INNOVATING NUCLEAR TECHNOLOGY
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AMS WHITE PAPER

ELECTRICAL MEASUREMENTS OF NUCLEAR INSTRUMENTATION CABLES AND DETECTORS

A number of measurements are made during the characterization testing of nuclear instrumentation (NI) to determine the health and condition of the cables and detectors. These tests, which include typical bulk electrical measurements and some specialized tests just for the NI, are described below.

1. IV Curve Comparisons

IV curves are produced by applying increasing, incremental voltages to the NI detector under test while measuring the detector leakage current. As incremental voltages are applied, the current from the NI is measured and it is plotted to produce an IV curve. The IV curves can be inter-compared and trended from one test to the next to identify detector degradation. The IV curve from a healthy detector is shown in Figure 1 with a degraded detector curve showing a higher leakage current rate as the voltage is increased.

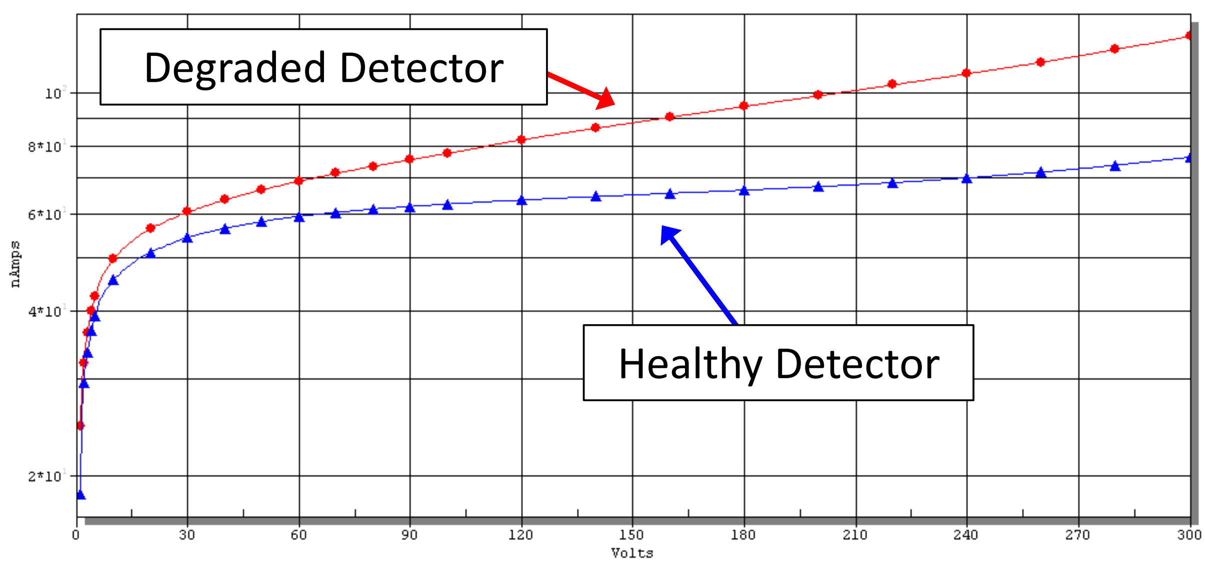

Figure 1. IV Curve Showing Healthy Detector (blue) and Degraded Detector (red)

2. TDR Testing and Dynamic TDR (DTDR) Testing

TDR measurements are normally performed on cables to identify and locate impedance changes along the cable circuit from the instrument cabinets to the detector.

As problems such as loose connections, moisture and cracks develop in the cable conductors, connectors, or on the cable insulation/jacket material, the impedance of the cable may be affected. TDR measurements are useful for identifying not only the location of an impedance change but also the magnitude of the change. Comparison data with historical tests or other similar circuits is important for making these determinations. For example, the small resistive change that indicates degradation in a penetration connection can be difficult to diagnose without the historical or comparison data (Figure 2).

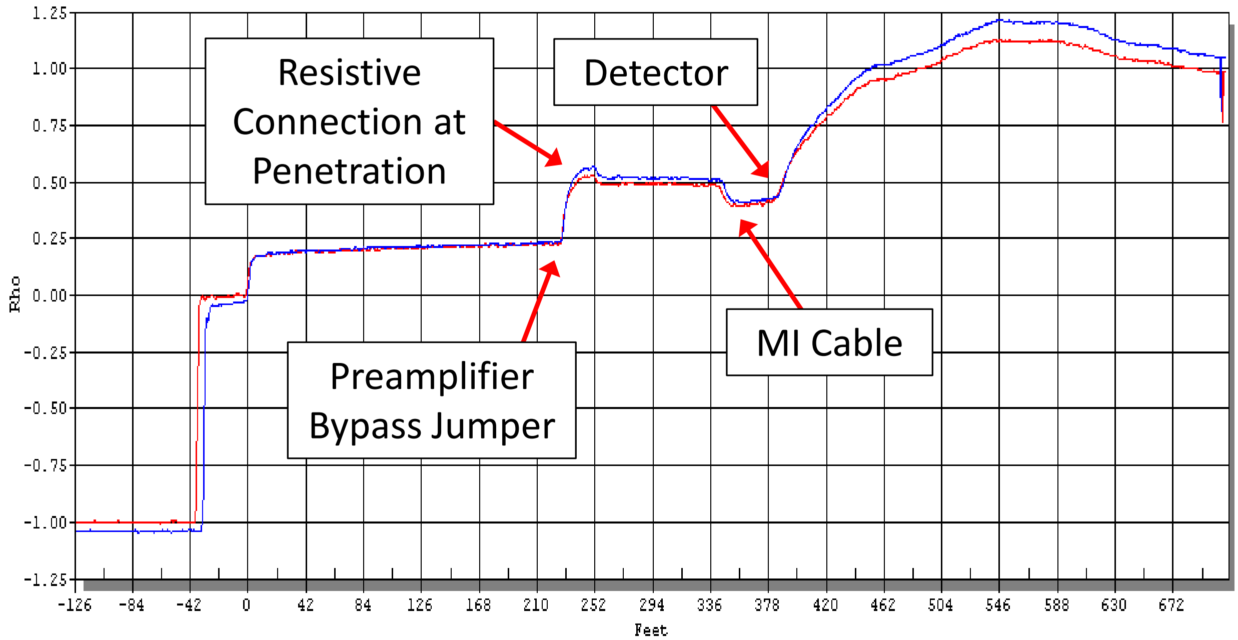

Figure 2. TDR Signature Showing Resistive Connection at the Penetration

The TDR test involves sending a pulse through the cable and measuring its reflection as a function of time or distance. The pulse has no significant power that might damage the cable or the detector and the test has been used extensively for the evaluation of NI cables and detectors in nuclear power plants.

For each cable/detector tested, TDR measurements are performed between all combinations of conductors including the center conductor, shield and ground. These measurements are made from the instrument cabinets in the control room.

Dynamic TDR (DTDR) is a continuous form of TDR which can be applied to the cable under test while modifications are made to suspect connections in the circuit. Results are monitored in real time to determine if cable performance improves as a result of troubleshooting efforts. This technique is also useful for identifying intermittent electrical problems in the cable circuit that do not always manifest themselves in a single test. The ability to perform multiple tests simultaneously greatly facilitates the ability to identify and resolve such issues.

3. Reverse Time Domain Reflectometry Measurements

Reverse TDR (RTDR) tests are performed to identify and locate intermittent or degraded connections in the cable circuits that can allow electrical noise to couple into the system and lead to anomalous neutron levels.

This test involves sending a small electrical pulse on the shield of a triax or coax cable and monitoring the center conductor for any coupling that may occur. The location of the coupling can be determined using the time it takes the pulse to travel to the location of degradation and then return to the source (Figure 3). This location can then be compared to a line diagram or TDR signature to identify the degraded component. RTDR is a very effective in-situ electrical measurement for determining cable shield integrity and locating NI problems related to electrical noise. It allows AMS to determine precisely where in the cable circuit EMI/noise may be coupling into to a system so that repairs can be made to mitigate the problem.

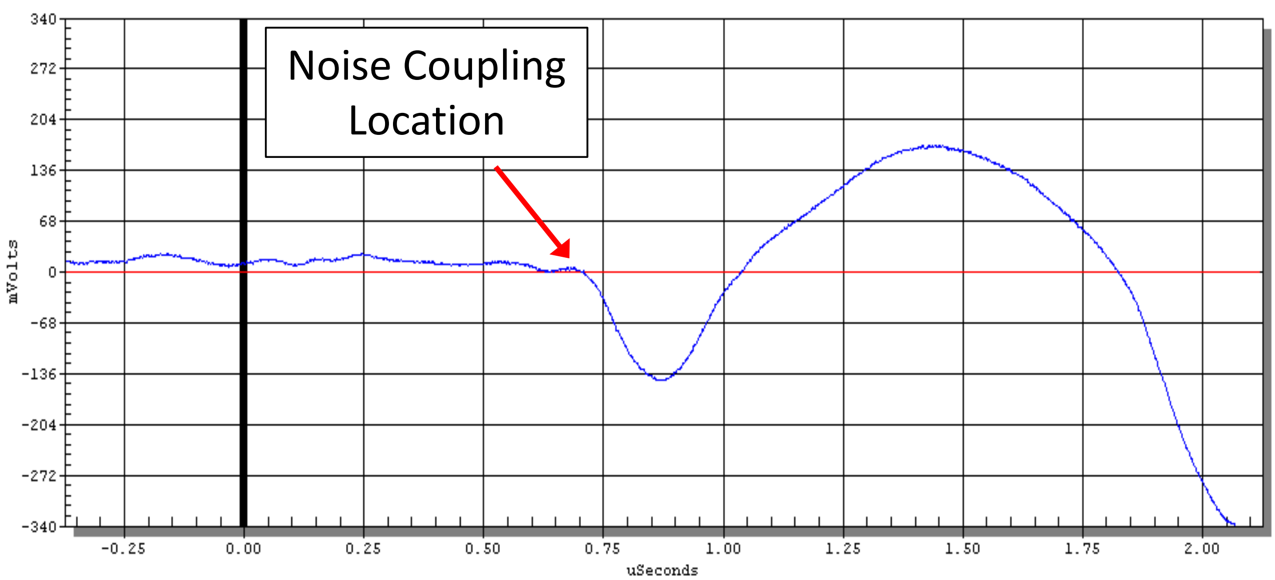

Figure 3. RTDR Signature Showing Healthy Baseline (red) with Noise Coupling (blue)

4. Impedance Measurements

Bulk electrical measurements including Inductance (L), Capacitance (C) and Resistance (R) measurements are made when testing each of the cable connections. These tests measure the lumped electrical properties of the circuits and are analyzed to provide aging assessment of the cable, connectors and detectors. Trending this data can also identify degradation due to environmental stressors such as heat.

5. Insulation Resistance Measurements

IR measurements are made on each cable and detector circuit to measure the leakage current. Low IR results can cause degraded performance of the system and erratic behavior. These measurements are made in accordance with acceptable standards using test voltages that are appropriate for the circuit rating. Timed IR measurements are a part of the evaluation of the detector cables. These measurements involve making IR measurements at specified durations to determine the Dielectric Absorption Ratio, which may indicate signs of cable aging, moisture intrusion, or degradation.

6. Waveform Measurements

Waveform measurements are first acquired with the detector energized from the drawer input (pre-amplifier output) and at the scaler output for source range monitoring (SRM) circuits. The waveform is also analyzed to verify the discriminator level (Figure 4). The detector is then de-energized and waveforms are recorded at the amplifier and scaler outputs. This provides an indication of noise that is recorded as neutron counts by the discriminator (Figure 5).

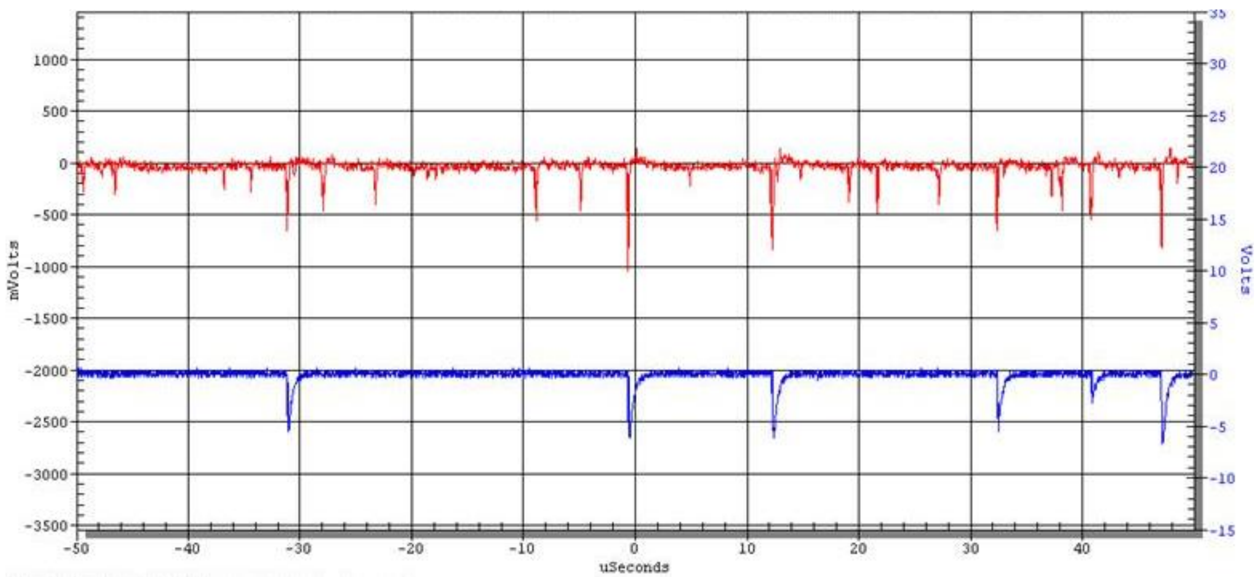

Figure 4. Amplifier Output (red) and Scaler Output (blue) with Detector Energized

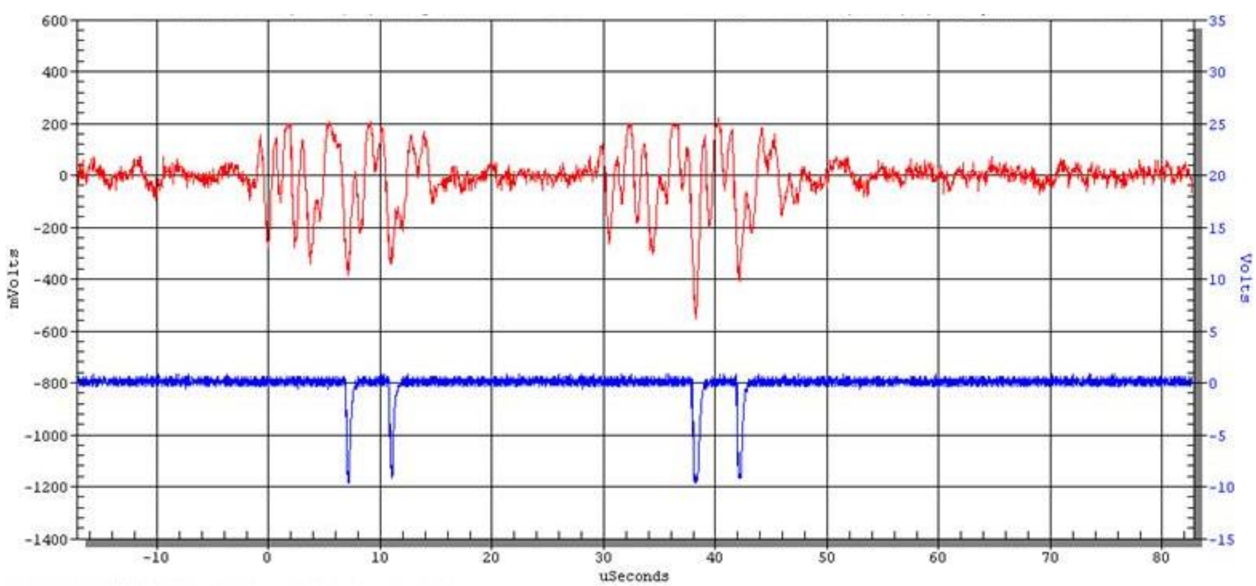

Figure 5. Amplifier Output (red) and Scaler Output (blue) with Detector De-energized

SUMMARY

Data was collected for each of the tests mentioned above with custom acquisition equipment and software designed to identify anomalies in electrical circuits in nuclear power plants. The equipment is connected to each cable associated with the detector assemblies in the instrument cabinets outside containment and the selected tests are performed automatically. The data is then analyzed to identify any anomalies that may exist in the circuit that could cause degradation in the performance of the system.