TDR MEASUREMENT WITH UTILITY-POLE-INTERVAL RESOLUTION OF REAL-SCALE DISTRIBUTION SYSTEM

Shimpei OE
Kansai Electric Power Co., Inc. –Japan
oe.shimpei@c2.kepco.co.jp

Tsuyoshi SASAOKA
Kansai Electric Power Co., Inc. –Japan
sasaoka.tsuyoshi@a5.kepco.co.jp

Tohlu MATSUSHIMA
Kyoto University –Japan
matsushima@kuee.kyotou.ac.jp

Takashi HISAKADO
Kyoto University –Japan
hisakado.takashi.7x@kyoto-u.ac.jp

Osami WADA
Kyoto University –Japan
wada.osami.4a@kyoto-u.ac.jp

ABSTRACT

We attempt to apply new method for locating fault point by injecting high-frequency short pulse into overhead distribution line. This method, which is called as TDR (Time Domain Reflectometry) measurement, enables to find the fault point easily by measuring propagation time of the pulse reflected due to impedance change at the fault point. In prior research, we have confirmed propagation characteristics of injected pulse through the experiment in test circuit. In this paper, we explain the result of our experiment on TDR measurement in real-scale distribution system. As a result, we confirm the method is able to apply to real-scale distribution system. Moreover, we confirm reflected waves at fault points has different characteristics based on fault type, such as short circuit, grounding, or broken wire.

1. INTRODUCTION

The Kansai Electric Power Company has introduced Distribution Automation System (DAS) since 1989. DAS has the function to isolate the fault area and minimize outage area when a distribution fault occurs; nevertheless, field technicians must be dispatched to the site and search for the fault point.

In order to identify the grounding fault point on overhead distribution lines, as a conventional method, DC pulse generator and electric current detector have been utilized. While this method has contributed to improving restoration efficiency, it requires a lot of labour force because the field technicians need to climb up utility poles and apply current detector at each of the branch lines.

For more restoration efficiency, we attempt to apply new method by observing reflected waveforms of high-frequency short pulse on overhead distribution lines.

This method, which is called as TDR (Time Domain Refletometry) measurement, enables to find the fault point easily by measuring propagation time of the pulse reflected due to impedance change at the fault point [1-3]. It is commonly applied for short-length circuit without branch lines such as underground distribution lines. In order to obtain propagation characteristics of injected pulse in overhead distribution line, we had carried out the experiment through the test circuit (approximately 50m length) [4].

In this paper, we attempt to apply TDR measurement to real-scale distribution system. The distribution system length tested in this experiment is set to approximately 1km because the fault area isolated by DAS is commonly less than 1km length. Moreover, we measure reflected waves from various types of fault points(short circuit, grounding, and broken wire) and examine the effectiveness of our proposed method.

2. TDR MEASUREMENT CIRCUIT

Fig. 1 shows application image to specify fault point by TDR measurement. We measure injected pulse and reflected pulse occurred at the fault point due to impedance change, and we find the fault point distance based on their time deference and pulse propagation velocity. (Eq.1)

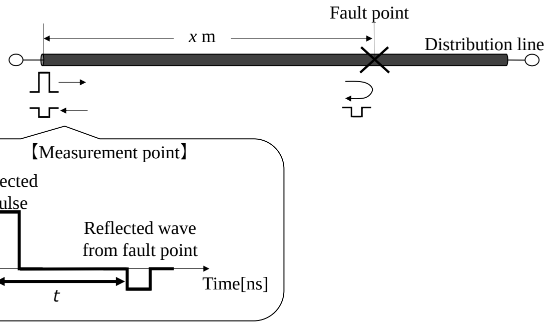


Fig.1: Application image of pulse wave measurement

$$x = \frac{1}{2}vt \quad \begin{cases} x(m): Fault\ point\ distance \\ t(ns): Time\ difference \\ v(m/ns): Pulse\ propagation\ velocity \end{cases} \tag{1}$$

For applying TDR measurement to overhead distribution network, the resolution ability should be that we can specify the utility-pole which contains fault point. Therefore, the pulse made by Pulse Generator (PG) is set between 50ns and 100ns in time width.

Fig. 2 shows TDR measurement circuit. Injected pulse by PG is applied to between two wires. An adjusted matching circuit is used to avoid multiple reflections between the source circuit and the distribution line; the matching circuit is composed of R_1 R_2 by impedance of the distribution line and coaxial cable. Propagation wave is measured by oscilloscope and voltage probe.

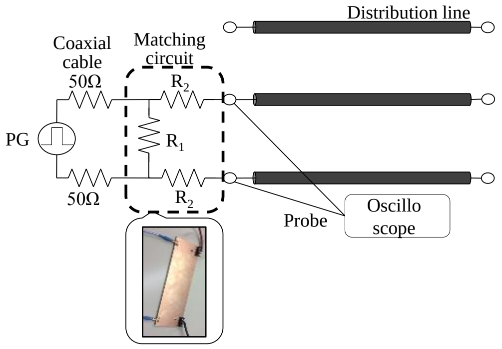


Fig.2: TDR measurement circuit

3. REAL-SCALE DISTRIBUTION SYSTEM

We experimented TDR measurement in real-scale distribution system. As shown in Fig.3, the circuit is 979m length with a branch line and an open-circuit. The branch line is near measurement point, and its end is disposed of the equivalent impedance circuit with the distribution line. The distance to the open end from measurement point is 979m. As PG parameters, injected pulse width is set to 100 ns and amplitude is set to 1V. In addition, a low pass filter is inserted to the oscilloscope to remove high frequency component above 30 MHz to eliminate noise. We measure reflected waves from a branch point and an open end.

As the results, each reflected wave is confirmed as shown in Fig.4. The pulse at Time=0s indicates injected pulse wave. The reflected wave due to impedance change at branch point B_1 appears at about 150ns, and open end O_1 appears at about 7000ns. The measured amplitude of the reflected wave from branch point B_1 is approximately -1/3 of the injected pulse, and the amplitude of the reflected wave from the open end O_1 is approximately 4/9 of the injected pulse; these numbers roughly agree with the theoretical values (Fig.5). This result shows that the injected pulse for utility pole interval resolution is able to propagate through approximately 1km length.

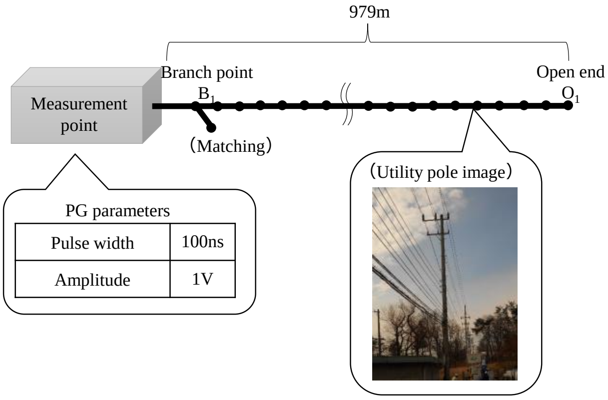


Fig.3: Test circuit composition of real-scale distribution system

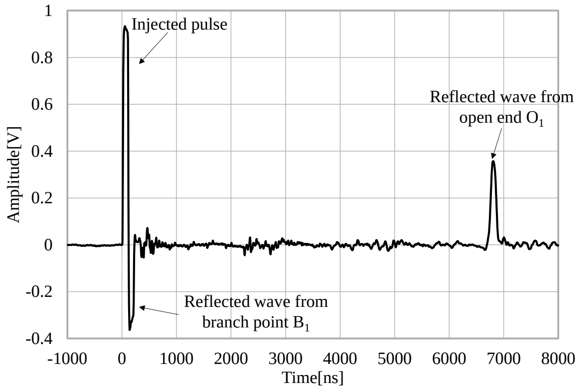


Fig.4: Measurement result of real-scale distribution system

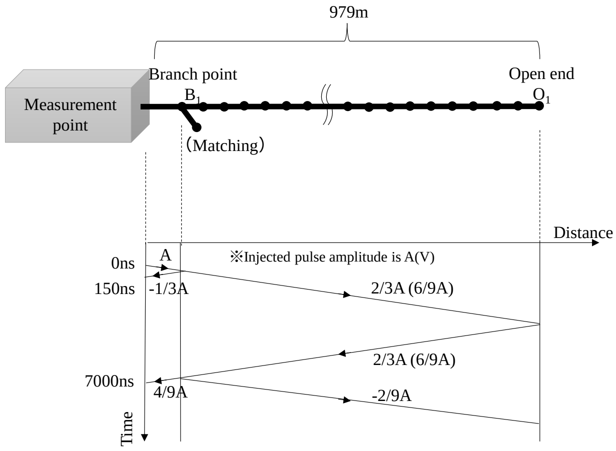


Fig.5: Trellis diagram of measurement result

4. MEASUREMENT RESULT OF REAL-SCALE DISTRIBUTION SYSTEM WITH BRANCHES

Next, we experimented TDR measurement in real-scale distribution line with two branch points and two open ends. The distribution system has many branch lines in general, so we have to take the effect of branch points into consideration. Fig.6 shows the test circuit. Each distance to measurement point from two open ends are 979m and 1368m respectively. In order to achieve resolution of distance between utility poles, injected pulse width is set to 100ns and amplitude is set to 1V. We measured reflected waves from the brunch points and the open ends.

As a results, each reflected wave is confirmed as shown in Fig.7. Injected pulse wave is at Time=0s, each reflected wave due to impedance change at branch point B_1 and branch point B_2 appears at about 150ns, 6000ns. And each reflected wave due to impedance change at open end O_1 and open end O_2 appears at about 7000ns and 9000ns. The amplitude of reflected wave from the end of branch B_1 is approximately -1/3 of injected pulse, because the branch point impedance is half as small as distribution line. The amplitude of reflected wave from branch point B_2 is approximately -4/27 of injected pulse because transmission wave attenuates by impedance change at branch point B_1 and branch point B_2. Therefore, the reflected wave appears at about 10500ns because the multiple reflected wave from open end O_1 and open end O_2 overlap each other. These result shows that each reflected waves from two brunch points and two open ends are clearly observed in real-scale distribution system.

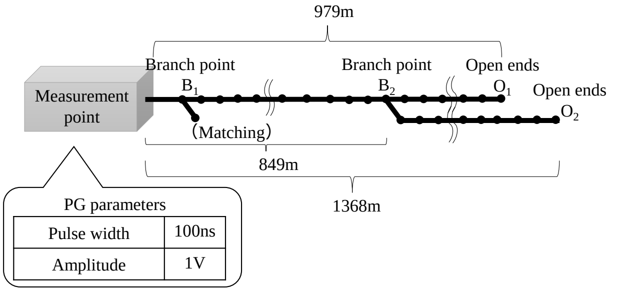


Fig.6: Test circuit composition of branch points and open ends

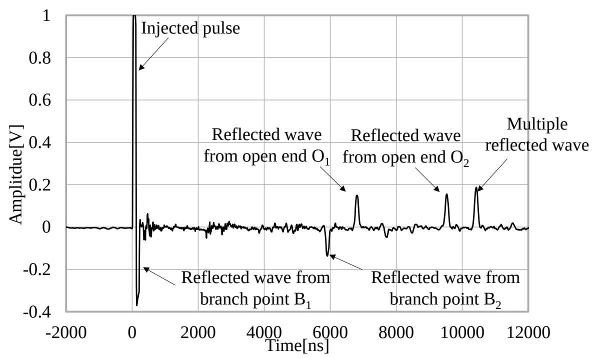


Fig.7: Measurement result of reflected wave from branch points and open ends

5. MEASUREMENT RESULT OF REFLECTED WAVE WITH GROUNDING FAULT POINT

We experimented TDR measurement on grounding fault distribution line in the test circuit as shown in Fig.8. The distance to measurement point from open end O_1 is 979m and the grounding fault point distance is 332m. The grounding fault point is made by connecting distribution line C to ground via supporting arm. As PG parameter, injected pulse width is set to 50ns, and amplitude is set to 2V. We measured three times as different set of distribution line phases (A-B, B-C, and A-C).

As a results, reflected waves at grounding fault point is confirmed as shown in Fig.9. In the case of that distribution line B-C or A-C is measured, the reflected wave due to impedance change at grounding fault point is confirmed at about 2500ns. In the case of that distribution line A-B is measured, the reflected wave of grounding fault point isn't confirmed. The measurement results of distribution line B-C or A-C shows that the reflected wave amplitude due to impedance change at open end O_1 is smaller than that of distribution line A-B. Moreover, we calculate the fault point distance from the propagation time of the reflected wave and pulse velocity, and the result nearly correspond to the actual setting. Consequently, we confirm that the TDR measurement is able to specify a grounding fault point.

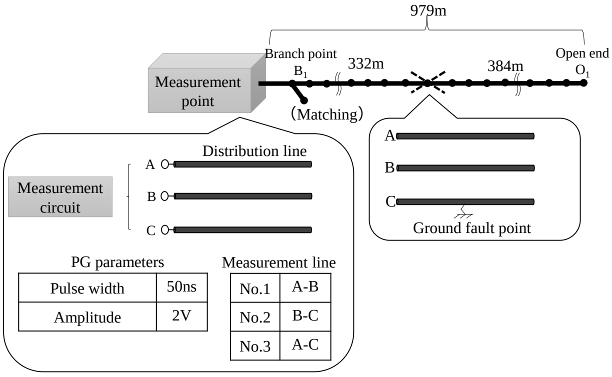


Fig.8: Test circuit composition of grounding fault

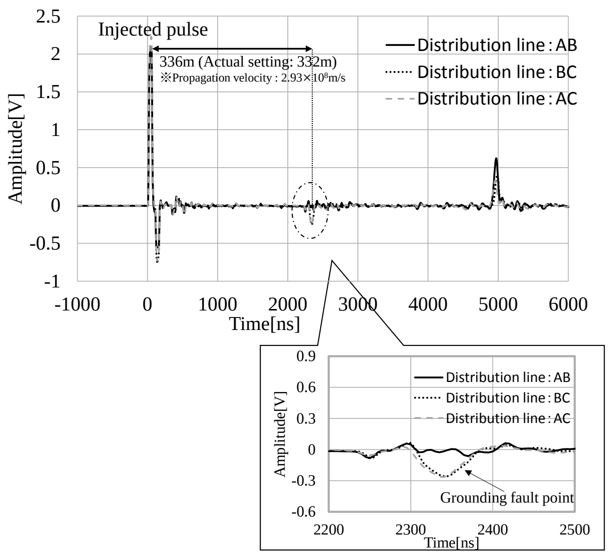
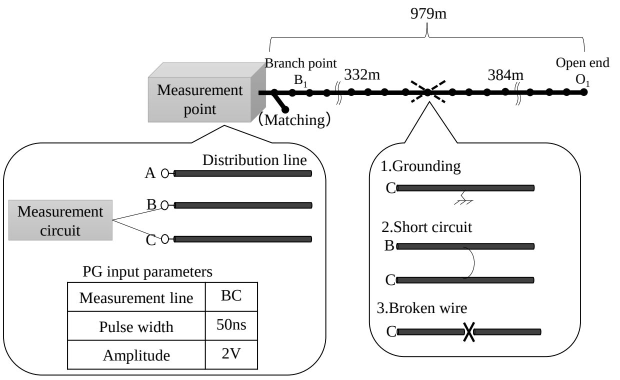


Fig.9: Measurement result of grounding fault

6. MEASUREMENT RESULT OF REFLECTED WAVE WITH DIFFERENT TYPES OF FAULT POINT

Next, we attempt to measure with the different types of fault (short circuit, grounding, or broken wire) in the test circuit as shown in Fig.10. The distance to measurement point from open end O_1 is 979m, and the fault point distance is 332m. Short circuit was made by connecting line B and C, broken wire is made by disconnecting line C and grounding is made by connecting line C and ground via supporting arm. These fault point is set at the same place. Injected pulse width is set to 50ns, and amplitude was set to 2V.

As a result, each reflected wave is confirmed as shown in Fig.11. Injected pulse wave appear at Time=0s, and reflected wave from branch point B_1 appear at about 150ns. The reflected wave due to impedance change at each fault point appear at about 2300ns. However, these amplitude is different by types of fault. In the case of grounding, the reflected amplitude is minus. In the case of short circuit, the reflected amplitude is minus and the pulse wave larger than that of grounding. In the case of broken wire, the reflected pulse amplitude is plus. In short, we confirm the reflected wave has a characteristic based on the types of fault.



Measurement line	BC
Pulse width	50ns
Amplitude	2V

Fig.10: Test circuit composition of fault point

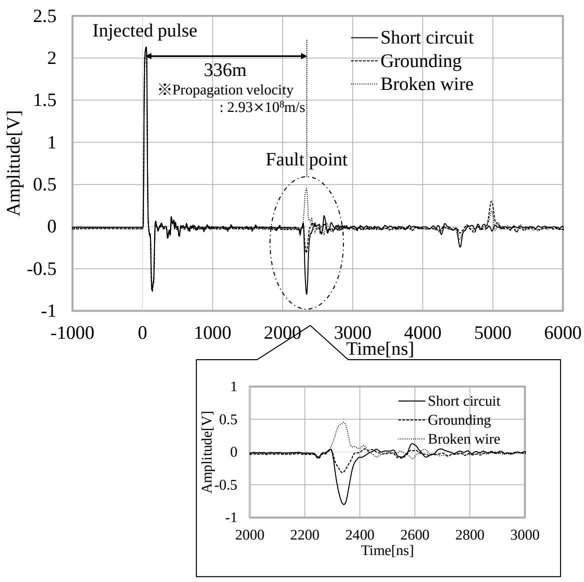


Fig.11: Measurement result of fault point

7. CONCLUSION

In this paper, we experimented TDR measurement in real-scale distribution system (approximately 1km length). First, we measured reflected waves from branch point and open end. As a result, each reflected wave is clearly confirmed. This result shows that injected pulse for utility pole interval resolution is able to propagate clearly in real-scale distribution system. Moreover, we measured reflected waves from a fault point in test circuit. As a results, reflected waves from each fault point are confirmed, and they had different characteristics by each fault type. We can specify the distance to the fault point based on the reflected wave propagation time and pulse velocity; the measured result nearly correspond to the actual setting. Through these experiments, we confirm this method is applicable to specify the fault point with high accuracy. As our future works, we have a plan to apply this method for more complicated actual distribution system.

REFERENCES

[1] Shweta Gajbhiye, 2013, “Cable Fault Monitoring and Indication: A Review”, IJCSN, Vol.2, Issue 4, 20-24

[2] Martin Hartebrodt, 2014, “Fault Detection in Fieldbuses with Time Domain Reflectometry”, IEEE AFRICON2014, 391-396

[3] Francesco de Paulis, 2016, “Detectability of Degraded Joint Discontinuities in HV Power Lines Through TDR-Like”, IEEE Transactions on Instrumentation and Measurement, Vol.65, No.12, 2725-2733

[4] Shinpei Oe, 2016, “The Influence of Overhead Distribution Facilities in TDR Measurement with Utility-Pole-Distance Resolution”, ICEE2016,