Flow Network Solutions

AREVA offers a full range of flow network engineering and consulting services to evaluate the performance of nuclear plant hydraulic systems for BWRs and PWRs.

AREVA has applied commercially-available hydraulic modeling software tools to a wide range of plant upgrade and modification projects. The analysis tools have been dedicated for safety-related applications under the Nuclear Quality Assurance (10CFR50 and 10CFR21, NQA-1) programs. With the use of these flow simulation tools, system and design engineers are able to:

- Develop efficient methods for calculating system-wide distributions of flow rates, pressures and temperatures in a network representation of plant systems. These have ranged from air cooling systems to the main coolant loops on the Nuclear Steam Supply System (NSSS), as well as various Balance of Plants (BOP) applications.
- Perform conservative or best-estimate evaluation of systems. The modeling of various types of equipment in piping systems (pumps, valves, heat exchangers, etc.) can be as simple or as detailed as required, based on the analysis goal.
- Make reliable and accurate decisions on the merits of plant system design alternatives, e.g., the benefits of pipe re-routing.
- Investigate "what if" studies and contingency scenarios (e.g., fan failure and rise in ambient temperature).

Using measured system data to benchmark calculation results against known operating conditions provides confidence that the models accurately reflect the systems being simulated.

A Tailored Approach for Customers

Modeling with flow networks is a strategy involving representation of hydraulic systems as a network of components and flow paths for the purpose of predicting system wide distribution of flow rates, pressure and temperatures. The system working fluid can be air, water or steam. There are no limitations placed on the interconnections of the components in the network or the size of the network.

Figure 1 shows an example of direct customer application for analyzing the air flow distribution to design a Permanent Canal Seal Plate (PCSP) to be installed in the reactor vessel (RV) refueling cavity. The network is constructed by graphically representing the flow paths as the air passes through different components of the system. By specifying the flowpath geometry, fan performance capability and reactor cavity heat loading, the resultant impact on concrete temperatures in the RV cavity and changes in air flow rates due to the installation of the PCSP were conservatively evaluated.

Figure 1: Flow network representation of the RV refueling cavity and PCSP

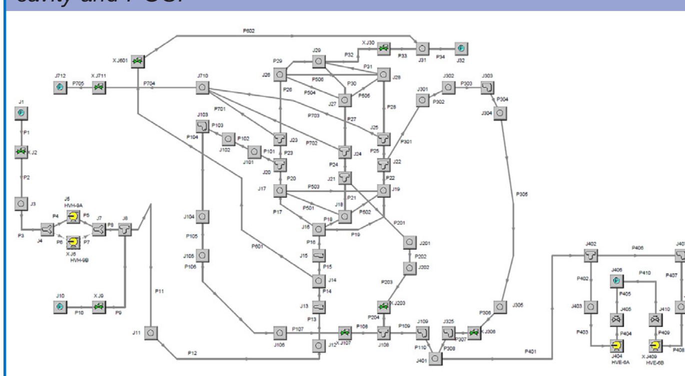
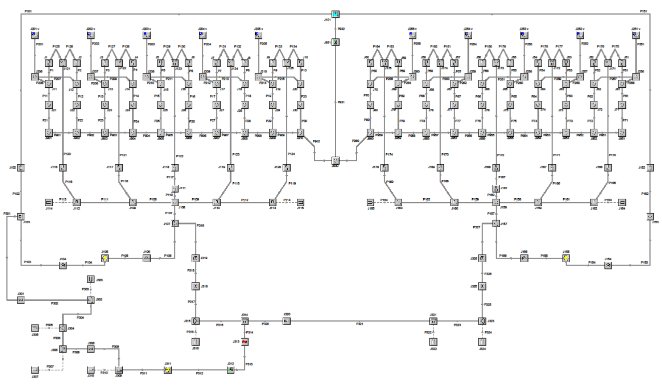


Figure 2: BWR reactor recirculation and residual heat removal (RHR) systems



More complex network representation using water as the working fluid is shown in Figure 2. The objective was to simulate simultaneous operation of both systems to save outage time and gain operation flexibility. In another application a generic hydraulic model of the hot water distribution header system of a cooling tower was developed. The model was used to optimize the design of a new distribution header and flow control valves, and to show how the system performance characteristics would change following the modification.

The hydraulic resistance coefficients for standard components (screens, ducts, bends, valves, etc.) are available from handbooks, and are embedded within the modeling software for convenience and ease of use. For nonstandard components, supplier data, more sophisticated flow analysis, or testing, can be used to get the flow characteristics, and the flow resistance to be modeled can be manually derived. The performance characteristics of centrifugal pumps can be explicitly accounted for in terms of rising pressure as a function of the flow rate, and variable pump speed can be analyzed.

The flow network modeling approach is cost-effective in terms of model definition and computation time (a few seconds on a laptop) due to the compact representation of the components. These advantages make a compelling case for its use as a system-level design tool customizable to a wide variety of engineering applications.

Applications & Experience

AREVA has a seasoned staff with a wealth of knowledge based on diverse experience in nuclear system operations and engineering modeling. Analysts work directly with plant modification engineers to support design modification packages and provide plant hydraulic and system performance assessment. AREVA is able to validate system performance, and accurately model the potential pressure and flow resistance for a variety of solutions: open and closed recirculating systems, forced and natural convection in cavity-driven flow and flow-split dependent tees.

Our experience in flow network modeling includes, but is not limited to:

Modeling of reactor coolant system hydraulics for different plant designs: calculation of core bypass flow, simulation of safety-related NSSS/RCS loop pressure drops and flow rates, plant heat balance, determination of pressure drop due to location correction factors for pressure-temperature limits, and core baffle upflow conversion.

NSSS component sizing for PWRs and BWRs: net positive suction head and flow delivery calculations for emergency core cooling and auxiliary system pumps, reactor vessel head and integrated assembly air flow, post-weld heat treatment air evaluation for steam generators.

Systems performance: post-Fukushima FLEX operations including several cooling strategies for operating plants, cooling tower and ultimate heat sink modeling.

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