Cyber Physical Simulator for Small Modular Reactors

Ian Gonzalez, Hampton DuBose, Andrew Huebner, Christopher Heaps, and Austin R.J. Downey[1,2]

[1]Department of Mechanical Engineering, University of South Carolina
[2]Department of Civil and Environmental Engineering, University of South Carolina

ARTS-Lab
Adaptive Real-Time Systems Laboratory

Abstract

- Over the years and decades of research into nuclear energy, SMR's have been shown to be a very clean and sustainable way of producing energy. A Small Modular Reactor (SMR) goes further by providing a downscaled application that can be used by smaller companies and universities to produce this clean energy while also getting their students and employees familiar with the process of an SMR. This project focuses on modeling the thermal loop section of an SMR by using LabVIEW for controlling/collecting data and a Simscape model to simulate different conditions.

Methods

- LabVIEW
  The LabVIEW block diagram controls the loop through manipulating the proportional valve by increasing or decreasing the angle it is open at.
- Simscape
  This model simulates the change in temperature of the loop and the amount of city water coming in for loop cooling.
- SpeedGoat
  A real time target machine which is used with a Simscape model to accurately monitor quick changes in the state of the simulation and track things such as Pulse Width Modulation (PWM) which is used for the proportional valve.

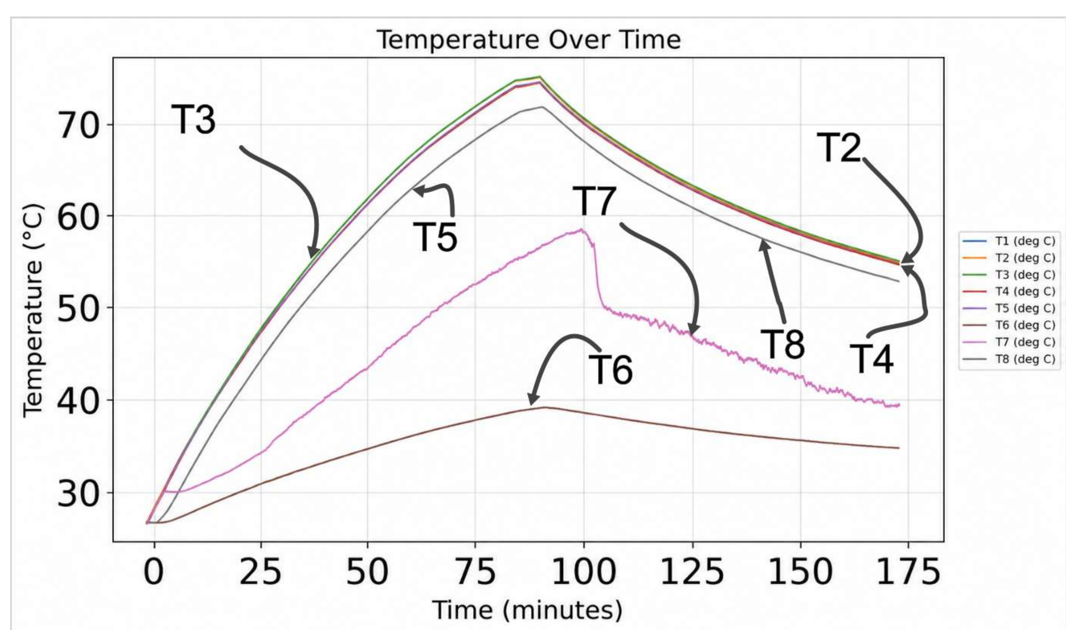

Figure 1. A LabVIEW graph of Temperature Over Time for eight thermocouples

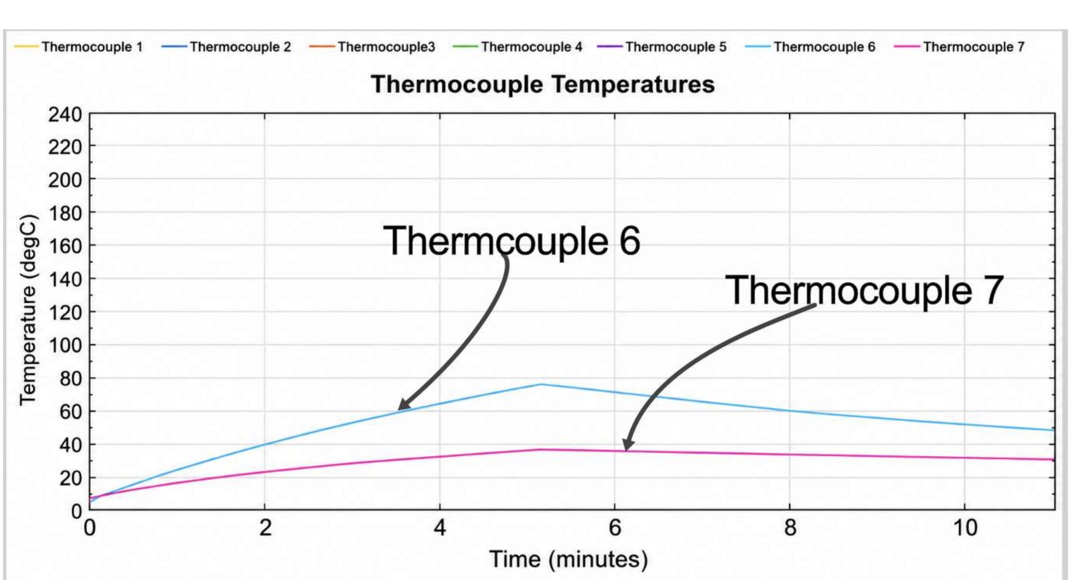

Figure 2. A Simscape graph of Temperature Over Time for eight thermocouples

Simscape Model vs. Real Model

- Shown is our SMR Thermal Loop with dimensions based on the CAD Model. All parts were sourced and documented in the bill of materials.

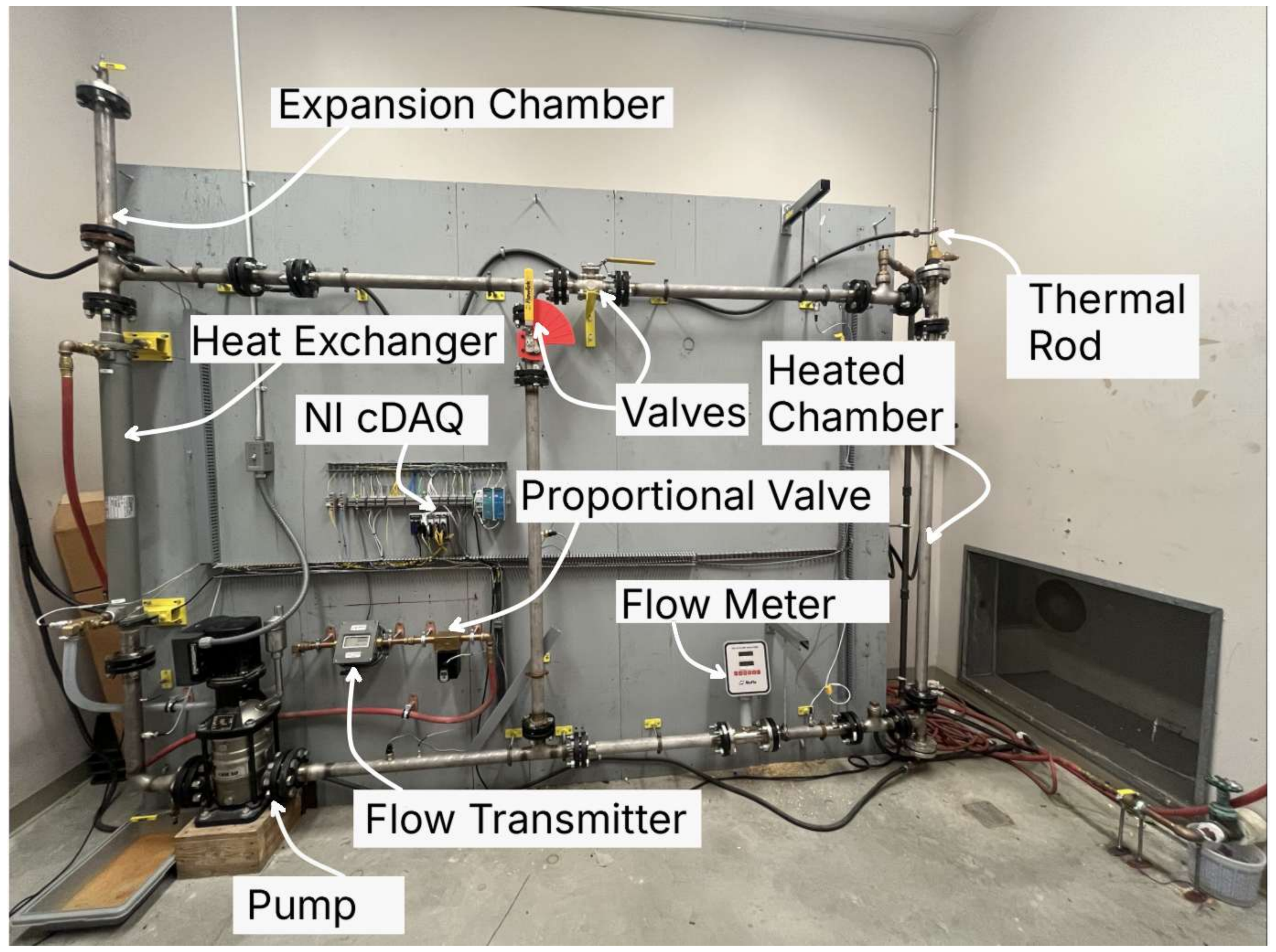

Figure 3. An image of the physical thermal loop testbed with all the parts of the testbed

How it works

- The Simscape model first gets a set of initial conditions such as temperature, pressure, and the type of fluid being run through the loop. It then uses individual blocks to represent each part of the loop such as the pump, the heated fuel rod, main circulation piping, bypass path, and the heat exchanger.
- The block diagram above shows the model taking the average of all the thermocouples values and subtracting the set temperature of 30 degrees and if the set temperature is higher than 30, then the proportional valve will open, allowing for cooler water to flow and help cool down the loop back to 30 degrees. .

Goals

- Run the thermal loop with the power supply at 2 volts up to 20 volts with two-volt increments
- Use the proportional valve and have it function across the LabVIEW diagram and Simscape model.
- Use data gathered to provide nuclear companies with information that can assist them in the future

Next Steps: Digital Twin and a PSO

- Creating a digital twin through Simscape where the model very closely matches the physical thermal loop
- This will allow for running the thermal loop in different or variable conditions without running the physical loop.
- Creating a Particle Swarm Optimization (PSO) program in Simscape

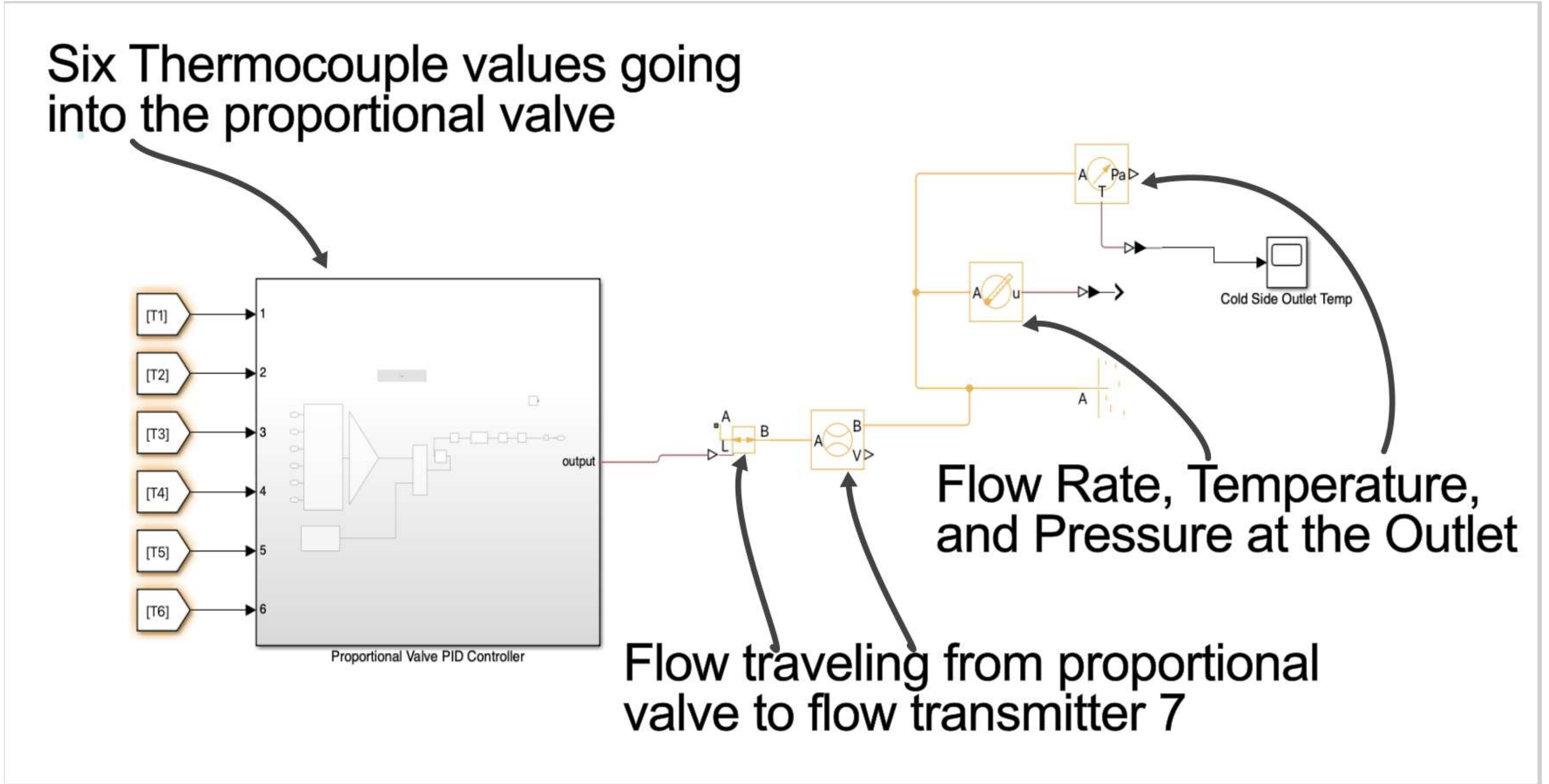

Figure 4. A Simscape block diagram showing the process of the cold city water flowing from the proportional valve to the heat exchanger outlet

Conclusion

This SMR Thermal Loop is a fully functional system that can accurately gather data and be controlled remotely by a LabVIEW diagram along with a Simscape model that can simulation the needed conditions. This will allow future students whose work on this project to achieve the desired results.

This project is supported by the McNair Summer Program through the Molinaroli College of Engineering and Computing at the University of South Carolina and is supported by the AQSEL project funded by The South Carolina Quantum Association/State of South Carolina Additional funding for this work comes from the National Science Foundation (NSF) through grant number CPS - 2237696. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of The South Carolina Quantum Association or the National Science Foundation.

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