MITSUBISHI POWER

WHITE PAPER:

MAKING AGING POWER PLANTS SMARTER IN A DYNAMIC AND COMPETITIVE POWER MARKET

Ratchaburi Power Plant, located in Thailand, began operations in 2008 and implemented additional digital technology to increase plant efficiency and flexibility.

CHALLENGES TO VIABILITY OF AGING POWER PLANTS

Aging power plants, regardless of their technology or fuel source, face significant challenges to their continuing viability, deriving from increased competition, tighter regulations and declining experience in the workforce.

With increased competition from renewable and distributed generation, energy storage and newer, more efficient plants coming online, aging power plants are challenged with declining income due to decreased kWh sales, inevitably leading to lower profitability and extreme pressure on O&M budgets. At the same time, the inconsistency of renewable generation leads to a fluctuating balance between demands and supply on the grid. This necessitates harsher duty cycles, including regular cycling, frequent startups and rapid load changes. These duty cycles are often far beyond the original design basis, threatening plant reliability and increasing O&M costs.

Due to environmental pressures, aging plants are seeing tougher emissions requirements and increasingly stringent grid codes, which are essential to maintain the stability and reliability of a more complex power grid. All while struggling to sustain decision-making effectiveness in the face of a declining experience base caused by retiring experts who had a wealth of plant knowledge.

As challenges for aging power plants continue to grow, this paper reviews how plants can intelligently use digitalization to stay competitive in this ever-changing landscape. It includes examples of how Mitsubishi Power's suite of digital solutions, TOMONI, is already benefiting power plants around the world.

INCREASING DISPATCH PROBABILITY

Increasing dispatch probability is an important component of staying competitive and increasing profitability, and there are many ways to use digitalization to achieve this. Digitalization can allow for faster and more reliable starts, improve operational readiness and increase part-load efficiency, allowing plants to stay online longer.

The speed and reliability of startups have a significant impact on the selection of plants to dispatch and are imperative to increase a plant's dispatch probability. Intelligent software and logic modifications can help combat these challenges by improving a plant's position for dispatch and increasing the probability that it gets online and starts making money when it is dispatched.

Often safe startup times are limited by the steam turbine, so a total thermal cycle solution is needed. Plants worldwide have had increased loading rates and reduced startup hold times from implementing several available solutions that optimize steam turbine startup time.

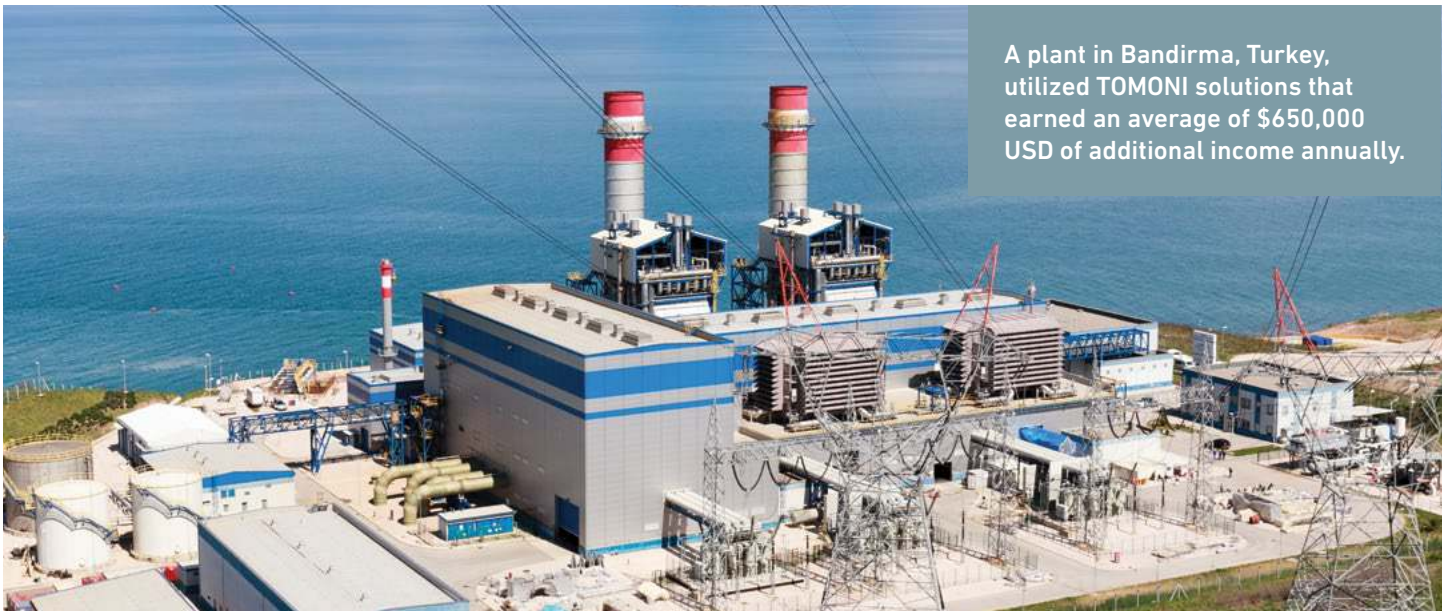
A plant's ability to immediately start or restart when called upon also impacts where the unit will be on the list for consideration when there is an immediate need for more online generation or spinning reserve. Therefore, the operational readiness of the plant is an important component in increasing dispatch probability. Aging plants can do this by implementing digital solutions that reduce the offline time required before a restart for both short and long shutdown periods.

Digital control logic and hardware upgrades can reduce the offline time by shortening the time required before a restart. This could be as much as a 25 percent reduction in the time required before a warm or hot restart. Aging plants can also experience long shutdown and reserve periods that can lead to delays in their ability to get back online. One digital solution that helps is automating the rotor cooling air (RCA) system corrosion protection, which can reduce the amount of preservation required to protect the equipment from corrosion while offline, in turn reducing the time needed to restart and get online. These types of upgrades allow aging plants to take advantage of more income-producing opportunities and increase profitability.

In today's environment, plants are running less and less at full load. Most aging plant equipment was not optimized to run at part load for long periods, but digital solutions can improve the efficiency at part load and flexibility over a wider load range. This arms plants to better pair with the inconsistency of renewable generation and operate at lower loads during times of low market demand, in turn improving dispatchability and profitability.

GT DIGITAL FLAME DETECTION INCREASES DISPATCH PROBABILITY.

Mystic Generating Station implemented the TOMONI GT Digital Flame Detection after experiencing an increase of starts and stops, and in one year, had 337 starts with zero startup trips caused by the ignition detection system. The software-based flame detection system, which operates in parallel with the physical flame detectors, utilizes a controls package of software and relay logic modifications to detect healthy ignition and allows the faster of either system to indicate successful ignition. This allows successful and faster startups even if there are instrumentation or signal strength issues with the flame detectors, so the plant is online and selling kWh faster and more predictably.



A plant in Bandirma, Turkey, utilized TOMONI solutions that earned an average of $650,000 USD of additional income annually.

BOOST INCOME POSSIBILITIES

As the power market becomes more competitive, plants must take advantage of every income opportunity. For aging plants, digital solutions can position power generators to pursue additional income while the plant is online, enable lower turndowns, compensate for degradation and reduce downtime and outages.

Income from grid ancillary services markets is becoming more significant in many parts of the world. Digital solutions can empower plants with faster startups, load ramping and frequency regulation services, increased demonstrated capacity and more flexible spinning reserve margins.

These solutions are already providing value to plants around the world. For example, a power plant in Bandirma, Turkey, utilized ramp rate maximization and power augmentation solutions to give the plant more secondary frequency control reserve capacity and increased the combined cycle ramp-up rate, which earned an average of $650,000 USD of additional income annually.

The opportunity to increase revenue is at its highest during times of peak power demand. An aging plant armed with digital solutions can use logic, monitoring and control algorithms to more precisely control equipment to increase output during periods of high energy-market prices. As technology evolves, artificial intelligence (AI) features will enable digital solutions to make recommendations and, in some cases, decisions on when to pursue peak power opportunities based on the income value and equipment life and health tradeoffs.

Lower turndown is another benefit to digital upgrades such as the TOMONI Flex Pack, which increases gas turbine firing temperature in a controlled way. At a U.S. gas turbine combined cycle (GTCC) plant, turndown was reduced by 22.5 percent utilizing TOMONI IGV Optimization and turndown reduction solutions.

DIGITAL SOLUTION BRINGS EFFICIENCY AND FLEXIBILITY AT PART LOAD, DELIVERS SAVINGS ACROSS THE WORLD.

Improving efficiency at partial load is increasingly important in many areas of the world. Two plants, Saltend Power Station, located in the United Kingdom, and Ratchaburi Power Company Limited, located in Thailand, implemented IGV Optimization with great results. Both were experiencing more part-load operation due to renewables penetration and challenging market demands. After installing IGV Optimization, the plants were more efficient at part load and more flexible to ramp up or down based on grid needs. This led to a fuel savings of as much as $521,000 USD per year at Saltend and $1.2 million USD per year at Ratchaburi.

Digital upgrades can also automatically recapture or compensate for equipment degradation between outages and as equipment ages. The TOMONI GT Cooling Air AI Optimization and other advanced combustion tuning systems solutions automatically adapt to degradation and environmental factors for disc cavity temperature and combustion dynamics. The solutions not only prevent alarms but also improve performance, efficiency and availability.

Digital solutions can act as a backup for existing systems to sustain reliability and reduce outage durations, avoiding missed opportunities. For example, the TOMONI Electronic Overspeed Protection replaces older mechanical overspeed trip systems and is fully independent of the existing overspeed backup system. It can be verified online through individual channel testing without needing to trip and reset the gas turbine, eliminating the need to repair or reset that device after outages for overspeed testing. This results in shorter outages and increased starting reliability.

MANAGE EQUIPMENT LIFE CONSUMPTION AND O&M EXPENDITURES

Aging plants can access the latest fleet knowledge and experience digitally to better manage equipment life consumption and O&M expenditures to help minimize the cost of operating the plant. Utilizing data and predictive analytics, automated equipment assessments, condition-based and predictive maintenance will save money on the maintenance of the power plant and increase its availability to be dispatched.

The effectiveness of remote monitoring, which applies advanced analytics and fleet-wide learning to reduce both planned and unplanned downtime, is well proven on GTCC plants, with documented savings exceeding $1 million USD annually. In a recent application to a coal-fired plant in Asia, 43 anomalies were detected in the first year, preventing seven unplanned outages and identifying seven more opportunities to reduce thermal performance deterioration.

Digitalization can also enable automated equipment lifetime assessment, condition-based maintenance and predictive maintenance. AI solutions, fueled by machine learning, plant data and fleet-wide knowledge, can automatically analyze complete operating profiles and provide meaningful insights. They can predict needed maintenance well in advance of failure while extending maintenance cycles from the more traditional and conservative schedule-based maintenance, which leads to a reduction in O&M costs.

The evolution of wholesale gas markets is increasing the quantity and diversity of fuel gas available for power generation in many parts of the world. These new options open the door for a reduction in fuel costs through sourcing from multiple suppliers, expanding the diversity of sources. This will pose a challenge for power generators, as it can increase the variability of fuel gas characteristics and affect combustion dynamics.

Remote Monitoring Centers

Takasago, Japan

Orlando, Florida, USA

Nagasaki, Japan

Alabang, Philippines

Remote Monitoring Service (RMS) is a well-established technology that Mitsubishi Power has been using to improve the reliability and availability of thermal power plants since 1999, combining advanced analytics with expert support that goes well beyond traditional remote monitoring.

The massive data acquisition and analysis that takes place in the Remote Monitoring Centers is used to validate new digital solutions and train advanced analytics. The technical support can also provide value to aging power plants where on-site technical expertise may be declining.

INCREASE IN OUTPUT DURING TIMES OF PEAK POWER SHOWS A SUBSTANTIAL RETURN ON INVESTMENT.

Plants in Europe and the U.S. have implemented the TOMONI Flex Pack or some of its component solutions, giving them the ability to increase gas turbine firing temperature, in a controlled way, to get more megawatts for short periods. Full implementation of this solution allows for multiple operating modes with pre-programmed optimal settings for normal (maximum efficiency), maximum and peak fire operation, so operators don't have to manually change settings and calculate optimal parameters. In these plants, the peak fire mode increased demonstrated output by as much as eight percent for use during times of high power-market prices.

Automated digital solutions help plants to optimize operation based on the fuel gas characteristics. Examples include TOMONI Smart Calorimeter and A-CPFM, which facilitate autonomous optimization of plant operation to address combustion pressure and emission fluctuations due to fuel gas composition changes, and TOMONI Boiler AI Combustion Tuning, which tunes combustion parameters when needed by simply executing optimization digitally through AI. The TOMONI Boiler AI Combustion Tuning saved a plant in Asia up to $1 million USD annually through a reduction of boiler operation costs.

LEVERAGING DATA AND EXPERT KNOWLEDGE

Power plants require actions based on expert knowledge. Digital solutions that leverage plant data, like TOMONI, are providing the bridge from a retiring experienced workforce to future plant operators. Loss of industry knowledge is a big challenge for power plants, and retention of this knowledge is a top priority for the industry, especially for aging plants looking to stay competitive. AI can help by using prediction models, based on industry knowledge and machine learning. Simulators can be used to transfer information from industry veterans and for training on best practices for the day-to-day management of a plant.

Digital solutions are already in place using machine learning and AI to determine changes in operating parameters and boiler operation conditions, including flue-gas emission, combustion balance, steam temperature and boiler efficiency. During the learning and modeling phase of these solutions, Mitsubishi Power built high-accuracy prediction models for each of the process values considered in combustion tuning, such as NO_x and unburned carbon. The AI solutions are built using those prediction models. For example, TOMONI Boiler AI Combustion Tuning estimates boiler characteristics according to operating conditions and finds optimal adjustment parameters. It has demonstrated the ability to duplicate the effectiveness of an experienced boiler-tuning engineer.

AI-DRIVEN ANOMALY DETECTION MAKES BEIJING PLANT MORE RELIABLE.

An early adopter of technology, Shenhua Guohua (Beijing) Gas-Fired Cogeneration Co., Ltd. implemented Pre-ACT, a digital solution that provides plant operators with real-time actionable knowledge on operational issues that may be in the early stages of development. Using advanced analytics to monitor data from the plant and adding Mitsubishi Power fleet-wide knowledge and AI, Pre-ACT detects if an anomaly is imminent and identifies the possible root cause to avoid an alarm occurrence and unplanned downtime. In the first two years of operation, Pre-ACT detected more than 15 anomalies at Shenhua Guohua (Beijing) before an alarm occurrence.

Netmation Protect Pack

- Security Patch Management
- Incident • Log Management
- Intrusion Detection
- System Backup/Restore
- Malware Protection
- Account Management

Mitsubishi Power worked with a plant located in a remote area in Asia that was challenged in training their operators, especially entry-level. Through the cloud, the entry-level operators were trained on normal operation through simulated experiences. Also, all operators were able to simulate potential problems and learn best practices, as they did not experience many actual problems that required operator intervention since they have newer, more reliable equipment deployed at the plant.

The plant estimated a potential savings of over $130,000 USD per day of unplanned downtime if future operator errors related to infrequent or once-in-a-lifetime events could be avoided.

CYBERSECURITY

As plants become more digital, they must remain secure. Mitsubishi Power continues to stay at the forefront of cybersecurity through the latest Windows upgrades, virtualized Netmation® controls and its digital solution, Netmation Protect Pack, which enhances the security of a plant's control systems in accordance with the latest North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP), National Institute of Standards and Technology (NIST) Cybersecurity Framework, ISA/IEC 62443 Cybersecurity Certification and other national and international compliance standards.

Control system software upgrades and application of the latest security patches are just as important for aging power plants as they are for new plants. They provide the needed protection against threats that could affect plant reliability and can add significant operator productivity enhancements.

SUMMARY

Intelligent application of digitalization can make a significant impact on the profitability of aging plants trying to compete in the changing power landscape. It can improve dispatch probability, increase income opportunities, facilitate equipment life consumption management, reduce O&M expenditures and overcome knowledge retention concerns. Mitsubishi Power continues to develop digital solutions, the building blocks of the smart power plant of the future, with ongoing validation at the new T-Point 2 Demonstration Facility at the Takasago Machinery Works in Japan. In addition to its ongoing role of validating new rotating equipment and digital solutions, T-Point 2 is poised to become the world's first autonomous combined cycle power plant. This will catapult power generation into a future where digital technologies are fully integrated into plant operations, allowing plant owners to leverage data to optimize performance, enable predictive maintenance, selectively automate O&M decision-making and reduce risk. The results of this ongoing R&D effort will be available for application to increase the profitability of future new plants and existing, aging thermal power plants.

Mitsubishi Power is continuing to advance the benefits available from digitalization of thermal power plants at T-Point 2, the full-scale GTCC validation power plant in Takasago, Japan. This plant entered service in early 2020, next to the original T-Point 1 plant that contributed so much to the reliability of the Mitsubishi Power advanced-class gas turbines over the years.

TOMONI™

Mitsubishi Power is leading the development of the smart power plant of the future with TOMONI™, a suite of intelligent solutions enabled by decades of O&M and plant knowledge. Our solutions use advanced analytics and are driven by customer collaboration to deliver powerful financial and environmental advantages.

For more information about TOMONI™ intelligent solutions, visit **changeinpower.com/tomoni**

Data Foundation & Enablers
O&M Optimization
Performance Improvement
Flexible Operation