Benchmarking: A Critical Step in Change to Nuclear Safety System

Nuclear power plants regularly utilize raw (untreated) water for cooling purposes. The Duke McGuire Nuclear Station contracted Purple Mountain Technology Group (PMTG) to calibrate their existing raw water system and evaluate the effect of a proposed engineering change (EC) to the system.

Figure 1: Highly Scaled Pipe from the Plant

The EC was intended to eliminate several issues at the pumps in an auxiliary feedwater system which is a part of the whole nuclear service water system (RN). These pump issues include:

1. High supply temperatures
2. Low NPSHa (suction pressure)
3. Entrained air

The proposed EC would relocate the auxiliary feedwater system supply to upstream of the RN system's heat exchanger. This EC would redirect a portion of flow and prevent increased temperatures and pressure drop caused by the heat exchanger. However, it was uncertain if the loss in flowrate through the heat exchanger downstream would cause flow to be below minimum values established by safety criteria.

In order to accurately model and predict the system's behavior after the EC, PMTG first had to build and calibrate a hydraulic model of the existing system. This proved to be a daunting task as the system had been in place since the 1980's and the constant exposure to raw water led to varying degrees of corrosion and build-up on the inner walls of the piping (Figure 1). This build-up can lead to significantly different system operation than when the system was new.

Calibrating a model consists of adjusting model input, such as pipe inner diameter and roughness, to match the calculated results from the hydraulic model to the measured field data. Calibration efforts for single flow paths can be fairly straightforward, but this system was a large network consisting of hundreds of pipes and components, resulting in so many combinations of adjustments that it would not be practical to evaluate them all manually.

In addition to the numerous combinations of adjustments possible for the hydraulic model of the RN system, there are also multiple operational configurations for the system. Each operational configuration results in a unique set of measured pressure and flow data. PMTG was able to iteratively adjust the model input in order to simultaneously match each of the multiple sets of measured data for the same network. This ensured that the hydraulic model would accurately predict pressures and flows no matter the configuration. This was especially important because a new configuration that had not yet been built was being evaluated.

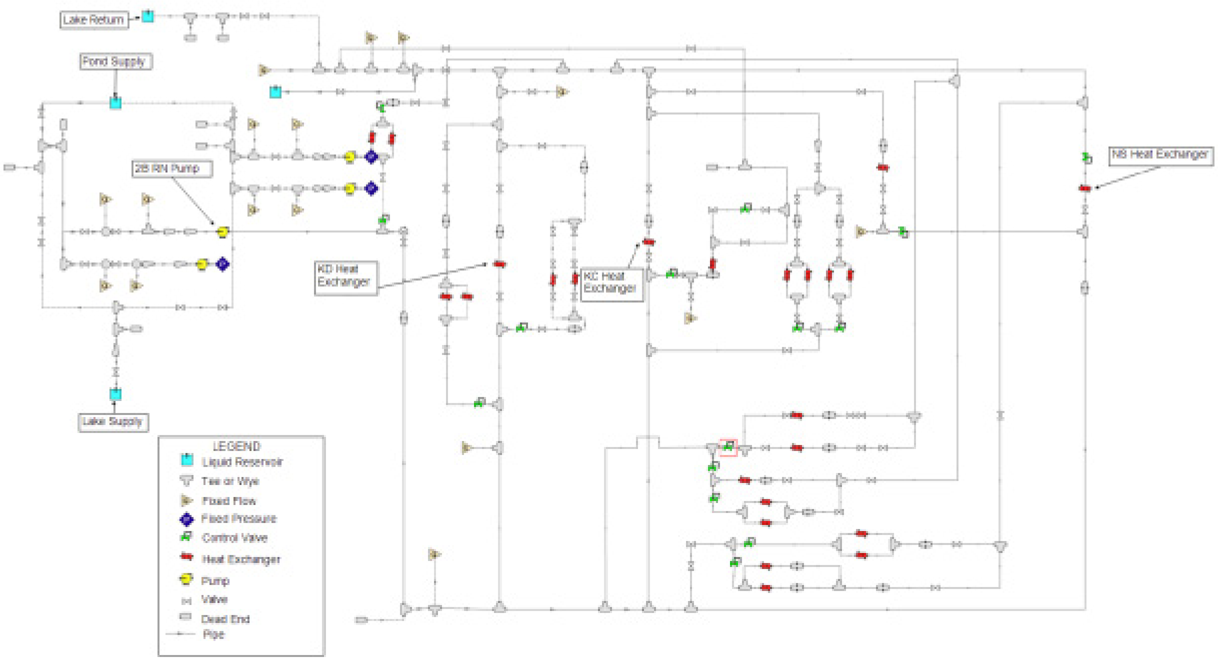

Figure 2: Part of the Nuclear Service Water System Modeled in Fathom

Using the Goal Seek and Control module within AFT Fathom allowed PMTG to largely automate the process of adjusting model input in order to calibrate the existing configuration to measured data. This methodology is further discussed in "Hydraulic Model Calibration of a Nuclear Plant Service Water System" [1]. The final calibrated model was within 2.3% of measured flows throughout the entire raw water system for all operational configurations, and was used for evaluating the relocation of the auxiliary feedwater system supply. PMTG was able to accurately determine that the EC was safe while maintaining the rigorous standards and code compliance that must be followed when working with a nuclear safety system.

[1] Onat E., Walters T., Mobley D., and Mead J., 2016, "Hydraulic Model Calibration of a Nuclear Plant Service Water System", ASME PowerEnergy2016-59062.

Need help with calibrating your system? Contact PMTG for help analyzing the issue.
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