HOW DIGITAL STRATEGIES IMPROVE STEAM POWER PLANT PERFORMANCE

The increase in renewables, the low cost of natural gas in some areas, and environmental regulations are changing the world of steam power plants.

A New Set of Realities

Steam power plants, typically using oil or coal for fuel, have been a critical component of power generation around the world for decades, but the industry is currently undergoing a profound structural transformation responding to megatrends in politics, the economy and technology. While steam power plants remain a leading source of electrical energy, they are facing new challenges to their financial and environmental viability.

Rapid growth in both solar and wind generation, with their intermittent nature, combined with an abundant supply and low price of natural gas in many areas of the world, have eroded the competitiveness of traditional steam power generation. New environmental regulations for flue gas emissions, as well as for combustion by-products and wastewater, while making these plants increasingly clean, are adding significantly to their costs for producing electricity. These disruptive forces create challenges for the operators of existing steam power plants. And new steam plants must be designed to new requirements to succeed.

These challenges are all taking place while other landmark changes to the generating mix happen around the world. According to the U.S. Energy Information Administration (EIA), in March 2017 monthly generation from wind and solar exceeded 10 percent of the U.S. total power generation for the first time, a tremendous growth from under 1 percent in 2007 and less than 5 percent only five years ago. EIA is forecasting that through 2050 over 50 percent of the new generation additions in the U.S. will be wind and solar.

Renewable energy sources accounted for a 17.5 percent share of the EU-28's gross inland energy consumption in 2017 and for a 29.6 percent share of the gross electricity consumption, according to Eurostat, and a 17.5 percent share of the Organization for Economic Co-operation and Development (OECD) Asia Oceania energy production in 2019, according to the International Energy Agency. The strong growth of wind and solar generation is certain to continue.

With increasing trade of low-cost coal around the world, operators are optimizing cost efficiency of coal power generation by the diversification of coal sourcing from spot markets and accepting large variations of coal quality. On the other hand, especially in Europe, Canada and Japan, there is a trend of co-combusting biomass or even retrofitting a coal-fired power plant to 100 percent wood pellet combustion. Like coal, biomass also has large variations of quality, depending on its origin.

Requirements of load flexibility and fuel flexibility impose challenges for power plant designers and operators to control and optimize the operation settings of the combustion system and boiler to ensure the highest possible efficiency and lowest emissions.

Avedøre Power Station, Ørsted A/S
Avedøre, Copenhagen, Denmark

Key Requirements to Meet the New Landscape

The shifting electricity generation marketplace requires a new level of flexibility among power generators. Older steam plants need to be increasingly nimble to stay competitive. Plant operators must look at a variety of ways to meet these challenges.

Fast Ramping Rate: Power output from solar and wind facilities varies from day to day, and often on an hourly or even minute scale. Because of low implementation levels of dedicated energy storage capacity, this means steam power plants need to provide required load support, ancillary services and frequency control through improved operational response and by tapping the thermal inertia in the steam and hot water in power plant systems.

Reduced Minimum Load: Most conventional solid-fuel boilers have a limited turndown range, originally designed for a minimum load of around 40 percent of maximum continuous rating (MCR). Operating in cycling mode requires reduced minimum load without the need for firing expensive support fuel. This would enable the plant to respond to grid demand and avoid startups, especially costly cold starts that can damage equipment due to thermal fatigue.

Reduced Startup Time: Fast and smooth startups allow a steam plant to respond to grid dispatch and maximize generation revenue.

Fuel flexibility: Successfully accomplishing the requirements for working with variations of fuel while effectively managing life consumption in key components and dealing with changing or fluctuating operation parameters requires a much higher level of digital control strategies and data-driven life consumption modeling than is typical in older base-loaded steam power plants.

Making Sure the Plant is Ready

Part of meeting the new realities is making sure a steam plant's equipment is ready for the challenge. Combustion stability is a determining factor in achieving minimum load and ramping rate. This requires operators to evaluate mills and burners, including testing to determine turndown ranges.

Operating at very low load means taking some of the mills and burners out of service in combination with running the in-service mills and burners at reduced output. Evaluating fuel flexibility and the potential to upgrade to the latest low-NO_x burner models is an option. Inspecting the flame scanners and potentially installing upgraded flame scanners can help avoid false trips due to weak signal strength at low burner load. Operators may also decide to retrofit rotary classifiers to improve fineness to enable higher flame stability.

Other actions coal plants can take include indirect firing by installation of a pulverized coal bunker between the mill and the burner to decouple the burner firing rate and the mill output rate. This offers a new level of freedom through data-driven combustion control. In all cases, increased use of advanced digital control strategies and data analytics will contribute to success.

Experience in Europe proves taking these steps with existing fleets can provide reliable combustion at 15 to 20 percent of MCR.

Operators with access to sufficient supplies of natural gas can cut startup costs by switching startup burners from fuel oil to natural gas. Co-firing with natural gas is effective in providing operating stability at low loads and helps avoid costly shutdowns.

Because cycling operations can expose boiler pressure parts to increased risk of fatigue, it is important to review heat-transfer components and pressure parts. Checking flow stability, improving attemperation system operation and control range, and monitoring critical parts for temperature difference and life consumption accumulation are all important steps.

Thick-walled boiler components such as steam headers can be the limiting factor for ramping rate. Operators may need to replace headers with an alloy that allows higher stress. Similar to thick-walled boiler components, steam turbine parts such as rotors, casings and valve bodies are frequently subjected to higher levels of thermal stress from the aggres-sive operation needed to remain competitive in operational flexibility.

Numerous plants have had success applying steam turbine variable-startup technology, allowing interpolation between the definitions of cold, warm and hot starts based on measured turbine metal temperatures. Additional technology is being developed to generate startup curves in real time by applying multi-objective evolutionary algorithms to optimize rotor life and fuel consumption within the constraints of rotor stress and internal clearances.

Another key area to consider with steam plants is the air quality control system. Plant operators want to meet emission limits even when the plant is operated at very low load and fast ramping conditions.

Electrostatic precipitators and fabric filters can generally accommodate a wide range of loads, but it is important to maintain flue gas inlet temperatures above the acid dew point to prevent corrosion. While wet flue gas desulfurization can operate in a wide load range, it requires a robust response and proper process control tuning. Selective catalytic reduction systems for NO_x control require special measures in some cases to maintain sufficiently high flue gas inlet temperatures and proper functioning at low load operation.


Boxberg Power Station
Boxberg, Saxony, Germany

Advanced Control Technologies

As part of its TOMONI™ digital power plant initiative, Mitsubishi Power is developing new AI-based control systems to enhance performance, efficiency and flexibility for power plants. Analyzing large volumes of data acquired during plant operations allows advanced analytics to provide a range of functions, including cost optimization and early detection of anomalies.

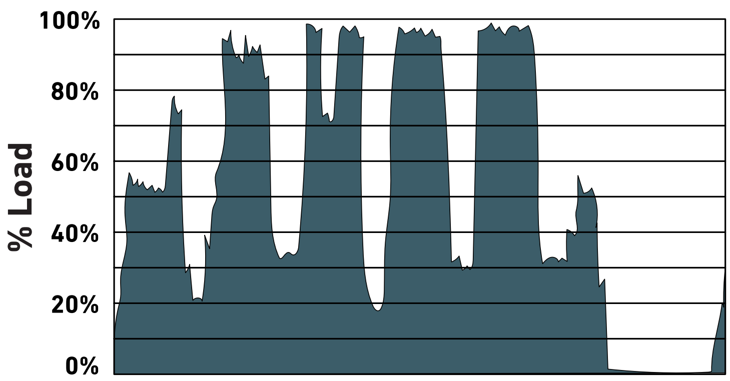
AI modeling has already been deployed to manage process values that achieve optimum boiler conditions by factoring in external parameters such as fuel cost and fuel quality fluctuations.

Looking to Europe for Proof

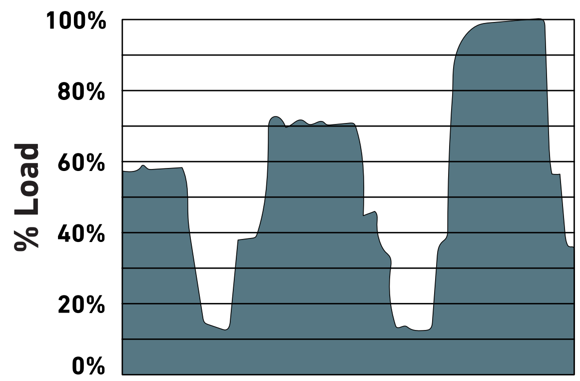
Europe was one of the first large power markets where the grid had to absorb the variability of widespread installation of wind and solar generation capacity. Germany is a leading renewable energy market and also has a relatively small natural gas–fired capacity.

High natural gas prices in Germany compared to electric market pricing means that coal-fired plants are called on for more support in stabilizing the grid. Here are two examples that show how, after implementing equipment and control improvement measures, a small subcritical unit and a large supercritical unit were able to perform.

Deep Cycling Operations



150 MW Plant, Hard Coal
Weekly Load Pattern



700 MW Plant, Hard Coal
Daily Load Pattern

The Role of Maintenance

Cycling operations for steam power plants demand more vigorous, knowledge-based and data-driven practices. Avoiding unplanned outages and preserving the useful life of equipment are critical. A single unplanned unit outage due to a boiler component failure can cost tens of millions of dollars in lost power generation and repairs. Risk-based maintenance programs derived from extensive boiler inspection and maintenance experience help avoid unplanned outages. A large metallurgical and failure assessment database, with historical information from a wide range of designs, fuel properties and operating conditions, can help with inspection planning, assessment and cost-based maintenance scheduling.

In addition to increasingly data-driven maintenance planning, TOMONI™ also offers a component condition monitoring tool, a software application for digitalizing, monitoring and forecasting the condition of power plant components. Reliable forecasting of component conditions can be achieved by both offline inspections during outages and online calculation using the databases and empirical correlations in the software.

Using Fleet Monitoring and Control Technologies

Fleet monitoring and diagnostics technology can be a key enabler of more flexible and aggressive operating regimes as well as data-driven maintenance. Mitsubishi Power began system- level implementation of massive power plant data acquisition and digitalization in 1997 at T-Point, the fully operational and heavily instrumented gas turbine combined cycle (GTCC) power plant at the Takasago Machinery Works in Japan. In 1999, a fleet monitoring and diagnostics center joined T-Point. Since then, several more centers have opened around the world, including two centers that support steam plants in Alabang, Philippines, and Nagasaki, Japan. Steam power plants can benefit from Mitsubishi Power's ability to monitor the total plant and report in real time on boiler, steam turbine and generator efficiency, operating condi-tions, creep life evaluation, fuel flexibili-ty, stress/life consumption, performance degradation and other important indicators.


Linkou Power Plant Linkou, New Taipei, Taiwan

Increasing use of AI enables lower emissions and ideal gas/air balance. This contributes to economical plant operation while burning a range of coal compositions.


Mitsubishi Power Remote Monitoring Center Nagasaki, Japan

Solutions for a Complex Energy World

Market conditions, global prices for natural gas and LNG, and government incentives have an impact on steam power plant operations. Increasing reliance on intermittent energy sources leads to higher volatility and more dynamic energy conditions. Even companies operating small fleets need to improve their capabilities to predict electricity prices, electricity and heat demand, and weather conditions. Tools are available in the TOMONI$_{TM}$ suite of digital solutions to optimize the operation and maintenance of existing power plants and help evaluate future investment needs.

Coal-fired and other steam power plants can no longer expect to operate at base load with high capacity factors or with constant fuel qualities. Plants need to be agile, with wide load range, fast ramping and frequent starts as well as with high fuel flexibility—all while maintaining efficiency, equipment durability, environmental compliance and low cost of electricity.

The combination of the latest digital technologies, targeted equipment upgrades and human insights has been proven to improve steam power plant asset performance, leading to reduced fuel cost and reductions in CO_2 and other emissions.

TOMONI$_{TM}$

Mitsubishi Power is leading the development of the digital power plant of the future with TOMONI$_{TM}$, a suite of digital solutions enabled by decades of O&M and plant knowledge. Our solutions are driven by customer collaboration and use advanced analytics and adaptive control to lower the cost of electricity and achieve environmental and business goals.

For more information about the TOMONITM suite of digital solutions, visit **changeinpower.com** or contact your Mitsubishi Power representative.

PSB0-01SB08E2-A