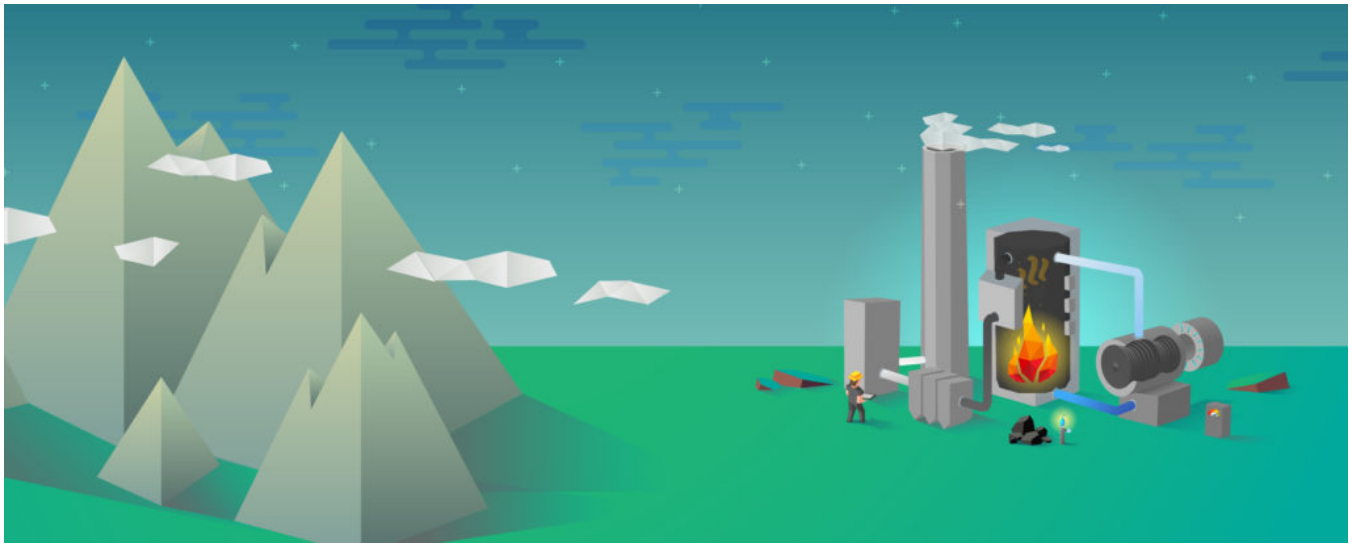
From Baseload to Flexible Operations



EPRI Examines New Technologies, Techniques, and Tolerances at Coal Plants

By Brent Barker

With growing renewable generation, low natural gas prices, and other market forces, coal plants designed for baseload operation increasingly operate in flexible modes such as:

- **Low-load operation or turndown:** Operating at reduced output.
- **Load-following:** Following the ups and downs of the daily load cycle, causing the temperature of key components to fluctuate hundreds of degrees in a short period.
- **Cycling:** Turning off the plant daily, followed by a "hot start" in a few hours.
- **Extended layup:** Turning off the plant for weeks to months. In regions with significant wind power, for example, operators may schedule extended layups during spring and fall when winds are high and sustained and load is not elevated by air conditioning or heating demand.

Flexible operations can take a physical toll on coal plants in many ways. For example, as the temperature of the steam in a plant's turbine rises and falls, metals expand and contract, leading to fatigue. This is compounded as thin and thick metal parts expand and contract at different rates. Environmental controls optimized for baseload operations may be less effective at lower loads and lower temperatures. During shutdown and layups, water can gather where steam usually flows, leading to pitting and corrosion in metal components.

Research by EPRI, utilities, and others indicates that the aging coal fleet can adapt to flexible operations with new technologies, new techniques, and a willingness to experiment with new operational practices.

Toward Technical Solutions

"Flexibility is so important that every program in EPRI's Generation Sector is examining it in some way. For example, the Boiler and Turbine Steam and Cycle Chemistry program (Program 64) is looking at novel treatments that produce protective coatings for components; the Boiler Life and Availability Improvement program (Program 63) is investigating how to better manage fatigue; and the Steam Turbines program (Program 65) is studying steam flow and the effects of low-load operation," said EPRI Senior Program Manager Mike

Caravaggio. “The 15 utility members in our Mission Profile Working Group [see box at end of article] are gaining a holistic view of all the impacts of various flexible modes.”

One way to minimize fatigue and creep damage is to keep steam temperatures as constant as possible through all operating modes. “Changing a plant’s power output can move heat absorption around the boiler,” said Caravaggio. “This can cause tubing to run hotter than it was designed for and cause components to change temperature rapidly. Managing these temperature changes requires systematic monitoring and control involving numerous systems.”

“A key lesson that we’ve drawn from years of flexible operations work with utilities is that turndown is always better than cycling on and off,” said EPRI Principal Technical Leader Merrill Quintrell. “With turndown, you can avoid a lot of operations and maintenance problems.”

This interactive graphic describes EPRI research to enable flexible operations at a typical coal plant.

During flexible operations, plants must continue to comply with regulatory limits for nitrogen oxides, sulfur dioxide, mercury, and particulate matter. “Load changes have a significant impact on how post-combustion control equipment performs,” said EPRI Senior Program Manager Tony Facchiano. “In low-load operation, the temperature of the flue gas exiting the boiler is reduced, which can adversely impact the performance of the selective catalytic reduction reactor.”

These reactors are designed to operate within a specific temperature range to avoid formation of ammonium bisulfate, which can clog the catalyst’s pores. Recent EPRI research has demonstrated that the temperature at which ammonium bisulfate forms can be lower than what has been observed in previous assessments. This means that in some applications, minimum operating temperatures may be safely lowered, although caution needs to be exercised.

To protect steam turbines, boilers, and other equipment from moisture during layups, EPRI has developed procedures that include deploying dehumidification systems. To inhibit corrosion in water/steam cycle equipment during layups, EPRI and several utilities demonstrated the effectiveness of film-forming products in field tests.

Experimenting in the Field

In working with utilities on flexible operations, EPRI has had considerable success experimenting with procedural changes, re-examining traditional margins, and testing new operating tolerances.

“When a utility asks to work with us, we first find out which flexible modes are relevant,” said Quintrell. “Then we examine plant operational and design data and identify possible problems with instrumentation and controls. After those are fixed, we run a protocol to test new tolerances. We take the unit down as low as it can go, then ramp it up as fast as it can go, then run it through cycling routines.”

This experimentation serves as a stress test to identify the unit’s limits. Based on the performance data, EPRI makes three tiers of recommendations. Tier one includes procedural and operational changes, such as taking a specific pump out of service or opening a particular bypass valve. Tier two involves relatively small capital investments such as new instrumentation and valve replacements. “These are things that may cost a few thousand dollars—small investments for large gains,” said Quintrell. “Level three recommendations are typically expensive capital modifications that would enable the operator to overcome significant design challenges with the plant.”

Typically, utilities implement tiers one and two, but not three. “Utilities are unlikely to commit large amounts of capital to a legacy asset that may not be in service in 10 years,” explained Quintrell.

One power plant dramatically improved its turndown capability by changing certain procedures and replacing the pyrometer in the boiler with a flame scanner. “The pyrometer only measures heat and does not indicate which burners are operational—information that is particularly important when the plant goes to an extremely low load,” said Quintrell. “EPRI recommended the flame scanners because they provide a picture of burner conditions. More precise control of the burners, along with the procedural changes, enabled operators to lower the plant’s load by roughly 70%.”

Operators at a plant with two 1,300-megawatt units were constrained from operating each unit below 800 megawatts because it would be below the optimal speed range for the two boiler feedwater pumps in operation. The units would “lug” the way a standard shift car does when it needs to be downshifted. “We suggested a simple solution—take one pump out of service,” said Quintrell. “Their first reaction was, ‘We can’t do that, it’s against our operating procedures.’ Then they agreed to experiment. It worked and enabled each unit to turn down to 550 megawatts.”

This inexpensive procedural change is now standard for turndowns. “At this facility, the utility can take an additional 500 megawatts off the grid without having to shut down any units, saving about $2 million per year in avoided startup costs.”

EPRI’s wide-ranging research plans for flexible operations include new materials and coatings for components, advanced component manufacturing, new ways to manage hotspots and fatigue, improved sensors to track component condition, innovations in inspection, enhanced tools to assess damage, and more.

“Our objective is to help the industry successfully transition from baseload to flexible operations by the mid-2020s,” said Caravaggio.

Mission Profile Working Group

The 15 power companies in EPRI’s Mission Profile Working Group are developing a comprehensive online resource to help power plant operators identify and address impacts of various flexible modes. The beta version draws on industry knowledge about power plant design, vulnerabilities with systems and components, field-proven solutions, and more. While it is currently available to members of the working group, in 2019 EPRI plans to expand access to all utility members of its Generation research sector.

Key EPRI Technical Experts

Mike Caravaggio, Tony Facchiano, Merrill Quintrell