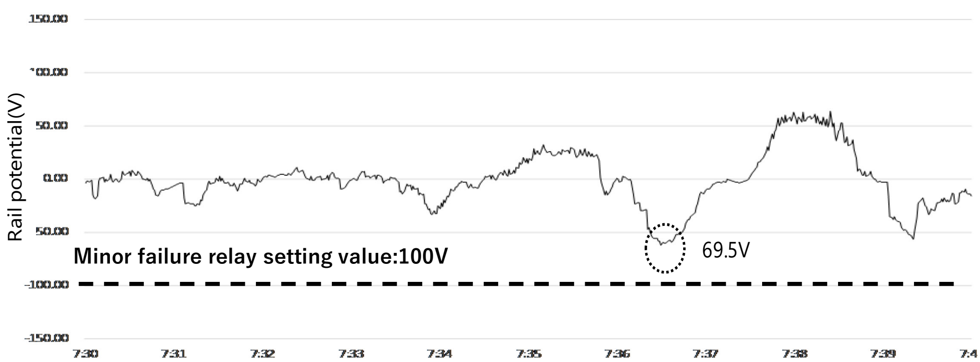


Figure 4: Rail potential measurement results.

## 5 CONCLUSIONS

The field test was conducted at Shiraoka Station on the Tohoku Main Line regarding the developed DC ground fault detector for the signal equipment room, and as a result of environmental resistance measurement and rail potential measurement, it was confirmed that there was no risk of malfunction. Also, considering that the operating voltage of the signal protector operates at 470V DC ± 20%, the major fault setting value was determined to be 350V DC so that the ground fault current can be cut-off due to a serious fault before the protector operates [2] (Table 1). The feature of this detection device is that the fluctuation range of the rail potential differs depending on the environment such as train load and rail leakage resistance. So the specifications are such that the settling value can be flexibly determined. On the other hand, when this detection device is introduced, it is necessary to measure the rail potential due to the train load for a certain period of time in advance to grasp the negative maximum rail potential in order to prevent erroneous detection.

Table 1: Relay setting value.

| Fault item | Relay setting value | Note |
|---|---|---|
| Minor fault | Operating voltage: 100V DC<br>Operation time limit: 10s | No cut-off signal |
| Serious fault | Operating voltage: 350V DC<br>Operation time limit: 15ms (fixed) | With cut-off signal |

## REFERENCES

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