USING THE TIME DOMAIN REFLECTOMETER TO CHECK FOR AND LOCATE A FAULT

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INTRODUCTION TO THE TDR (HOW IT WORKS)

The Time Domain Reflectometer (TDR) is one of the most useful tools for finding cable faults (opens, shorts, bad cable splices). The TDR is connected to one end of the line and shows the distance to the fault. It uses a low voltage signal that will not damage the line or interfere with nearby lines. The TDR sends a pulse of energy down the cable under test; when the pulse encounters the end of the cable or any cable fault, a portion of the pulse energy is reflected. The elapsed time of the reflected pulse is an indication of the distance to the fault. The shape of the reflected pulse uniquely identifies the type of cable fault.

INTERPRETING TDR TRACES

Faults that are Inductive or of a higher resistance (i.e. bad splice, open) than the cable impedance will cause a positive (upward) deflection on the reflected TDR trace. Faults that are capacitive or of lower resistance (i.e. short) than the cable impedance, will cause a negative (downward) deflection on the reflected TDR display. Refer to Figure 1 which shows TDR reflectometer traces for an open and short. The amplitude of the reflection defines the impedance change, at the fault. The greater the amplitude, the greater the impedance change. As a result, the TDR is very useful for detecting intermittent faults such as poor crimps or bad solder connections, which are usually very difficult to find. Other faults such as, opens and shorts are very easy to locate with the TDR.

TDR traces require some interpretation. However, this interpretation can be minimized by comparing traces of known good signal loops with suspect loops. In addition, information such as the number of connections and distances between connections in a loop, should be researched from station equipment drawings, to obtain an understanding of the TDR trace.

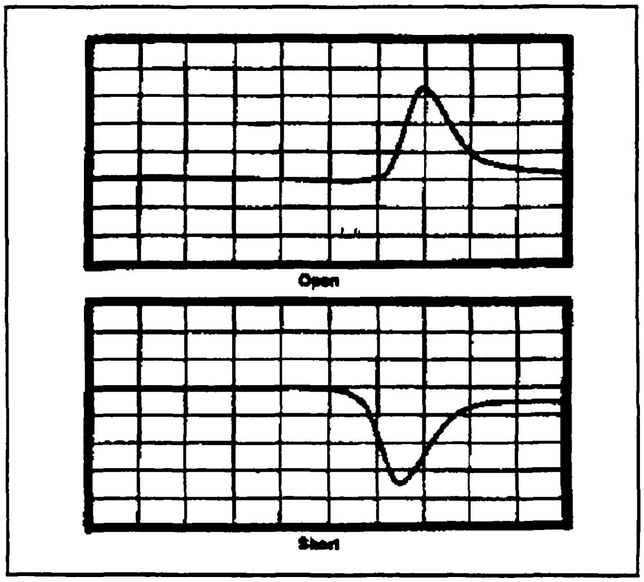

FIGURE 1— (Show figure that illustrates open/short)

APPLICATION OF TDR FOR CABLE FAULTFINDING

At Darlington NGD, the TDR has been used effectively to troubleshoot intermittent faults on incore flux detector signal loops. In one application, which is described in detail below, the TDR was used to locate a fault which had expended over 70 hours of control maintenance troubleshooting time. The location of the fault was found inside the reactor vault at the flux detector assembly. This information was extremely useful since it allowed preplanning for material to be ordered to site in preparation for the repair work. Preplanning is important to minimize outage time and maximize productivity.

DNGD- INTERMITTENT TEST FAILURE ON SDS2 NOP SAFETY RELATED SYSTEM TEST (SRST)

A Shutdown System #2 (SDS2) safety related system test (SRST) is performed on each Neutron

Overpower Detector (NOP) to test NOP trip logic. The test also confirms the integrity of the NOP cabling to the detector (but not the actual detector itself). This test is done by sending a test current down the TEST line. At the Detector Assembly Housing, the SIGNAL wire is connected to the TEST line. Hence, the test current ramp can pass from the TEST Line to the SIGNAL line and be received by the AMPLIFIER, resulting in a NOP loop trip. Figure 2 illustrates the signal path of the SRST.

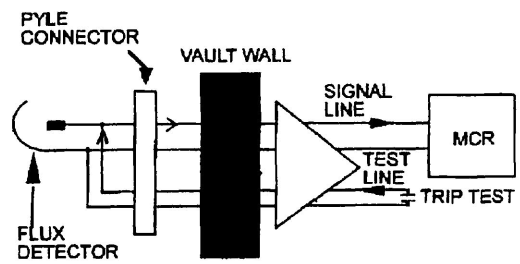

FIGURE 2— (Show figure that illustrates SRST 2.06).

ORIGINAL SYMPTOM

Often, when a current ramp waveform was sent down the TEST Line, the test results would be *poor* or the test would *fail*

- poor in the sense that the amplifier response was slow, sluggish
- failure of the test to complete the ramp in the allotted time or to the required amplitude

No fault was observed on the SIGNAL line. The incore flux detector output signal as seen at the output of the amplifier showed no signs of sluggish behaviour.

TROUBLESHOOTING OUTSIDE CONTAINMENT

All of the accessible components (amplifier, connectors, cabling) associated with this in-core flux detector circuit were examined, checked, cleaned, and replaced, but the intermittent problem still persisted. As a result, **the fault appeared to be related to the wiring inside the reactor vault (INSIDE CONTAINMENT).** A total of about 70 hours was spent in troubleshooting this intermittent problem. In addition, when troubleshooting was being done, one channel in SDS2 would have to be taken out-of-service for several hours at a time. This was undesirable since it increases the risk of firing SDS2 on a spurious channel trip.

TROUBLESHOOTING INSIDE CONTAINMENT

TDR

The TDR was connected to the flux detector loop, at the amplifier end. A few test traces (i.e. "signatures") were produced. One set of traces for the suspect loop; one set of traces for a known good loop (to be used for comparison).

A review of the TDR traces showed (reference Fig. 3):

1. relative to the known, good detector loop, there was a distinct difference in the TDR traces from the "suspect" detector loop.
2. the suspect detector loop showed an unusual situation that indicated both a high impedance and a low impedance at essentially the same point depending on which line the TDR pulse when send on (i.e. the SIGNAL or TEST line).
3. the distance of the fault from the amplifier cabinet room was such that *the fault had* to be in the reactor vault, at the flux detector assembly.

Within one hour, the TDR was able to determine the location of the fault.

The resolution of the TDR in this application is approximately 5 to 6 feet, hence it was not possible to determine whether the fault was :

- At the soldered connection between the SIGNAL and TEST line, internal to the Detector Assembly Housing or
- External to the Detector Assembly Housing (e.g. at the cable connector)

CAPACITANCE

A capacitance meter was connected to the flux detector loop, at the amplifier end.

A review of the capacitance values measured showed that there was something quite different with the suspect detector loop.

1) capacitance of TEST line on good detector: 25,000 pF.
2) capacitance of TEST line on suspect detector: 10,000 pF.

Capacitance is proportional to length. The flux detector capacitance is typically 5000 pF. The total capacitance of a 'good' detector loop was 25,000 pF. Hence the length of the wiring alone would be (25,000 - 5000 pF), and since the TEST and SIGNAL wiring is approximately of equal length, the distance to the flux detector assembly would be 10,000 pF. The capacitance results for the 'suspect' detector indicated a discontinuity at the flux detector assembly.

Both the TDR results and the capacitance measurements indicated that the fault was at the flux detector assembly. The fault would likely be at the pyle connection or at the solder junction inside the Detector Assembly Housing. The focus was on the wiring, internal to the Detector Assembly Housing, since the TEST line and SIGNAL line are solder connected together in the Detector Assembly Housing and it was postulated the the fault might be a cold solder joint.

OUTAGE MAINTENANCE

The fault was suspected to be at the connection between the SIGNAL and TEST lines. A workplan was prepared to troubleshoot and repair the fault in an outage. The flux detector cable was disconnected from the flux detector assembly and checks were performed on the flux detector assembly to determine if the fault was internal to the assembly.

If the fault was internal, the internal wiring was to be replaced. It was suspected that the fault was internal since the SIGNAL and TEST lines were soldered together in the assembly. Parts were ordered from the manufacturer to replace the internal wiring. Replacing the internal wiring in a plastic suit with rubber gloves would be a very intricate job and extensive post maintenance testing would be required to ensure that no other wiring was disturbed. Refer to figure 4 which shows the details of the internals of the flux detector assembly.

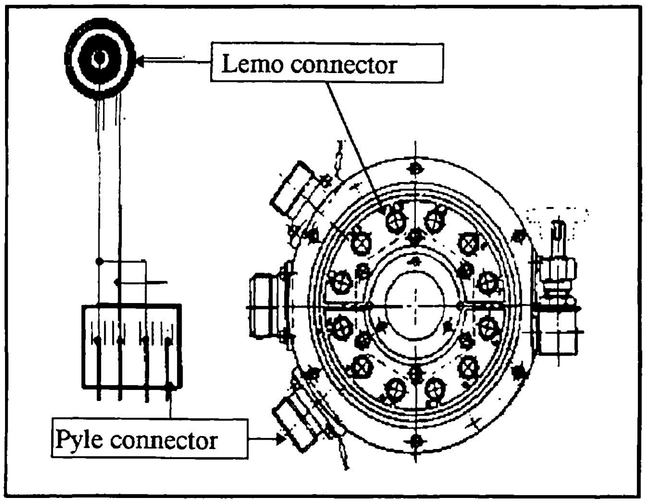

FIGURE 4 - (Show figure of internals of the flux detector assembly)

If the fault was external to the assembly then checks were to be performed on the flux detector cable. Material was ordered to repair the flux detector cable connector. For example, the potting compound has a 1 year shelf life, hence it is not a regularly stocked item, but must be ordered to meet workplan demands. Figure 5 shows the flux detector cable connection.

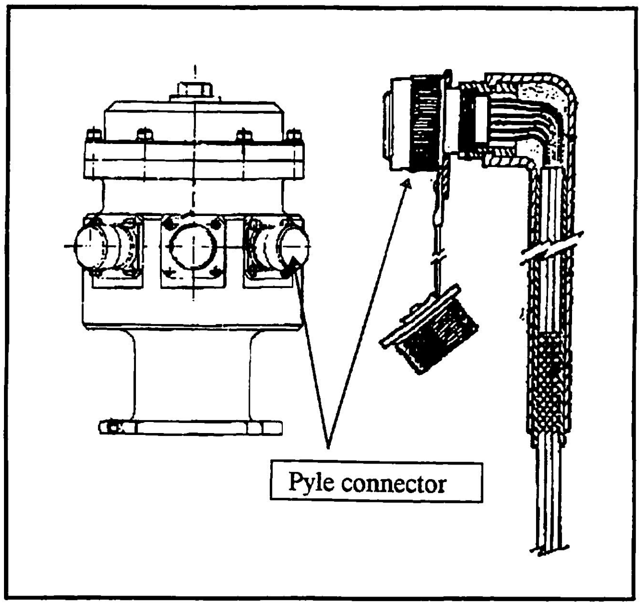

FIGURE 5 —(Show figure of flux detector assembly)

During in the outage, the fault was found to be on the flux detector cable connector. Resistance testing showed an intermittent connection in the TEST line to the Pyle connector. When the protective boot was cut away and some of the rubber sealant was removed, it was discovered that there was a poor crimp on the TEST line. The TEST wire was so loose, that it could be easily pulled out of the connector, by hand. It was postulated that the wrong crimp wire setting was used, since the cable termination procedure used two different crimp wire settings for the signal and the shield wires.

The connector was cut off and re-terminated using the correct crimp tool settings. The connector was potted with a rubber type sealant and protected with a heat shrink boot to meet environmental qualifications. The entire repair took approximately 72 hours to complete, since the potting compound alone requires 12-18 hours to cure.

Once the pyle connected was secured to the Detector Assembly, a repeat of the TDR scan showed that the repaired TEST line had a signature similar to the good detector loop. As well, the capacitance measured was as seen on the good detector loop.

The repair was successful as verified by the TDR scan and the Capacitance measured.

PREDICTIVE MAINTENANCE

The nature of the fault (use of the incorrect crimping tool) was such that the potential existed for a number of Shutdown System NOPs and Reactor Regulating System (RRS) flux detectors to be poorly connected to the flux detector. Plans were made to perform TDR traces and capacitance measurements on all NOPs and RRS flux detectors.

Of all the NOPs and RRS flux detectors scanned, three flux detector loops required cable re-termination. In these cases pins were found partially inserted into the connector. This resulted in high impedance connections.

CONCLUDING REMARKS

- The TDR is a very useful troubleshooting tool for indicating the **position** of a fault in cable wiring. Once the location is determined, material can be ordered in preparation for maintenance.
- If there is more than one fault, the TDR will show the first fault with a strong echo and then a weaker echo from each succeeding fault. Hence, the TDR can indicate **multiple faults**.
- The TDR measurements can be performed with the reactor **at power**. It can be used to locate a fault inside of containment.
- The TDR scan can be used as a check on **quality of repair** by comparing the before and after scans.
- The TDR can be used as a "**second opinion**", to check the fault assumption being made based on some other test method - such as resistance, or capacitance check.
- TDR scans can be made of newly commissioned loops and then put away - to be **consulted at a later date** for signs of deterioration in the loop.
- TDR scans can be **digitized and stored** as a computer file; for ease of comparison of scans from another unit or at a later date.
- TDR scans require a sense of **interpretation**; but this interpretation can be kept to a minimum if there is a scan of a known good loop to be used as a reference for comparison.

FIGURE 3A: FORWARD TEST CONNECTION

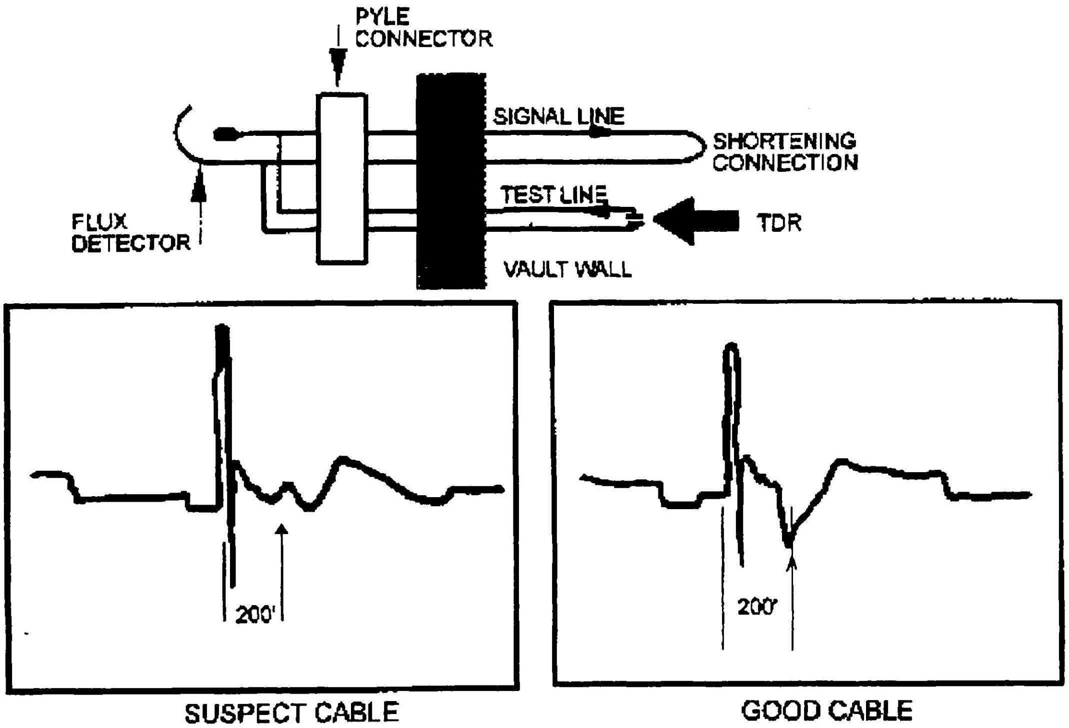

FIGURE 3B: REVERSE TEST CONNECTION