

Verification test of fault locator on a 6.6 kV power distribution line

Y. Mitoma¹, H. Yoshizumi¹, S. Uematsu¹, T. Ishii¹, K. Amano²
& T. Tanaka²

¹*East Japan Railway Company, Japan*

²*Fujikura Ltd., Japan*

Abstract

When a ground-fault problem occurs on a 6.6 kV power distribution line, it is essential to locate the fault point immediately and restore power to that line as soon as possible. However, in a combined system of both insulated wires and cables, surge signals could be affected by attenuation and reflection at both connected points and branch points, making an accurate determination of the fault point more difficult. Moreover, the surge signals of a 6.6 kV ungrounded power line are smaller than those of an ultra-high voltage grounded power line, further making it difficult to detect surge signals. Therefore, we have developed the fault location system and conducted verification tests on a fault locator on a 6.6 kV power distribution line. The ground-fault point is detected by measuring surge voltage propagation at both ends of line utilizing both noncontact voltage sensors and GPS (Global Positioning System) synchronizing technology. We found it important to acquire the first arrival surge and determine the surge traveling speed. These two points are key factors in improving the accuracy of the fault locator. First of all, as the power line produces much base noise, we have difficulty acquiring the first arrival surge. To solve this problem, we succeeded in developing a differential amplifier which improved the S/N (Signal /Noise) ratio. Secondly, we have established a method of calculating the fault point and the surge traveling speed from the switching surge in the combined insulated wire and cable system. In conclusion, we have conducted verification tests, enabling us to detect the fault location with an error rate ranging from 278 m to 363 m (3%) at a distance of 12.258 km. We are continuing work to improve the system.

Keywords: fault locator, 6.6 kV power distribution line, surge signal.



1 Introduction

East Japan Railway Company installs many electrical facilities such as power stations, substations, electric power transmission lines, power distribution lines and so on. We utilize a 6.6 kV power distribution line system to supply electricity for railway signals and stations. An outline of East Japan Railway Company’s electrical facilities is shown in Fig. 1. This line system is a combined system of both insulated wires and cables laid along the tracks. Until now, the fault locator system has never been installed on 6.6 kV power distribution lines (three phases, ungrounded, parallel). One reason is that it is difficult due to the fact that grounded currents are too small to be detected. Another is that it had been considered reliable as a parallel system. However, when a ground-fault problem occurs on a 6.6 kV power distribution line, reliability of power distribution lines decreases. Thus, it is essential to locate the fault point immediately and restore power to that line as soon as possible. We have developed the surge fault locator system and conducted verification tests for this purpose.

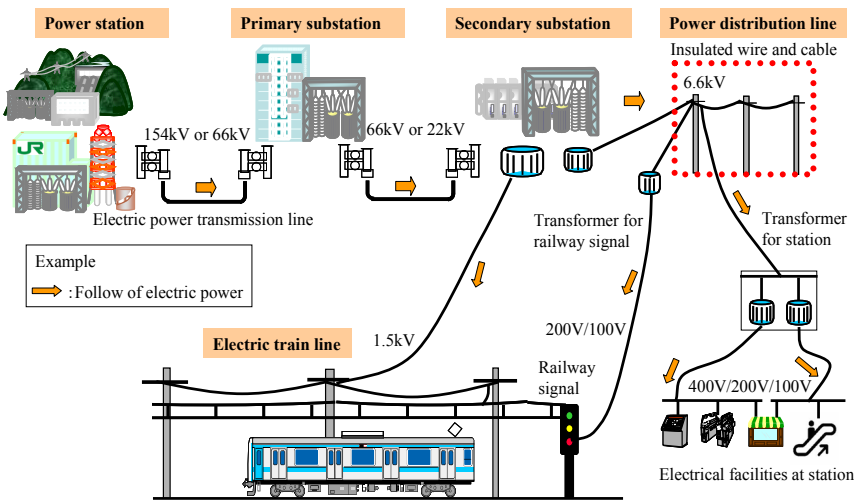


Figure 1: Outline of East Japan Railway Company’s electrical facilities.

2 Problems in applying a surge fault locator system to a 6.6 kV power distribution line

Electric power companies and East Japan Railway Company have already installed the surge fault locator system in ultra-high voltage grounded power lines [1, 2]. However, there were two problems when we installed this surge fault locator system on 6.6 kV ungrounded power distribution lines. First of all, in a combined system of both insulated wires and cables, surge signals could be affected by attenuation and reflection at both connected points and branch points,



making an accurate determination of the fault point more difficult. Secondly, the surge signals of a 6.6 kV ungrounded power line are smaller than those of an ultra-high voltage grounded power line, further making it difficult to detect surge signals. Therefore, we utilize voltage sensors to detect small surge signals instead of current sensors.

3 Theory and feature of the surge fault locator system

When a ground-fault problem occurs, surge signals generate from the fault point. These surge signals are transmitted through the power line and reach the substations which are located at both ends of the line. These surge voltage propagations are detected by noncontact voltage sensors installed in a high-voltage cubicle. These voltage sensors are noncontact type in consideration of safety. Each fault locator makes waveform processing and computes the surge arrival time. Next, each fault locator transmits this surge arrival time information to a locator main system by each communication wire. The locator main system computes the distance of the fault point from the substation. Each fault locator is set in each substation and the locator main system is set in the control center. The fault locator system makes it possible to synchronize the surge arrival time accurately using GPS (Global Positioning System) technology. The theory of the surge fault locator system is shown in Fig. 2. The configuration and features of the surge fault locator system is shown in Fig. 3.

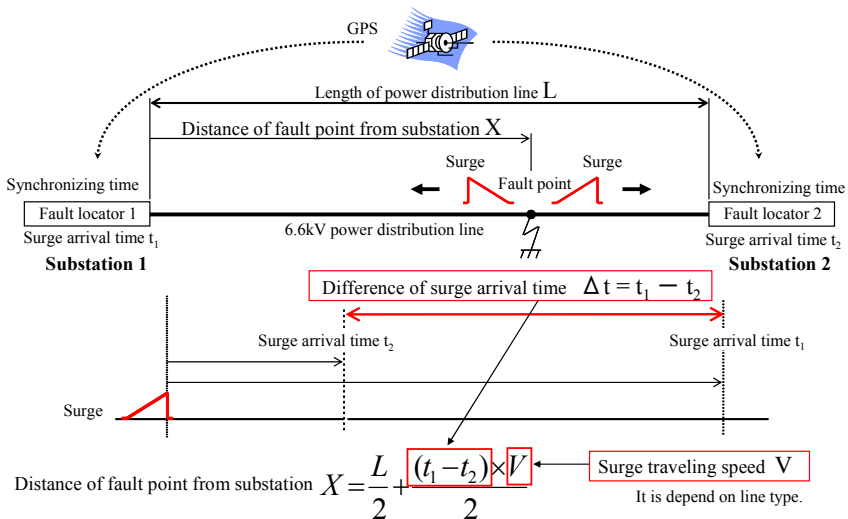


Figure 2: Theory of the surge fault locator system.

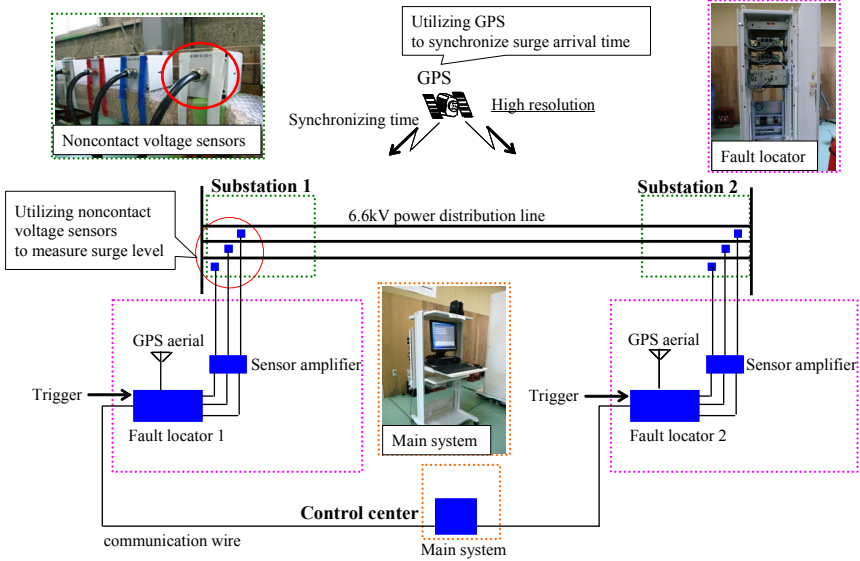


Figure 3: Configuration and features of the surge fault locator system.

4 Making accurate determination of the fault point

When the fault locator system computes the distance of the fault point from the substation, it is essential to acquire both Δt (difference of surge arrival time) and V (surge traveling speed) accurately. We found it important to acquire the first arrival surge and determine the surge traveling speed. These two points are key factors in improving the accuracy of the fault locator.

4.1 Acquiring the first arrival surge

It is important to acquire the first arrival surge accurately. In a 2010 verification test, the fault locator at one substation was able to detect the first arrival surge, but the other fault locator at the other side was not able to detect it. (the other fault locator at the other side detected the second or third arrival surge.) Therefore, the error rate of fault locator is about 10%. The reason is that, in a combined system of both insulated wires and cables, surge signals could be affected by attenuation and reflection at both connected points and branch points. The power line produces much base noise and the surge signals are too small to be detected in the ungrounded power line. Therefore, we detected the second arrival surge but not the first arrival surge. As a result of measuring base noise, we found that base noise was mainly generated from outside induction. To solve this problem, we succeeded in developing a differential amplifier which improved S/N ratio. This differential amplifier can intensify the output 4–5 times on the condition that a ground-fault occurs at particular phase. The image of the differential amplifier is shown in Fig. 4. On the other side, this differential

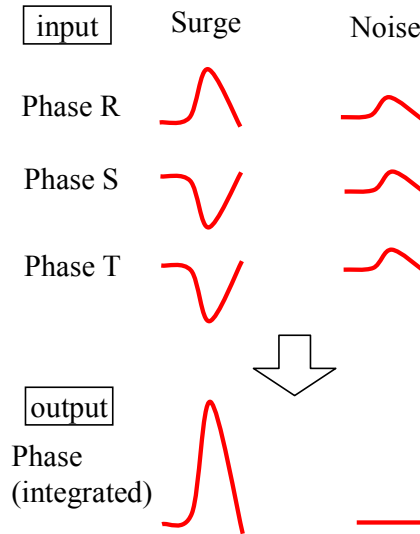


Figure 4: Image of the differential amplifier.

amplifier can decrease the output on the condition that noise occurs at several phases. Next, we measured base noise both day and night, and we determined the proper trigger level of detecting the first arrival surge signal.

4.2 Establishing a method of calculating the fault point and determining the surge traveling speed

It is important to establish a method of calculating the fault point in a combined system of both insulated wires and cables. Also it is important to determine the surge traveling speed, the characteristics of which are generally known [3]. However, we confirmed the surge signal characteristics by conducting a factory test. The results of the factory test are as follows:

- (1) Surge traveling speed:
The surge traveling speed of insulated wires is faster than that of cables.
- (2) Relation between frequency and surge traveling speed:
High-frequency surge is faster than low-frequency surge. This image is shown in Fig. 5.
- (3) Influence of both connected points and branch points:
The surge traveling speed does not change at either connected point or branch point. However, the surge signals could be affected by attenuation and reflection.

Therefore, we reflected this factory test results in the method of calculating the fault point. The surge traveling speed of insulated wires is different from that

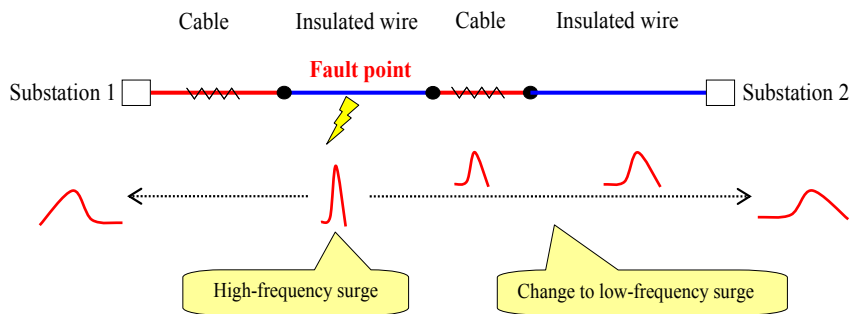


Figure 5: Relation between frequency and surge traveling speed.

of cables. Thus, we set up the surge traveling speed of insulated wires as a standard. Thus, we constructed a corresponding line. The schematic diagram of calculating the fault point is shown in Fig. 6. The method of calculating the fault point is as follows:

- (1) We convert the length of cables equivalent to the length of insulated wires on a corresponding line. In this case, we make the length of cables longer.
- (2) We temporarily locate a fault point on the corresponding line.
- (3) We perform the correction for the surge delay. The correction for the surge delay depends on the variation of frequency of surge.
- (4) We return to the original line from the corresponding line. After that, we determine the actual fault point.

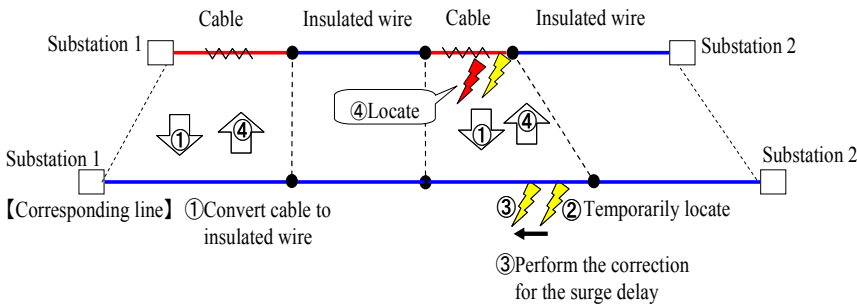


Figure 6: Schematic diagram of calculating the fault point.

We also calculated the surge traveling speed from the switching surge in the combined insulated wire and cable system. To reduce the effects of data measurement errors, a high-precision calculation based on the least squares method is used.

5 Outline of verification tests

We conducted verification tests for the surge fault locator system on a 6.6 kV power distribution line (three phase, ungrounded, parallel), confirming its validity. The length of a 6.6 kV power distribution line is 12.258 km, the rate of cables being about 10%. We attached the grounded wire to that line without electricity. The wire was grounded through a high voltage circuit breaker. This high voltage circuit breaker was temporarily installed in the field. After finishing setting the grounded wire, we set off an artificial ground-fault with impressed voltage. We implemented full preparations for the verification tests that did not effect near by electrical facilities around the artificial ground-fault point. The circuit composition of the artificial fault test is shown in Fig. 7, and the images of the artificial fault test are shown in Fig. 8.

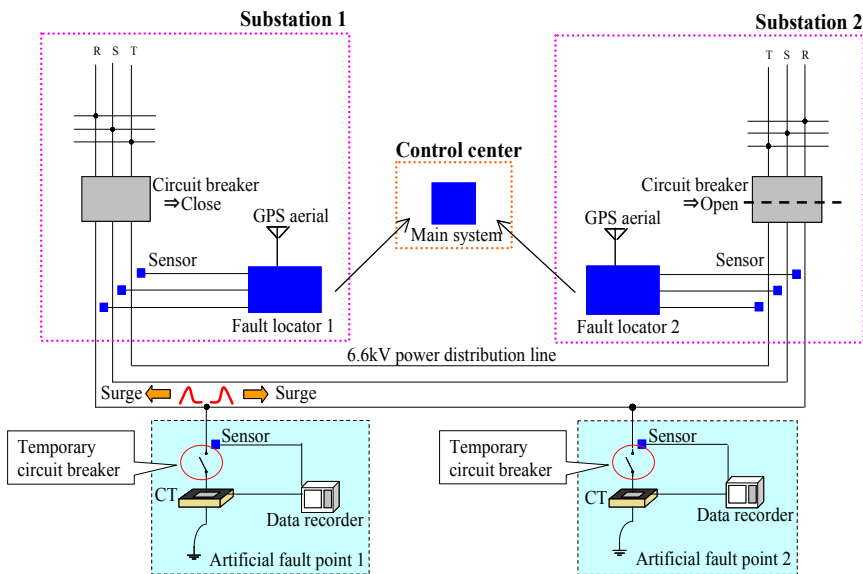


Figure 7: Circuit composition of the artificial fault test.

6 Result of verification tests

As a result of the verification tests, we detected the fault location with an error rate ranging from 278 m to 363 m (3%) at a distance of 12.258 km. When we set off the artificial ground-fault, the distance of the fault point from the substation was instantly displayed on the screen of the locator main system. The result of verification tests is shown in Table 1, and the example of output display for verification test is shown in Fig. 9.

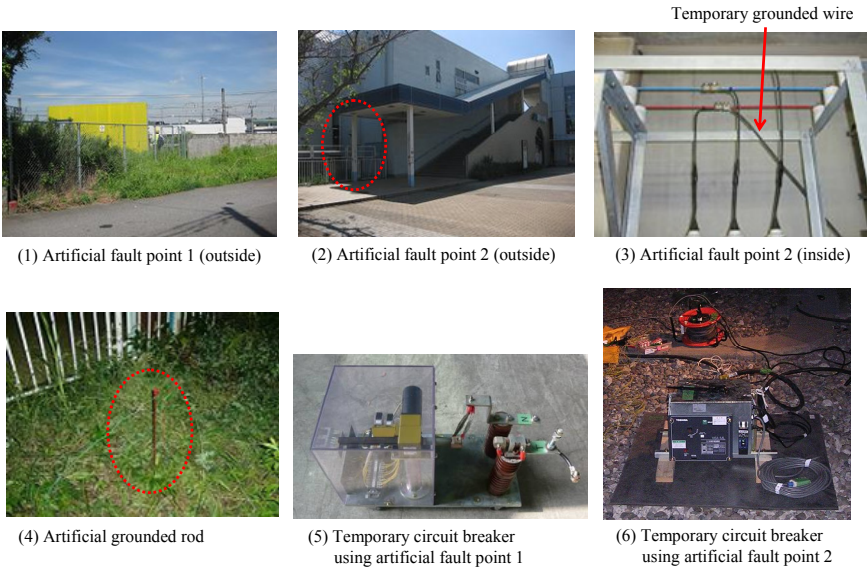


Figure 8: Images of the artificial fault test.

Table 1: Result of verification tests.

Test number	Distance of fault point from substation [km]	Error [m]	
1	10.117	326	
2	10.102	311	
3	10.154	363	Maximum
4	10.069	278	Minimum

Artificial ground fault point (No. 2): 9.791 km.

7 Conclusion

We have developed the fault location system and conducted verification tests on a fault locator on a 6.6 kV power distribution line (three phases, ungrounded, parallel, a combined system of both insulated wires and cables). As a result of the verification tests, we detect the fault location with an error rate ranging from 278 m to 363 m (3%) at a distance of 12.258 km. We are continuing work to improve the system.



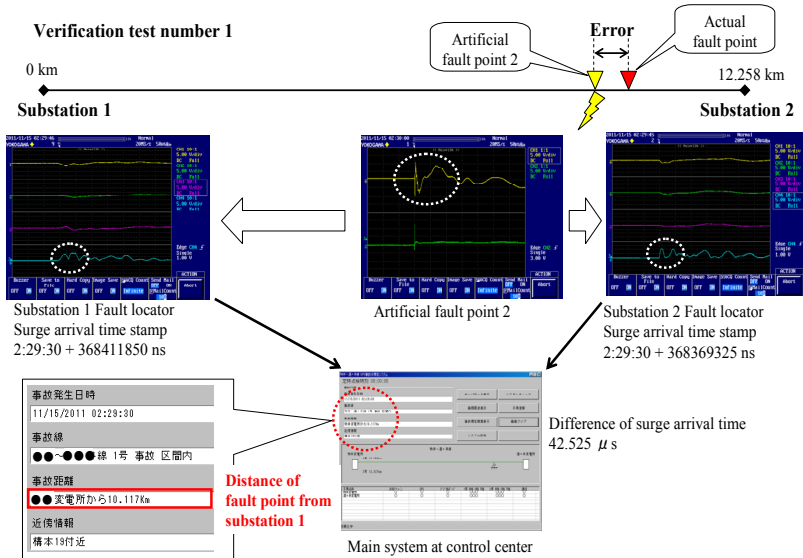


Figure 9: Example of output display for the verification test.

References

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