Spread Spectrum Time-Domain Reflectometry and Frequency Domain Reflectometry to Detect Shielded and Unshielded Cable Moisture Exposure

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ABSTRACT

This work evaluates the feasibility to extend spread spectrum time-domain reflectometry (SSTDR) and frequency domain reflectometry (FDR) electrical cable testing to characterize whether an electrical cable is submerged in water or not and where it may be submerged. Using PNNL's ARENA cable and motor test bed, shielded and non-shielded electrical cables were evaluated using SSTDR and FDR methods to detect and locate electrical cable exposure to water. Both SSTDR and FDR showed the presence of water with a non-shielded cable. Moisture was only detectable with the shielded cable if the insulation was damaged.

KEYWORDS

Spread spectrum time-domain reflectometry; Frequency domain reflecometry; Electrical cable; Diagnostics.

ABREVIATION GLOSSARY

ARENA	acronym for PNNL cable motor test bed
CPE	chlorinated polyethylene
EPR	Ethylene Propylene Rubber
IFT	Inverse Fourier Transform
FDR	Frequency Domain Reflectometry
PN	Pseudorandom Noise
SSTDR	Spread Spectrum Time Domain Reflectometry

INTRODUCTION

Insulation degradation due to thermal, radiation, and mechanical damage can be detected using reflectometry techniques such as frequency domain reflectometry (FDR) and spread spectrum time-domain reflectometry (SSTDR). Previous work has shown FDR measurements to be more sensitive than other reflectometry techniques to small-radius bends, temperature changes, and cable contact with various materials, including conductors like steel and water. One concern for electrical cables in service is whether they are dry or immersed in water that can damage the insulation over time. If reflectometry tests could be extended to determine if and where electrical cables were exposed to moisture, damage could be minimized by selectively drying or lifting the cable above the potentially damaging moisture. In this work, the feasibility of immersion detection for both shielded and unshielded cables was evaluated using FDR and SSTDR approaches.

ELECTRICAL REFLECTOMETRY

An FDR instrument – typically a vector network analyser or VNA – is connected to two cable conductors, one

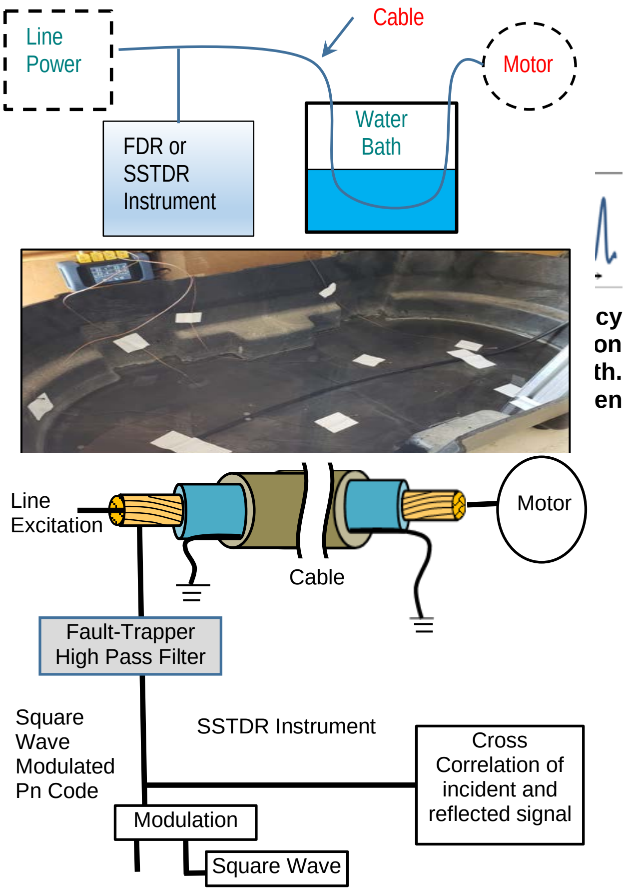

Fig. 2: SSTDR cable test applies PN code modulated with a square wave carrier frequency through a highpass filter to the conductor for cross correlation signal analysis to minimize noise and allow measurements on energized cable up to 1kV.

considered the primary conductor under test and the other considered as the system ground as shown in Figure 1 or to a parallel conductor within the cable bundle [1]. The instrument directs a swept frequency chirp along the conductor and then listens for any reflection caused by an impedance change along the cable length. By listening and detecting the reflections in the frequency domain then transforming to the time domain, significant noise immunity and sensitivity to subtle impedance changes can be achieved [1]. Bandwidth for the FDR is software adjustable up to 1.3 GHz but experience shows the best responses from 100MHz to 500MHz. Higher bandwidth FDRs produce sharper peaks capable of spatially resolving more closely spaced impedance changes but the higher frequencies do