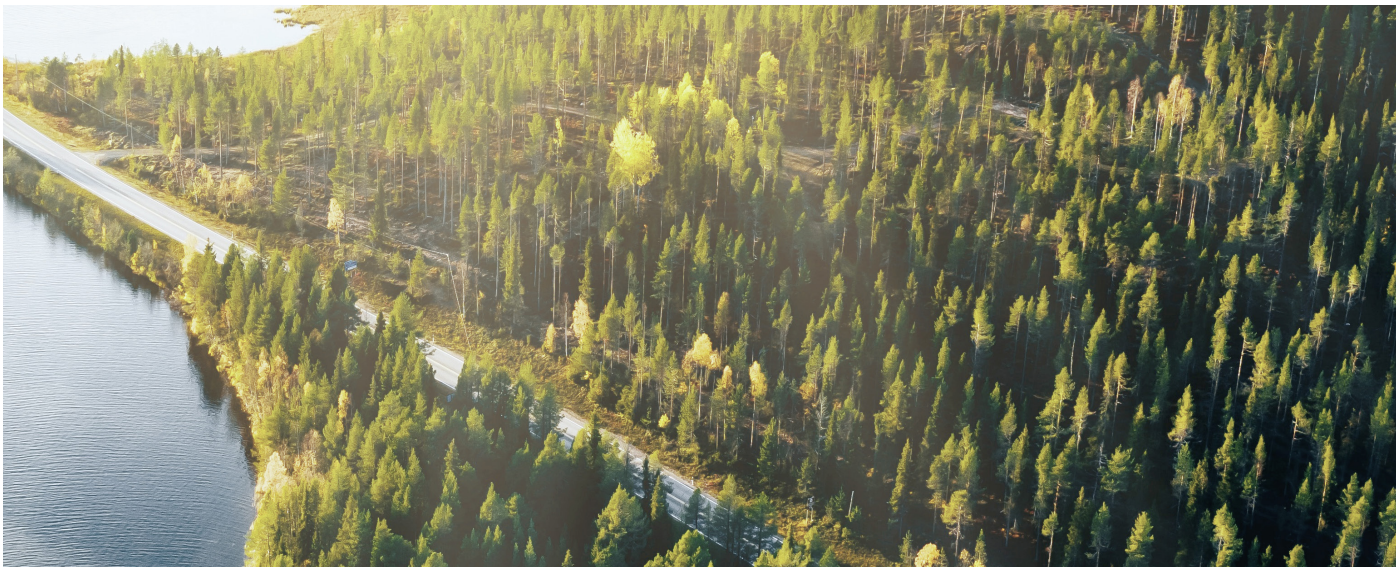
MITSUBISHI POWER

THE VALUE OF RELIABILITY

HOW POWER GENERATORS CAN PROTECT THEIR BOTTOM LINE WITH MITSUBISHI POWER'S WORLD-CLASS GAS TURBINES



EXECUTIVE SUMMARY

The path toward 100% decarbonized power systems is long and requires the right decisions now. As renewable energy continues to grow and large baseload coal-fired power plants come offline, there is an increasing role for flexible gas-fired power plants to fill the gaps of intermittent renewable generation and maintain grid stability. Gas turbines can help meet this need.

The reliability of large gas turbines is paramount for the future of energy. In recent years, rolling blackouts across the western and southern United States have sounded an alarm for power systems throughout the country. If a power plant goes down, even for a short duration—millions of dollars in revenue can be lost.

For today's power producers, disruption is not an option. They need reliable gas turbine systems built on years of innovation and backed by proven technology. With industry-leading reliability recorded at higher than 99.5% —about 2% higher than other advanced class gas turbines —Mitsubishi Power's J-Series gas turbines can add over 1.6 million MW hours of electric power generation and tens of millions of dollars to a power generator's bottom line over the 30-year lifecycle.

In this white paper, we examine the economic value of reliability and how power generators can increase profitability and minimize risk with Mitsubishi Power's advanced class gas turbines.

INTRODUCTION

To achieve decarbonization and energy transition goals, utilities and energy stakeholders need to address the industry's biggest challenge: the integration of renewable energy with grid networks.

The rise of solar and wind power and the retirement of large baseload coal-fired power stations has led to an accompanying decrease in the security of supply on the grid. Today, there is an opportunity for reliable gas-fired power plants to fill the gaps in intermittent renewable generation and maintain grid stability.

The advanced class gas turbines will face tremendous stress from the increased cycling caused by the under-and over-scheduling of renewable resources. As the industry moves towards hydrogen as a new energy source, the gas-fired power plants will provide stable decarbonized power for the grid.

Hence, the reliability of large gas turbines is paramount for the future of energy. As the energy mix changes, gas turbines will be essential to ensuring continuous power to consumers as well as maintaining power plant profitability. Therefore, reliability holds the key to a stable grid—and to a power plant's bottom line. Because when a power plant is up and running, it's generating cash. When it isn't, millions of dollars in revenue can be lost.

THE COMPLEX CHALLENGES OF TODAY'S GRID

In recent years, rolling blackouts across the western and southern United States have sounded an alarm for power systems throughout the country. Rolling blackouts—generally the result of either insufficient generation capacity or inadequate transmission infrastructure—are becoming increasingly common.

According to Direct Energy, an energy provider in the U.S. and Canada, rolling blackouts are "systemic, temporary power outages that help bring balance to the supply demand of electricity in the market." Generally, rolling blackouts occur as the "last step in a series of emergency procedures" when a power supply shortage is detected in a market. Often, they help prevent widespread blackouts across a region.

In 2020, a blistering, record-setting heat wave blanketed the western U.S., putting enough stress on the electric grid for California to implement rolling blackouts for the first time in two decades. Then in the summer of 2021, soaring temperatures once again strained the state's electrical system. Millions of people were left without power, and dozens of deaths were attributed to the heat wave and the rolling blackouts.[ii,iii]

In February 2021, the state of Texas also suffered a major power crisis. When three storms swept across the region, a massive electricity generation failure led to water, food, and heat shortages. For days, more than 4.5 million homes and businesses were left without power, and hundreds of people died.

The economic impact was unprecedented. Experts estimate the state suffered between $80 billion to $130 billion in direct and indirect losses, and the repercussions were felt throughout the U.S. [iv]

These recent blackouts lay bare just how dangerous an unstable electricity grid can be; and they expose the tremendous cost to plant operators. Years ago, when plants were smaller—relying, for instance, on 50 to 150 MW gas turbines—the grid could absorb a failure, with customers who were buying strictly for reliability installing multiple gas turbine units. Today's highly efficient advanced class gas turbines of more than 400 MW are able to generate huge operational cost savings for the customer. However, if the plant goes down, even for a short duration – millions of dollars in revenue can be lost. Hence, the need for a highly reliable power plant.

J-CLASS TECHNOLOGY

100+	1.6M	>64%
technical selections	operating hours	efficiency

As of Jan 2022

GUARANTEEING RELIABILITY WITH PROVEN EVOLUTIONARY DESIGN

For today's power producers, disruption is not an option. They need reliable gas turbine systems built on years of innovation and backed by proven technology. This is where gas turbines from Mitsubishi Power are leading a change in power.

With industry-leading reliability recorded at higher than 99.5%—about 2% better than other advanced class gas turbines—Mitsubishi Power's J-Series has surpassed 1.6 million operating hours in the field. Of the 47 units powering communities and businesses around the globe, 45 have surpassed 8,000 operating hours—the equivalent of one full year running baseload or two years at cyclic operation.

Mitsubishi Power supplies small, medium, and largeframe gas turbines to 50 and 60 Hz markets. The experience is evident in the 400+ large units of F, G, and the latest J class technology installed across the globe and having achieved over 25 million total operating hours.

Mitsubishi Power uses an evolutionary design approach in the development of its successful platforms, starting with the 60 Hz F-Series gas turbine in the late 1980s and introducing the 50 Hz F-Series in 1992. As it continued to produce higher outputs, achieve lower heat rates, and deliver greater reliability, Mitsubishi Power launched the G-Series and J-Series gas turbine models. In 2015, Mitsubishi Power introduced the JAC series of air-cooled gas turbines, which have a world-class combined cycle efficiency greater than 64%.

Now, Mitsubishi Power ships all of its heavy-duty gas turbines with hydrogen capability for deeper decarbonization. As delivered, the gas turbines are capable of operating on a blend of up to 30% hydrogen and 70% natural gas, with a 100% hydrogen capability target by 2025.

INDEPENDENT VALIDATION OF RELIABILITY RECORD

The reliability of the industry's existing gas turbine fleet is monitored by the Strategic Power Systems' (SPS) Operational Reliability Assessment Program (ORAP), an unbiased third-party resource for energy industry owners and operators to benchmark their plant's reliability. In 2009, SPS began collecting current and historical data on Mitsubishi Power's M501G turbine. Today, it continues to work with individual plant owners and operators to create a statistically significant sample of data for the F, G, and J fleet. Information gathered directly from each site is reported to ORAP through a detailed engineering rule-based data verification process.

Independent analysis from SPS for the Oct 2016-Sept 2021 period is reported in Table 1 and shows the superior reliability of the M501J turbine compared with similarly configured advanced class and F class machines. Across all measures that are routinely used by power generators to evaluate turbine reliability, Mitsubishi turbines deliver superior results.

SPS ORAP RELIABILITY DATA

PERIOD	OCT 2016-SEPT 2021		
CATEGORY	"F" CLASS	ADVANCED TECH	M501J***
Number of Units	573	210	12
Reliability*	97.31%	97.25%	99.49%
Availability*	89.69%	89.05%	90.96%
Forced Outage Factor **	0.92%	1.10%	0.28%
Unscheduled Maintenance Outage Factor**	0.67%	0.96%	1.07%
MTBF** (hours)	2,859	3,274	8,853
MTTR** (hours)	22.17	37.76	19.05
Frame	GT24/26, 6F.01-.03, 7F.01-0.3, 9F.01-0.3 W501F, V84.3, V64.3A, V84.3A, V94.3A M501F/M701F	7F.04/.05, 9F.04/.05 7H/9H W501G M501G/M701G	M501J

* - Values based on "Simple Cycle Plant" = GT + Gen. + Controls + Direct Ancillaries + Station Equip.
** - Values based on "Gas Turbine only"
***- The M501J Unites started reporting in August 2018

February 2022

TABLE 1

SPS COMPARISON OF ADVANCED TECHNOLOGY, M501J, AND F CLASS GAS TURBINES, OCT 2016 – SEPT 2021

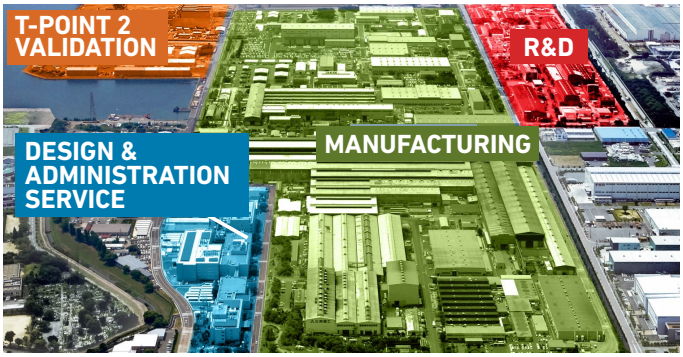
Take the Forced Outage Factor (FOF), for instance. A 1% higher FOF is the equivalent of an additional 87.6 hours per year of unexpected downtime per unit. As calculated for one utility, FOF during the turbine's second year of operation represents approximately $2.11 million in lost revenue opportunity and an additional maintenance expense of around $770,000. By year 30, that one percentage point reliability difference has the potential to cost the utility company around $13 million in net present value.

WHY MITSUBISHI POWER HOLDS THE RECORD FOR 99.5% RELIABILITY

Achieving industry records for reliability requires a fundamental approach anchored in a commitment to long-term validation testing, coupled with aggressive research and development, sophisticated design capabilities, a focus on high-quality manufacturing and advanced technical service skills training.

Mitsubishi Power has a unique design and validation approach, which is unlike any other Original Equipment Manufacturer (OEM).

The current verification process for the J Class technology takes place at its T-Point 2 commercial combined cycle power plant located near Kobe, Japan. In one single location, the company houses four key pillars: (1) research and development, (2) design, (3) manufacturing and (4) full-scale validation.



"T-Point 2 is the only power plant in the world used for full-scale long-term reliability validation. This plant allows for further investment and innovation as lessons are learned and built upon," says Ajay Gupta, Director, Product Line Management for Gas Turbines at Mitsubishi Power. "There is no doubt that gas turbine design has benefited enormously from recent computation enhancements, but the verification of the components' design resilience to complex failure mechanisms, and their durability under prolonged operation, can only be determined by long-term exposure to sustained operation under different demand conditions."

Mitsubishi Power's vision for the T-point facilities came about 30 years ago, when Mitsubishi Power recognized that actual operation of new and more advanced gas turbines can reveal issues that are very difficult to predict on the drawingboard, or in the first few hundred hours of operation. For example, low cycle fatigue, thermal fatigue, creep, and thermal barrier coating deterioration are just a few failures that can severely impact turbine operation and life, and likely come with high unexpected repair costs. These failure modes take longer to develop and detect.

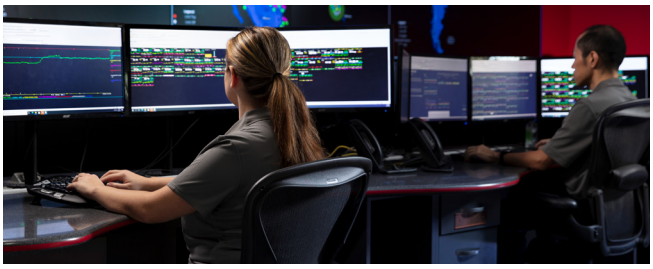
The main roadblock to extending validation at an OEM facility for longer periods of time is the cost of fuel, as it can surpass the cost of the gas turbine in just a few months. Mitsubishi Power's solution to this financial constraint was to construct combined cycle power plants with dispatching contracts to the local utility, ensuring operational expenses are covered.

Built in 1997, the original T-Point power plant developed and commercialized the G-Series and J-Series gas turbines. Now at T-Point 2, which entered commercial operation in July 2020, technology development of the M501JAC (air-cooled J-Series) continues to advance. The M501JAC is Mitsubishi Power's largest and most efficient 60 Hz gas turbine on the market.

Mitsubishi Power validates its new gas turbine technologies and digital solutions under long-term grid-connected operation for a minimum of 8,000 hours under real-world operating conditions, which is equivalent to roughly one year of normal operation and is a key insurance industry criterion for fleet reliability. This extensive process ensures that unit serial number 2 and beyond are ready for deployment.

While this validation process extends the overall product development schedule, Mitsubishi Power's philosophy is to invest in time for high reliability. This investment in time during the validation process translates to less troubleshooting issues at the customers' expense once the product is purchased, and it helps reduce unplanned downtime—saving costs, minimizing forced outages, and increasing unit availability. The bottom line: power generators can maximize their revenue opportunities with designs validated in the real-world environment.

Mitsubishi Power's customers can see the process at work, too, through onsite or live video tours. Named Plant of the Year by Power magazine in 2020, T-Point 2 has been recognized by the Financial Post, Forbes, and Power Engineering, for its innovative approach to advancing turbine technology and improving power plant performance.



UNLOCKING NEW INSIGHTS WITH ADVANCED ANALYTICS

T-Point 2, a grid-connected facility, was built featuring the JAC gas turbine and Mitsubishi Power's advanced intelligent solutions. The facility tests not just gas turbine performance, but also the reliability of the advanced controls with intelligence, auxiliaries and supporting systems.

That's because analytics are at the heart of Mitsubishi Power's TOMONI™ digital solutions, which analyze the individual plant data in real time. With TOMONI digital solutions at T-Point 2, some functions are automated, while others can be operated remotely. The number of automated functions is steadily increasing; Mitsubishi Power's goal is for T-Point 2 to become the world's smartest power plant.

TOMONI™ digital solutions include a growing suite of operations and maintenance (O&M) solutions, including key performance indicator (KPI) visibility, rapid alarm response, anomaly detection, cybersecurity, and predictive maintenance planning. As the digital power plant evolves, it will increasingly be able to take action to protect itself, optimize performance and emissions, and optimally interact with its environment, the grid, and energy markets. Reliability and availability will be further improved, and forced outages will be reduced.

A LEADER IN REAL-TIME REMOTE MONITORING AND DIAGNOSTICS

The combination of remote monitoring and big data analysis using advanced analytics enables preventive maintenance and asset optimization for turbine generator and associated electrical equipment. In addition to receiving validation metrics derived through real-world operations at T-Point 2, customers can benefit from Mitsubishi Power's continuous fleet-wide monitoring and predictive analytics by saving significant time and money through improved and efficient operations.

With more than 20 years of experience in remote monitoring and diagnostics, Mitsubishi Power has led the development of a suite of analytical capabilities that unlock even more value for customers.

THE BOTTOM LINE: THE VALUE OF 1%

A 1% increase in gas turbine reliability can substantially add to a power generator's ability to respond to market opportunities, manage outages effectively, and deliver power to customers whenever they need it.

In fact, over the 30-year lifespan of a high efficiency, heavy-duty, 600 MW combined cycle plant, a 1% increase in reliability can add up to more than 1.6 million MW hours of electric power generation. That's equivalent to nearly 1 month of electricity use for the entire city of Los Angeles.

1.6 MILLION MEGAWATT HOURS = OVER ONE MONTH OF ELECTRICITY FOR L.A.

And, in competitive power markets, a 1% increase in reliability can add tens of millions of dollars to a power generator's bottom line. With Mitsubishi Power J-Series' industry-leading 99.5%-plus reliability, other manufacturers need to guarantee 70 MW more power to match the benefits of Mitsubishi Power's reliability and resulting profits.

Additionally, independent system operators (ISOs) and regional transmission organizations (RTOs) are increasingly imposing penalties for unplanned loss of generation as well as requirements to procure replacement power, which could be far greater than lost revenue opportunities. As a result, Mitsubishi Power's higher reliability contributes directly to the bottom line.

The value of high reliability is clear. And, while all leading turbine manufacturers claim to have the highest reliability, only Mitsubishi Power offers the proof behind the promises.

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TO LEARN MORE ABOUT OUR RELIABILITY, VISIT CHANGEINPOWER.COM

Learn More About M501JAC

Learn More About T-Point2

[i] https://www.directenergy.com/learning-center/rolling-blackouts
[ii] https://sacramento.cbslocal.com/2021/09/30/ca-avoid-rolling-blackouts-new-power-plants/
[iii] https://apnews.com/article/climate-change-government-and-politics-business-environment-and-nature-6a66be20ed86ad18ed131156c9f7a517
[iiii] https://www.dallasfed.org/research/economics/2021/0415.aspx

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