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Applicability test of cable diagnostic method based on Time-Frequency Domain Reflectometry

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1. Introduction

Low-voltage cables in nuclear power plants are equipment that play an important role in controlling the operation of safety facilities, transmitting safety-related signals, and operating controls to mitigate accidents.

Failure of these critical facilities can result in a critical situation of the nuclear power plant, such as transient conditions of the plant, unexpected shutdown, and failure of multiple safety facilities. Cables can be classified as control cables, low-voltage and medium-voltage power cables (less than 1KV), general service cables (for communication, ground). Control and power cables, which account for about 75 percent of all cables, play an important role in supplying control signals and power to facilities related to the safety of nuclear power plants. Despite this importance, proper condition monitoring and management of low-voltage cables in nuclear power plants was difficult due to the lack of technology to detect cables abnormalities and location accurately. As a result of cable damage, such as "the failure of the low-voltage cables on the transformer at Kori #2 in 2007, the damage of the excitation transformer cable at Gori #3 in 2011 and the damage of the excitation transformer cable in Kori #1 in 2013" the nuclear power plant was shut down. The cable accident in Kori #3 occurred after three years of replacement with a new cable in 2011. This accident highlighted the need for diagnosing cable condition and predicting remaining life. In order to ensure the soundness of safety facilities and the safety of nuclear power plants, it is necessary to develop diagnostic equipment and condition evaluation techniques that can systematically monitor the cable condition.

In this paper, the applicability test of the diagnostic equipment for cable developed by applying the Time-Frequency Domain Reflectometry(TFDR) was carried out to evaluate the integrity of the cable, and the results of the condition diagnosis of the cables were presented.

2. A Study on the Application of TFDR

2.1 Diagnostic method with TFDR

Typical methods for diagnosing cable defects include tanδ techniques, partial discharge techniques, and reflected wave instrumentation. The tanδ technique has a limitation that it can diagnose only the insulation layer condition of the entire cable. The partial discharge technique has the disadvantage of obtaining partial discharge signals for the entire cable. The partial discharge technique has the disadvantage of obtaining partial discharge signals by an air gap in insulating layer for the entire cable.

Reflective technique has the advantage that reflection occurs when the characteristic impedance of an electronic wave along a transmission line changes, and that when compared with other techniques, the diagnosis method is simple, as compared with other techniques, by estimating the location of the fault according to the change. Reflective wave instrumentation can be classified in three ways: Time Domain Reflectometry (TDR), Frequency Domain Reflectometry(FDR), Time-Frequency Domain Reflectometry(TFDR). Time-freque ncy domain reflected wave measurement method, which utilizes hybrid treatment method that takes and optimizes both the advantages of TDR and FDR, has the advantage that strong to noise and accurate compared to other reflected wave instrumentation method.

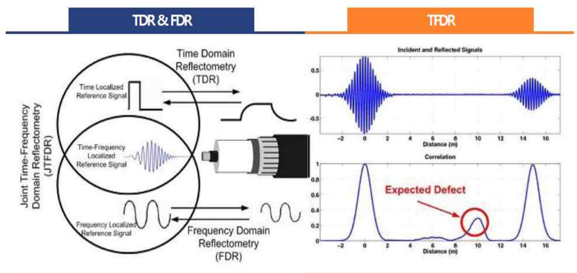

Fig. 1. Comparison of TDR & FDR and TFDR

2.2 Applicability tests of cable diagnostic method for Photovoltaic Power Plant

The applicability test of TDR and TFDR were performed on the suspect cables in photovoltaic power plants with symptoms of the breaker (30A) operating in rainy or humid environments. The target cable is TFR-CV (600V, Length: 53m) and installed on underground about 1.5m deep.

Fig. 2. Comparison of TDR & FDR and TFDR

As shown in Figure 2.2. diagnostic tests were carried out by disconnecting the suspected fault cable from the junction box and connecting it to the Y-jack connector.

Diagnosis by time domain reflector measurement using DC signal confirmed that it was difficult to identify the cable's starting point and the cable's end point due to input matching and external noise. (Refer to Fig.3.)

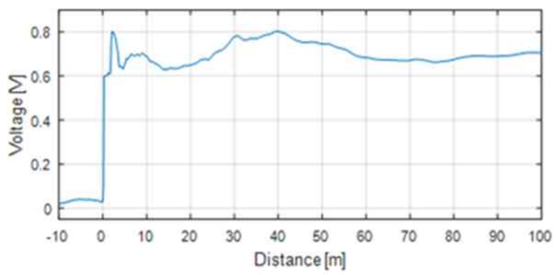

Fig. 3. Results of application of TDR

The time domain reflectometry measurement using Gaussian's signal enabled the determination of the suspected spot of the fault, but it was difficult to detect the exact point due to the spread of the signal. Also, it was found that it was difficult to detect the end point of the cable due to repeated reflections. (Refer to Fig.4.)

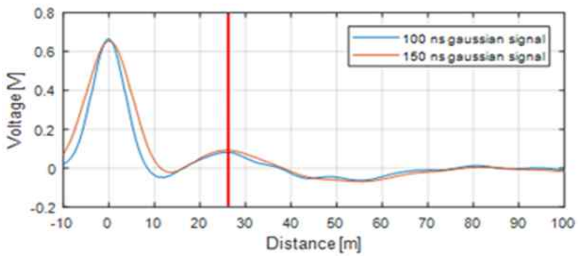

Fig. 4. Results of application of TDR using Gaussian's signal

The time frequency domain reflectometry measure-ment detected the likely spot of the fault and the location of the fault was estimated to be between 27 and 28 meters from the starting point. (Refer to Fig.5) As a results of the instantaneous frequency estimation, the reflected wave was able to detect same frequency as the reference signal and detected the fault point and cable end point. Cross correlation results show a common fault at 28 m in the 53 m cable. As a results of the applicability test, the TDR technique was difficult to determine the point of failure for the entire length of the cable. However, it was confirmed that the diagnostic method using TFDR was able to detect the total length of the cable (about 53 meters) and the suspected point of failure (Detected insulation defects at approximately 28m).

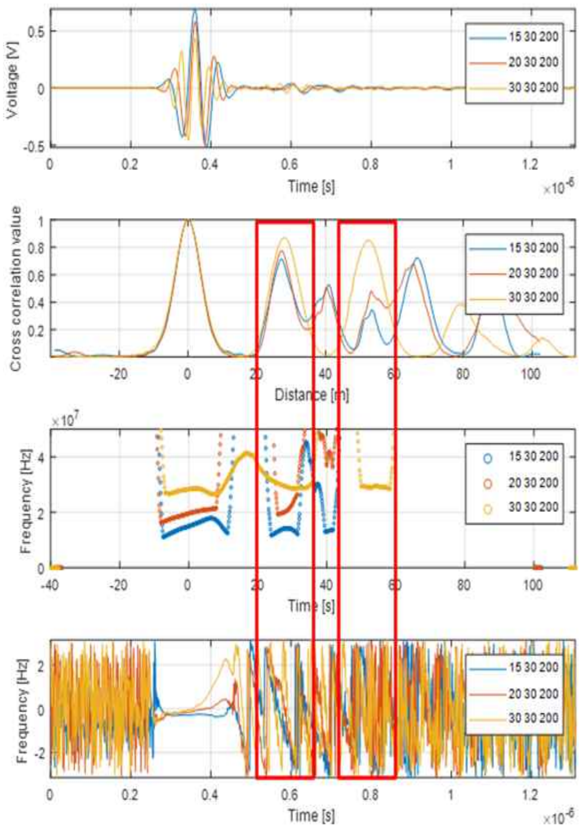

Fig. 5. Results of application of TFDR

2.3 Applicability tests of I&C cable diagnostic method for Thermal Power Plant

The applicability test for low-voltage cables was conducted at the thermal power plant. Target cables are TFR-CV (600V, Length: 230m) and FR-CVVS (600V, Length: 310m). For the test, the cable on the control panel was disconnected and the target cable was connected the terminal block and using TFDR diagnostic equipment to conduct the test.

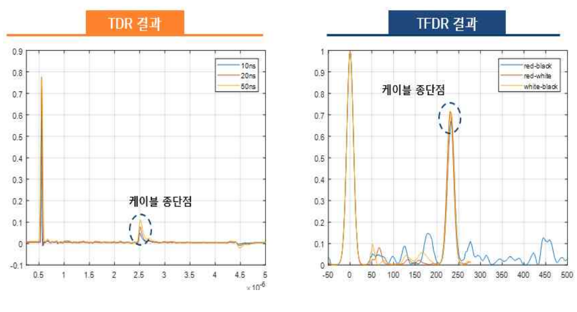

Fig. 6. Results of application of TDR/TFDR

As a results of the diagnostic test, the phase change at the end point was observed for both TDR/TFDR when they changed to open/short states. In particular, for TFDR, it was observed that the termination point was clearly distinguishable when the end was shorted.

3. Conclusions

As part of a preceding study to develop a time-frequency reflector-based cable diagnostic system for assessing cable condition in nuclear power plants, the applicability test was carried out for cables at power generation facilities using the TFDR.

The results showed that the detection of cable defects and defect points is relatively easy when applying the TFDR to the total length of the cable and the suspected defect points, which are difficult to determine with the TDR. It also plans to carry out an applicability test on nuclear power plants using its history of conducting application tests on photovoltaic and thermal power plant.

Acknowledgements

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REFERENCES

[1] Jong Min Jeong, Chun Ku Lee, Tae Sung Yoon, Jin Bae Park, Image Processing Based Time-Frequency Domain Reflectometry for Estimating the Fault Location Close to the Applied Signal Point, The Transaction of the Korean Institute of Electrical Engineers Vol. 63, No. 12, pp.1683~1689, 2014