System Assessment Capabilities for Nuclear Power Stations

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The mission of Flowserve Technical Services is to help nuclear power plant operators optimize unit performance and maximize profitability. This is accomplished by a team of more than 150 design and applications engineers stationed around the world. Comprehensive system assessments using advanced data collection tools and methods coupled with highly sophisticated modeling techniques provide the blueprint by:

- Assessing performance and verifying operability of key pumps and flow systems
- Identifying opportunities to reduce energy usage of major systems and critical equipment
- Diagnosing the root cause(s) of under-performing systems and premature equipment failure, regardless of OEM or type
- Identifying opportunities to improve operator safety
- Developing solutions for chronically problematic equipment using life cycle cost (LCC) projections

The Assessment Process

The life cycle of a well-engineered utility pump can easily exceed 35 years. Over time, however, changing operating conditions coupled with equipment degradation can result in their operating far off best efficiency point (BEP). Pump reliability and efficiency are negatively affected and system performance suffers. The impact also extends to the bottom line, where increased maintenance and operating costs can significantly depress plant profitability.

Increasing plant profitability is no easy task though. Safely maximizing unit power generation is key and to do this the performance of the system and all its components must be optimized. Focusing efforts on any single piece of equipment may provide some relief, but the results are marginal at best and typically short lived. Meaningful and lasting improvements can be achieved only by analyzing the system as a whole.

Technical Services’ five-step assessment process has proved highly successful in optimizing system performance.

1. Evaluate symptoms of deficient equipment or under-performing systems by forensically auditing current process parameters, maintenance history and operational demands.
2. Implement a testing methodology utilizing proprietary and non-proprietary data collection hardware and software tools to generate actionable data.
3. Analyze collected data, technical documentation and interviews to delineate root cause solutions.
4. Generate a comprehensive report with recommendations supported by life cycle cost analysis that enables the customer to achieve operational and reliability goals.
5. Provide continued technical and commercial support to secure sustainable and measurable results.
A Systems Approach

Flowserve Technical Services is fully committed to maximizing plant profitability by reducing the total life cycle costs of pumping systems. And while boiler-feed and circulating water pumps are critical components of any power plant, Technical Services recognizes that no pump operates in isolation. It is part of a system with myriad other components, all with crucial roles in achieving optimal plant efficiency and availability. That’s why Technical Services is system driven rather than component driven. Through this holistic approach, a truly effective solution can be implemented.

Assessments by Technical Services can help plant operators optimize unit performance by identifying deficiencies in systems including, but not limited to:

- Nuclear Steam Supply
- Circulating Water
- Safety-Related Systems
- Auxiliary Cooling Water
- Fire Water Distribution
- Essential Service Water

Nuclear Steam Supply System Assessments

Over a station’s life, perhaps no single power plant system can impact plant efficiencies more than the feed water system. Numerous factors – varying plant output, degradation of equipment and system modifications – lead to inefficient plant operation along with increased maintenance costs and, ultimately, reduced profits.

Technical Services understands that to truly change a plant’s output a complete system evaluation must be conducted. To that end, these experts analyze all systems and equipment in the steam cycle, focusing on energy and hydraulic optimization with advanced monitoring, diagnostic, modeling and analytical tools.

To this end, nuclear utilities are increasingly turning to Stretch and Extended Power Uprate (EPU) projects, which have proved more cost effective in increasing power output than new unit construction. Technical Services’ assessment of a system’s actual capabilities under increased demand and extended transient conditions establishes a more realistic baseline for unit uprates than relying on the original design criteria.

An assessment by Flowserve Technical Services can ensure the proper steps and corrective actions are taken to address:

- Unit uprates
- Unit derate due to high condenser backpressure
- Heater fouling and inefficiency
- Energy optimization
- Hydraulic optimization
- Pump performance or efficiency degradation
- System anomalies
Circulating Water System Assessments

The thermal efficiency of a power plant is largely determined by the pressure of the condenser to which the main power turbine is exhausting. When the actual condenser backpressure is above the design value, steam cycle efficiency declines, resulting in a net loss in power produced.

Increased condenser backpressure can be caused by any of several factors, including tube fouling, poor pump performance, low source water level and air leakage. And while reducing the backpressure may seem straightforward, there are numerous pitfalls that must be recognized and avoided when engineering changes to this system. For example, increasing the circulating water flow rate may indeed reduce the condenser backpressure but it may also reduce pump efficiency and cause premature condenser tube failure due to velocity erosion.

Technical Services engineers use advanced hydraulic modeling tools and life cycle costing methodologies to evaluate system modifications using actual performance data. They then develop corrective action plans that maximize plant output without compromising equipment efficiency or component mean time between repair (MTBR).

Assessments by Flowserve Technical Services can help plant operators identify and rectify the root causes of problems such as:

- Low circulating water capacity
- Inefficient condenser performance
- High condenser backpressure
- Low component MTBR

The Right Tools for the Job

Flowserve engineers use numerous analytical tools to aid them in their assessments, including:

- Powerful elimination schemes (rather than truth tables) to diagnose root cause for vibration-pulsation problems
- A 48-channel vibro-elastic data acquisition system to allow signature analysis, ODS, field model analysis, etc.
- Water-steam cycle thermodynamic modeling software
- Software to model steady state and transient pipeflow in complex pump systems
- Hydraulic design CFD analysis, flow visualization, energy optimization, erosion modeling, etc.
System Assessment Capabilities for Nuclear Power Stations

Safety Systems Assessments
Nuclear power plants must continuously assess and maintain the operability of their engineered safety systems to ensure they perform as designed. These systems are low- and high-pressure pumped fluid systems including, but not limited to:

- Residual Heat Removal
- Low-pressure Injection
- High-pressure Injection
- Core Spray
- Essential Service Water

Plant specifications mandate the flow rates the systems must be able to sustain against system head determined by reactor pressure. Engineering and maintenance personnel typically verify compliance with these specifications via scheduled testing and utilization of data from system actuations. But this approach is often problematic as the instrumentation utilized may be dated and the available local gauges are likely in areas where ALARA concerns exist. Further compounding the issue are the decades of system and plant modifications which make realizing the initial system design capability more difficult.

Technical Services engineers can make verifying safety system operability significantly easier, safer and more accurate. By installing and utilizing accurate wireless sensors on critical components, real-time data is collected on parameters such as flow, temperature, pressure and vibration levels. The sensing equipment’s long life and “always on” capability ensures all planned and unplanned actuations result in a high-resolution bank of data. Using this data and hydraulic modeling software, the Technical Services engineers are able to determine the maintenance or modifications required to restore system performance.

Fire Water System Assessments
A fire event is not the time to test the true capability of a power plant’s fire protection system. Over time, the condition of system piping can degrade and pump performance may diminish. Biological fouling, sedimentary buildup and corrosion can impact the system’s distribution pressure with catastrophic results.

Nuclear power plants practice “defense in depth” to minimize the chance of fire and ensure the plant’s ability to continue operation or safely shut down should one occur. Testing the plant’s fire water delivery system is a vital part of this defense. Typically, however, the actual flow and pressure of the system are not tested, despite the criticality of these parameters to the system’s strength of distribution and its ability to extinguish fires.

Flowserve Technical Services has proven itself an indispensable resource for evaluating the actual performance of fire water systems and alerting customers to the hidden risks. Utilizing the company’s proprietary IPS wireless technology, Technical Services engineers gather real-time flow and pressure data under various system demands, including multiple fires. This scenario-based testing assesses the piping distribution and headers for head loss, appraises pump performance and evaluates the configuration of the system. The result is a comprehensive analysis that informs decision making regarding expenditures to restore and maintain the effective performance of this critical safety system.
**Technical Services Determines Cause of Circulating Water System Inefficiency**

**The Challenge:** A multi-unit power station located on a large river suspected the circulating water system supplying Units 1 and 2 was operating inefficiently, resulting in derated performance. Consequently, the station's profitability was negatively impacted.

**The Assessment:** Flowserve engineers conducted a thorough assessment of the system which consisted of four vertical pumps operating in parallel. These pumps provide water to the Unit 1 and 2 condensers, condensate coolers, jacket water coolers and raw water pumps.

Using non-invasive flow monitoring instrumentation and state-of-the-art wireless technology, Flowserve engineers collected high-resolution data under various operational scenarios. A hydraulic study was performed from which a highly accurate model was developed. Validated with actual field data, this model was used to evaluate the system's response to multiple variables.

Flowserve Technical Services engineers determined:

- Unequal flow distribution existed throughout the system. Flow to the Unit 1 condenser was greater than design in all field test scenarios. Flow to the Unit 2 condenser only reached design level when four pumps were in operation.
- A significant reduction of flow to both condensers occurred during periods of low river elevation.
- Low-flow caused increased condenser backpressure in both units, compromising unit power generation during low river level conditions.

**The Solution:** To correct the flow imbalance, Flowserve recommended two circulating water pump trains be retrofitted with higher speed motors to provide greater capacity when the river is low. The hydraulic model was used to verify that two higher speed motors the client already owned would provide the necessary increase in pump capacity. The resulting increase in flow would also reduce the condenser backpressure and improve steam cycle efficiency, increasing station profitability.

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**Auxiliary Cooling Water System Assessments**

Like all power generating plants, nuclear power plants have auxiliary cooling water systems. They handle plant loads such as purification heat exchangers, residual heat removal heat exchangers and lubricating oil coolers. And while they are indeed secondary to critical systems such as feed water, circulating water and safety-related systems, auxiliary systems provide important heat removal services that impact the efficient operation and safe shutdown of the plant.

Some of these systems have operability requirements that must be assessed and maintained. Flowserve Technical Services is able to assess these systems to determine their overall performance as well as the pump and cooler efficiencies. Hydraulic modeling combined with highly accurate data collection enables Technical Services engineers and plant operators to determine actual operating conditions and make informed decisions regarding system changes.

Some of the auxiliary cooling water systems that Flowserve Technical Services can assess and provide recommendations for optimization include:

- Reactor Building Closed Cooling Water
- Turbine Building Closed Cooling Water
- Residual Heat Removal Service Water
- Essential Service Water
- Reactor Plant Fresh Water
Knowledgeable People With Powerful Tools

In addition to pump expertise, Technical Services engineers have extensive experience with power plant systems and process applications. These credentials are augmented with state-of-the-art monitoring, diagnostic and modeling technologies, including proprietary Flowserve engineering software and evaluation methods. The result is actionable information that plant operators can use to optimize system performance and increase plant profitability.

Acquiring the Data

Performing an in-depth analysis of any power plant system requires the collection of a large amount of historical information and actual current performance data.

Experienced Flowserve Technical Services engineers perform extensive on-site audits to define pump reliability issues and maintenance history, operating issues and possible system and component design weaknesses. This is accomplished in part by interviewing power plant staff and by collecting historical data like maintenance files, design and construction data.

Technical Services engineers also conduct comprehensive field testing to establish actual performance data. This testing may include the company's proprietary IPS Wireless monitoring and diagnostics hardware and software. Data including pressure, temperature, mass flow, etc., can be recorded in real time at various unit loads. This data is used to validate high-resolution thermodynamic and hydraulic models which help Technical Services engineers identify system deficiencies and predict changes in system performance.

Hydraulic Modeling Removes Guesswork

Flowserv uses sophisticated software and techniques to develop highly accurate hydraulic models of plant systems. Validated with real-time field data, these models enable Flowserv engineers and plant operators to:

- Analyze actual system performance
- Establish system head loss curves and any process variable, e.g., flow, head, velocity, pressure drop, etc., at any location within the system under various modes of operation
- Run “what if” scenarios to determine the impact of proposed modifications
- Develop a cost-effective action plan that achieves real and measurable improvements in the performance and profitability of the plant

Thermodynamic Model Tests Efficiency

Using actual performance data obtained during testing, Technical Services engineers can develop a thermodynamic model of a unit’s entire steam-water cycle. This model simulates pump and system operation under various system loads. Armed with this information, Technical Services engineers and plant operators can then develop detailed corrective action plans for optimizing system performance, reducing fuel costs and increasing plant profitability.

An advanced thermodynamic model also addresses with a high degree of confidence questions regarding:

- Changes in steam flow to the turbine and its new output, exhaust steam properties and efficiency
- Changes in feed-water heating in terms of new turbine extraction steam flow parameters, steam pressure, turbine operating values, plant output and efficiency
- Changes in circulating water flow through the condenser and its effect on heat removal capability, backpressure reduction and condensate temperature