Evaluation for RTD Circuits Diagnosis System Under the Severe Accident Conditions

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1. Introduction

To diagnose a severe accident it is essential to determine the plant status and to monitor the plant response to actions taken by the plant staff. Correct interpretation of plant instrumentation during severe accidents is important to successful accident management. In SECY 89-012 " Staff plans for accident management regulatory and research programs, " the NRC identified instrumentation as one of the key of utility accident management plans [1]. A review of plants accident management capabilities is one of the key elements for the circuit simulation and diagnosis methods.

2. Circuit Simulation and Diagnosis Methods

Circuit simulations are one way to assess instruments in a detail when they give apparently abnormal reading. The simulations can be useful for investigating what the signal and circuit characteristics would look like for a variety of symptoms that can result from severe environment conditions [2-3]. In this paper, circuit simulations are performed for RTD circuit types. Circuit diagnosis refers to the determination of whether a circuit is malfunctioning, is damaged, or if useful information can be obtained even when indication is abnormal or off-scale. Instrument circuits are first modeled and tested, using a commercially available circuit simulation program. Then degraded conditions are introduced by modifying the instrument circuit models. The response characteristics of the simulated instrument circuits to degraded conditions provide the basis for diagnostic checklists.

3. Resistance Temperature Bridge Circuit Modeling, Simulation and Evaluation

As loop description and simulation model, the RTD element itself is normally supplied with four output leads and may be connected to the receiver electronics for signal conversion to temperature several different ways, using 2, 3, or all four leads. If all four leads are used, one pair of wires provides the current and the second pair of wires senses the voltage across the element. The cable, penetration, and RTD element are considered for the degraded operation analysis. All diagnostic tests are defined so that they can be implemented from the terminal broad in the control room area. If it is necessary to disconnect leads, then the measurements will be made on the RTD portion of the circuit.

3.1 Resistance Temperature Detector Transmitter Element

The typical RTD resistance element has been represented to include lead connection resistance, input resistance, and input capacitance that can be varied through the circuit analysis program to obtain realistic circuit responses to containment environment change. The significant electrical parameter included: Input leakage resistance which is affected by damage to the interconnecting cable or water in the element housing. Input series resistance to represent the spliced connections that might be affected by corrosion. Input capacitance which is easily increased by moisture intrusion into either the cable or RTD housing. Capacitance between leads and shield and ground which is easily caused by moisture intrusion.

3.2 Cable-4wire, Twisted Pair, Shielded Cable

The typical cable is represented as the inductance of the wires and the capacitance of the dielectric to simplify analysis. Any resistance properties are accounted for as connection resistance and shunt resistance in the RTD element model. The individual pairs may be shielded separately or the entire cable may be shield. However, it is important that the twisted pairs be assigned to either voltage measurement or to the current source.

3.3 Reactor Coolant Temperature, RTD Receiver

The typical 4-wire RTD receiver consists of a proprietary linear bridge circuit that includes a constant current source and a high impedance differential input amplifier to detect the voltage across the element and convert it to an analog output signal that represents the temperature. The input to the proprietary circuit is normally protected with a low pass filter about 10 Hz to prevent display of 60 Hz and above noise. The negative side of the circuit is normally tied to plant ground. Cable lead resistance will only affect this measurement if the resistance approaches the input impedance of the measurement circuit or the maximum load resistance of the current source. In practice, failure can occur, but seldom do small errors occur. To determine if the simplification is realistic, the simplified component circuits are connected and the out in response to a change RTD resistance is observed. The RTD resistance is changed from 100 ohms, representing 0 C, to 300 ohms, representing 600 C. Normal temperatures is assumed to be 282.7 C. The response time of the RTD element is assumed to be no better than 1 Hz. Once this is confirmed, the normal plant electrical noise sources are introduced into circuit and the analysis program is rerun to confirm that the RTD loop is immune to this noise under normal design installation conditions.

4. Observations Related to RTD Circuit Diagnostics

Five different abnormal models are off-scale high, off-scale low, higher than expected, lower than expected, varying excessively. Unchanging temperature was also considered. However, this is not a likely failure mode for components inside the containment. Should this symptom be observed, the proper action would be to diagnose the receiver electronics.

4.1 Off-Scale High

1) Critical environment and assumed cause - Mechanical shock, extreme temperature. Stress on platinum element due to mechanical or thermal shock to transmitter.
2) Diagnostic check – Resistance measurement: expect > 300 ohms
3) Conclusion – Instrumentation out of range, Total failure RTD
4) Corrective action –If out of range, increasing range of receiver instrumentation or manually measure voltage across sensing leads and converts to temperature from calibration data.

4.2 Off-Scale low

1) Critical environment and assumed cause - Mechanical shock, high temperature damaging the cable and causing short circuit.
2) Diagnostic check – Resistance measurement: all leads to each other and to shield, shield to ground. Time domain reflectometry: all leads to each other and to shield
3) Conclusion – For shorted wires, a complete failure of the channel will result.
4) Corrective action –For shorted element, it may be possible to determine a temperature multiplier by comparing the damaged channel to a known temperature for the area.

4.3 Varying excessively

1) Critical environment and assumed cause – Moisture attacks the cables/splices causing grounding loops and bad connections which may rectify high frequency transients, causing them to appear as low frequency fluctuations.
2) Diagnostic check – Resistance measurement and capacitance measurement, and use to time domain reflectometry
3) Conclusion – The cable or connections are in an advanced state of degradation and the circuit is no longer functioning as designed.

4.4 Higher than expected

1) Critical environment and assumed cause – Steam, spray, moisture can cause ground loop which can couple 60 Hz current through RTD element and cause self heating that will cause a small increase in the indicated temperature.
2) Diagnostic check – Capacitance measurement of any RTD lead to shield with all leads discounted from receiver.
3) Conclusion – RTD operational but reading slightly high.
4) Corrective action – Reduced expected accuracy(It may possible to determine the 60 Hz heating current and adjust for self heating on a case by case basis)

5. Summary and Conclusions

In this paper, we provided a diagnostic process and shown how circuit evaluation fits into the process. There are many options and ways to obtain information during severe accident conditions. In general, precise measurements would not be required. Experience has shown that the failure of RTD to provide information usually has been because the RTD has been destroyed by the accident itself, or the RTD was faulty. According to the number of options and the ruggedness of the instrumentation at a nuclear plant that would be provide a range of opportunities to acquire the needed information.

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