Study of Thermally Induced Currents in High Range Radiation Monitor Cables

ME Team 56
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Project Statement
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**Statement of Need**

Zachry Group is a privately held company with 13 offices nationwide averaging 20,000 employees. Zachry Nuclear Engineering, headquartered in Stonington, CT, provides engineering and design services for the nuclear power industry. They also perform safety analysis, system design, system analysis, evaluations, and conceptual design studies for the existing U.S. nuclear fleet, nuclear suppliers, Electrical Power Research Institute (EPRI), and new plants.

Inside the containment building of a nuclear power plant, coaxial cables are used to transmit signals from a High Range Radiation Monitor (HRRM) sensor, located in the containment building, to a reader located in the control room. A “keep-alive” current is run through the coaxial cable, and once the signal reaches the control room, it is converted from a current level, measured in Amperes (A), to a radiation level, measured in Roentgens per hour (R/hr). During an accident, such as a Loss of Coolant Accident (LOCA), or any other operational transients, HRRMs provide operators with radiation level readings so that they can properly diagnose and respond to the event.

A Thermally Induced Current (TIC) can be generated in the HRRM coaxial cable due to rapid temperature changes within the containment building, such as what can occur during a LOCA. Previous research indicates that a positive temperature gradient generates a positive TIC, which may mislead operators within the control room and cause unnecessary evacuations. A negative temperature gradient generates a negative TIC, which causes the “keep-alive” current to drop. An event such as this may also mislead operators in the control room into thinking there has been a loss of instrumentation.

Currently, within the nuclear power industry, training exists to help operators decide when to ignore HRRM readings brought on by TICs during known temperature gradients. Since no two nuclear power plants utilize the same coaxial cable-in-conduit configuration, the purpose of this project is to understand the TIC effects on different coaxial cable-in-conduit configurations used in HRRM systems, and to provide potential suggestions for improving or upgrading HRRM systems to eliminate the TIC problem. This project will involve designing, constructing, and operating a safe and financially feasible test rig to collect data on TICs, as well
as performing transient 2D Computational Fluid Dynamics (CFD) analysis of one cable-in-conduit configurations.

**Requirements**

**Experimental Portion:**
- Determination of electrometer or picoammeter and compatible Data Acquisition systems (DAQs) to be used to measure TICs.
- Determination of coaxial cable-in-conduit configurations and the maximum length of cable that can be feasibly tested.
- Design experimental test rig that is structurally, logistically, and financially feasible to measure TICs for each coaxial cable-in-conduit configuration.

**Analytical Portion:**
- Develop transient 2D CFD model of one of the cable-in-conduit configurations used in the experimental test.
- The 2D CFD model must be run using the transient ambient conditions measured during the test.

**Analysis:**
- Identify sources of error and uncertainty in the test rig and experimental process.
- Create TIC vs. Time and Temp. vs. Time graphs and data sets.
- Compare the average surface temperatures calculated by the CFD model to the experimentally measured values (similarities/differences).

**Limitations**
- Determine if cable-in-conduit testing is possible.
  - The range, resolution, accuracy, and sample rate of the electrometer or picoammeter must be sensitive enough to capture TICs when performing the experiment using cable-in-conduit.
The conduit surrounding the coaxial cable will reduce the temperature gradients the cable is subjected to, and thus the TICs might not be large enough to measure.

- Maximum length of cable must be feasible for testing in experimental rig.
  - Consider the cost per foot of cable as factor when deciding on cable length.
  - To save on cost, look for cable donations from cable manufacturers.
- Experimental rig must incorporate a safe and reliable means of achieving a rapid temperature change.
- Develop a reliable means of recording the transient ambient and cable surface temperatures using multiple thermocouples at various locations to eliminate any spatial bias.
- Begin learning ANSYS Fluent to model heat transfer within the coaxial cable.

**Specifications**

**Equipment:**
- Electrometer or picoammeter which must be capable of measuring current on the level of picoamperes to nanoamperes.
- Hot and cold reservoir.
- Thermocouples to measure transient ambient and wire surface temperatures.
- Data Acquisition system (DAQ).
- Conduit (can be reused for testing of each of the different coaxial cables)
  - Material: Steel
  - Length: Same length as coaxial cables
  - Diameter: No larger than 2 in.
- Coaxial cables
  - Commonly used types of coaxial cable:
    - Cross-Linked Polyethylene (XLPE)
    - Polyether Ether Ketone (PEEK)
  - Length: To be determined (possibly 3 ft)

*Figure - Coaxial cable material layers.*
Facilities:

- IMS Building: Dr. Cao’s Lab

Sponsor Policies:

- Email weekly status reports containing:
  - Activities performed that week.
  - Activities planned for the following week.
  - Updates to projected schedule.
  - Any issues encountered.
  - Tasks each team member is working on.
• Provide Zachry with an itemized list of materials and prices for approval prior to purchasing any material.
• Interim report at completion of Fall semester.
• Final report at completion of Spring semester (prior to Demo day).
• Final presentation at Zachry prior to end of Spring Semester.

Software:
• ANSYS Fluent

Verification Approach

• Review previous research papers to get a better idea of how to approach the project and to understand what experiments have been performed in the past.
• Design an experimental test rig with conduit that does not exceed the limited length of the cable. If experimental testing with the conduit does not work, the experiment will be modified and done without a conduit.
• Perform computational fluid analysis via ANSYS on transient 2D configuration using the transient ambient condition data from the experimental setup. If the experimental part is not successful, Zachry will provide transient data to base the design on.
• Consider the sources of error and uncertainties of the experimental setup and how they affect the validity of the results.
• Compare the surface temperature obtained by the CFD analysis to the experimentally measured values and justify any discrepancies or agreement between the data and the CFD model.
Schedule

In the next month, everyone in the group will work together to select the coaxial cables to be tested and to design the experimental test rig. Charlotte and Kelsey will begin learning ANSYS Fluent by modeling basic 1D conduction problems. Once the test rig is designed, Charlotte and Kelsey will start working on creating the transient 2D CFD model of one of the coaxial cable-in-conduits that will be tested. Alex, Peter, and Rick will simultaneously start assembling the test rig. At the beginning of the Spring semester, we will begin testing different coaxial cables, and make any necessary design changes to the test rig. Once the testing begins, we will use the ambient temperature readings measured as boundary and initial conditions in the CFD model.

References