Development of Surge Detection Type Fault Locating System for AC Feeding Circuits

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When a ground fault or a short circuit has occurred in the contact wire system due to bird strikes, fallen trees, flying objects or rolling stock failures, normal service will immediately be recovered to restart train operations if the fault point can quickly be located. Two types of fault locating systems are now used for this purpose in AC electric railways: one is the type to measure the reactance of fault circuits in feeding circuits as an indicator of the distance to the fault point (widely used across the world) and the other uses the ratio of the neutral terminal current of adjacent autotransformers as the indicator (developed in Japan and used for Shinkansen railways in Japan and Taiwan). These systems can normally locate the fault point with errors of 1 km or less, but the measurement involves substantially large errors and sometimes it is impossible to locate the fault point for certain types of accidents. Thus improving the precision of fault locating system to quickly resume train operation is very desirable.

As high voltages such as 20 kV and 25 kV are used for AC electrification, a fault generates a surge voltage that is propagated in the contact wire. Recently, we developed a new surge voltage detecting device used to locate fault points (see Figs. 1 and 2 for its principle of operation). To calculate the distance from a substation to the fault point, this device uses the difference between the surge voltage arrival time at the substation on either end of a section and that at the sectioning post, together with the surge propagating speed in the contact wire. This principle has already been applied to the system of power transmission cables. As the surge propagating characteristics in feeding circuits are different from those in power transmission cables, however, several technologies had to be developed.

There is virtually no prior literature on the measurement of the waveforms or the propagating speed of surge voltage in railway feeding circuits. Therefore, we implemented a test to inject an impulse voltage into a contact wire to confirm that (1) the surge voltage propagating speed is approximately 90% of the velocity of light and (2) the surge voltage can be captured at the secondary winding of the instrument voltage transformer (VT) normally installed at substations, though it is attenuated and deformed to a large extent. We also manufactured a surge voltage measuring/recording device that synchronizes the times at two distant places using the GPS clock (Fig. 3). The methodology requires only a GPS antenna to be connected and use of the voltage output from the instrument voltage transformer (VT) at substations as an input. No expensive high-voltage high-speed voltage sensors are required. We also developed software to automatically (1) determine the surge voltage arrival time from the surge voltage waveform recorded by the prototype device and (2) locate the distance to the fault point. Finally, we implemented an artificial fault test and used the prototype device under working conditions to locate actual faults at a substation on a revenue service line for approximately seven months to verify its precision. As a result, we were able to confirm that the device can locate fault points at high precision with errors of about 100 m or less when applied to approximately 20 km-long feeding sections.

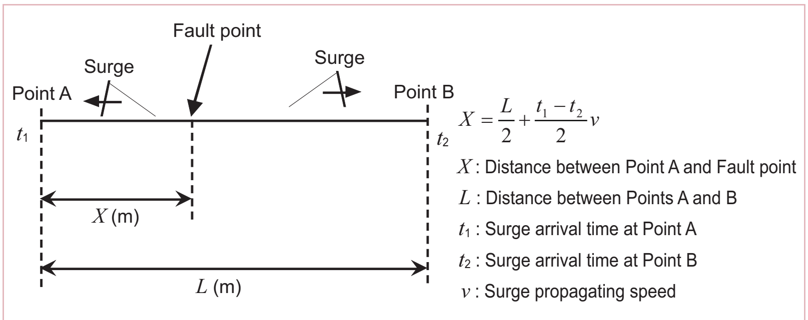

Fig. 1 Principle of the surge detection type fault locating system

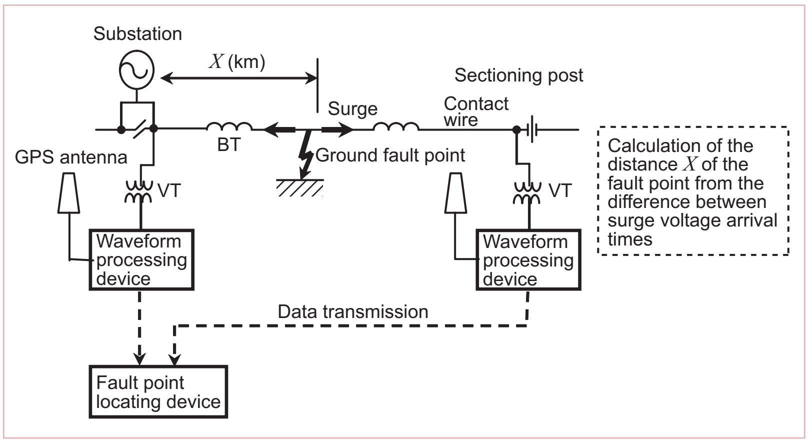

Fig. 2 System composition

Fig. 3 Prototype surge detection type fault locating system (waveform processing device)