Diagnostics of control and instrumentation cables in nuclear power plant via time-frequency domain reflectometry with optimal reference signal

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Control and instrumentation (C&I) cables are used for sensing critical parameters such as temperature, to monitor performance and to control the reactor operation which are considered one of the most crucial components in nuclear power plant's safety. Moreover, the C&I cables are exposed to severe environmental aging factors such as thermal and radioactive sources that aggravate aging of C&I cables. Therefore, a non-destructive diagnostic technique, capable of assessing the cable's condition, estimating its remaining life, and locating defects before the failure occurs is required for safe operation of nuclear power plant operation.

Among varieties of cable diagnostic techniques in physical, chemical and electrical dimension, one of the electrical diagnostic technique, time-frequency domain reflectometry (TFDR) is characterized by providing benefits of both time domain reflectometry (TDR) and frequency domain reflectometry (FDR) and also non-destructive which does not destroy cable under test. Figure 1 depicts an experimental result of TFDR. The first graph on the top illustrates the incident and the reflected signal in oscilloscope and the second graph describe the Wigner-Ville distribution of reference and reflected signals in time and frequency domain simultaneously. The last graph shows time-frequency the cross correlation results of distribution signals.

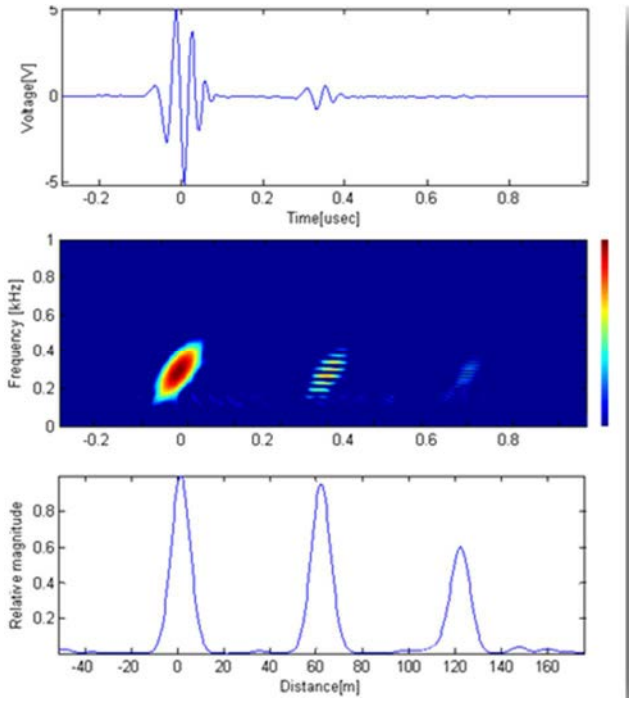

Fig. 1: Cable fault detection using Time-Frequency domain reflectometry

One of advantages of the TFDR is that it allows one to design the optimal reference signal in time and frequency domain simultaneously considering cable length and insulation of cable under test. Since the resolution and the accuracy of TFDR depend on design of parameters of the reference signal in time and frequency domain; it is important to design the optimal parameters of the reference signal to gain the optimal performance of detection and location of defects on cable under test. At present, TFDR method to set parameters requires network analyzer to determine the frequency characteristics and both ends of the cable should be connected to the network analyzer together which is not easy task to apply to the installed cable in the nuclear power plant. Therefore, it is necessary to develop the algorithm which obtains optimal parameters for each cable under the trade-off relationship between the resolution and the accuracy.

This paper will propose the automatic algorithm which optimizes parameters (center frequency, bandwidth and time duration) of the reference signal in time and frequency domain. The followings are steps to implement the algorithm.

- Find the cable length and rough center frequency region by observing the attenuation of the reflected signal at the cable end
- Set the minimum bandwidth for acquiring the specific resolution by changing the bandwidth
- Set the time duration which satisfies the uncertainty principle
- Determine the center frequency with selected bandwidth and time duration

Detailed procedures and algorithm will be presented in full-paper, but the proposed technique does not require extra devices to find the adequate frequency bandwidth and can be used on site immediately. Furthermore, the TFDR experimental results of a cable with joint such as splice, terminal block and thermal/mechanical faults will be presented in order to verify the usefulness of the algorithm for selecting optimal parameters. We could expect the best result of TFDR and time-saving for selecting optimal parameters by using this algorithm.

Key words

Reflectometry, Control and Instrumentation Cable, Fault Detection, Cable Insulation