# Successful 10 Units Completion of M701JAC Gas Turbine Combined Cycle in Thailand

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*In Thailand, where power generation demand is growing, Mitsubishi Heavy Industries, Ltd. (MHI) has constructed three sites of highly efficient gas turbine combined cycle (GTCC) power plants with state-of-the-art M701JAC gas turbines (manufactured by MHI) as a full turnkey project. MHI has completed all ten units (6,700 MW in total) on schedule. Starting with the operation of the first unit in March 2021, actual operating hours of these ten M701JAC gas turbines have been accumulated 140,000 hours, demonstrating high reliability. In addition, MHI has concluded a 25-year, long-term maintenance service agreement (LTSA) for these GTCC power plants, and will continue to contribute to the highly efficient and reliable energy supply in response to the electricity demand in Thailand.*

## 1. Introduction

Mitsubishi Heavy Industries, Ltd. (hereinafter referred to as MHI) has provided Thailand with many power plants over the years, and has contributed to the growth and stable supply of electric energy in support of the country's remarkable economic development. Currently, Thailand relies heavily on natural gas-fired power generation, accounting for approximately 60% of the country's total power generation. Seeking to reduce environmental impact through lower carbon dioxide emissions, the use of renewable energy is expected to increase significantly even in Thailand. At the same time, continued high demand for natural gas-fired power generation to stabilize the power grid is anticipated. Hence, demand for new, high capacity gas turbine combined cycle (hereinafter referred to as GTCC) with high efficiency and operability is strongly expected. Under these circumstances, MHI has carried out a large-scale project to construct ten new GTCC units at three sites. Despite various restrictions and difficulties due to the COVID-19 pandemic during the project, all the units could be completed on schedule according to the contract. The features of the GTCC power plants and the project details are presented in this report.

## 2. Plant plan overview

### 2.1 Plant overview and main features

(1) Specifications of main equipment

Specifications of the main equipment of the three plant construction sites in this project are shown in **Table 1**.

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**Table 1 Specifications of main equipment**

| Site name | | GSRC[1)] | GPD[2)] | HKP[3)] |
|---|---|---|---|---|
| Plant comprehensive specifications | Net generating power | 2,650 MW | 2,650 MW | 1,400 MW |
| | Configuration | Single shaft type x 4 units | Single shaft type x 4 units | Single shaft type x 2 units |
| | Cooling method | Wet cooling tower | | |
| Gas turbine | Model | M701JAC | | |
| | Fuel | Natural gas / Oil | | |
| Steam turbine | Model | TC1F-48 axial-flow exhaust | | TC2F-40.5 side exhaust |
| | Steam condition | High pressure: 16.1 MPaG x 600°C<br>Intermediate pressure: 3.1 MPaG x 600°C<br>Low pressure: 0.51 MPaG x 306°C | | High pressure: 16.2 MPaG x 600°C<br>Intermediate pressure: 3.4 MPaG x 600°C<br>Low pressure: 0.44 MPaG x 303°C |
| Heat recovery steam generator | Type | Horizontal triple-pressure reheat natural circulation type | | |
| | Max. continuous rating | High pressure: 423 t/h<br>Intermediate pressure: 51 t/h<br>Low pressure: 44 t/h | | High pressure: 490 t/h<br>Intermediate pressure: 47 t/h<br>Low pressure: 52 t/h |
| Generator | Cooling method | Hydrogen indirect cooling | | Water cooling |

1) GULF SRIRACHA POWER PLANT
2) GULF PLUAKDAENG POWER PLANT
3) HIN KONG POWER PLANT

(2) Configuration of main components

The power plants are single shaft combined cycle systems comprised of a gas turbine, generator, and steam turbine, which are connected to the same shaft. The gas turbine is MHI's latest model, M701JAC, with the largest capacity and high efficiency. In addition to the gas turbine, other equipment also employs the latest technologies to achieve high power generation efficiency. Each power plant is located inland and uses a wet cooling tower as the cooling method. A view of the external appearance of the power plants is shown in **Figure 1**.

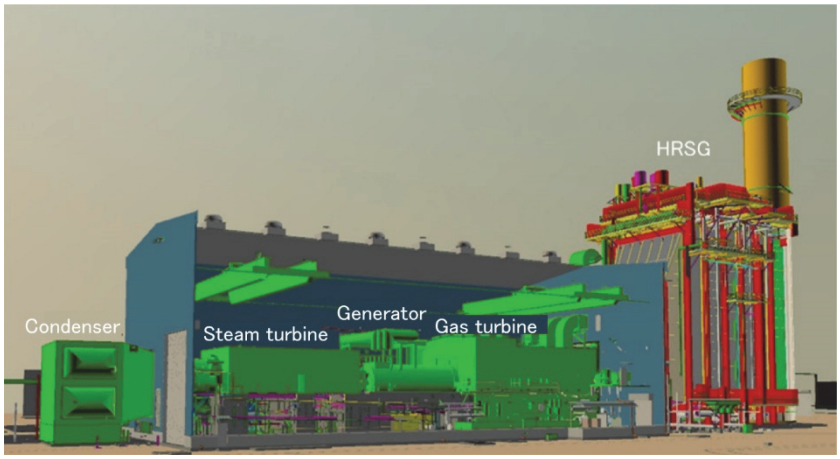


**Figure 1 External appearance of the power generation facility (3D CAD model, some internal features are shown)**

## 2.2 Environmental performance

(1) Emission performance

Emission regulation level for the three sites constructed in this project are shown in **Table 2**.

The state-of-the-art M701JAC gas turbine uses an enhanced cooling air system. While increasing turbine inlet temperature to improve efficiency, generation of nitrogen oxide is controlled. In addition, the improved thermal efficiency leads to a reduction in fuel consumption, resulting in a significant decrease in carbon dioxide emissions. During oil firing operation, a water injection system is used to suppress the formation of localized high-temperature areas, thereby reducing nitrogen oxides.

**Table 2 Emission regulation level for each site**

| | | | Natural gas-fired | | | Oil-fired | | |
|---|---|---|---|---|---|---|---|---|
| | | | GSRC | GPD | HKP | GSRC | GPD | HKP |
| Denitration equipment | | | Used | Not used | Used | Same as left | | |
| Nitrogen oxides | (NOx) | ppmv | 8.9 | 21.1 | 21.0 | 10.5 | 35.4 | 35.4 |
| Sulfur oxides | (SOx) | ppmv | 2.0 | 2.0 | 2.0 | 7.1 | 7.1 | 7.1 |
| Carbon monoxide | (CO) | ppmv | 246 | 246 | 246 | 246 | 246 | 246 |
| Soot | (TSP) | mg/Nm$^3$ | 7.1 | 7.1 | 3.6 | 12.5 | 12.5 | 6.1 |

* The above values are based on 16% $O_2$ concentration

(2) Noise performance

In accordance with noise regulations and contractual requirements from Thailand, measures to reduce noise levels at the site perimeter to 70 dBA and less, and an annoyance noise level in neighboring residential areas to 10 dBA and less were carried out. Annoyance noise level indicates the amount of increase in background noise, and is calculated by the following equation.

$$Annoyance\ Noise\ Level = 10\ log_{10}\left(10^{LA_{eq}/10} - 10^{LA_{90}/10}\right) - LA_{90} + A$$

$LA_{eq}$ : Equivalent noise level

$LA_{90}$ : Time rate noise level

A : Nighttime correction value (3 for nighttime 22:00-6:00, 0 for daytime)

Installing excessive noise barriers wall to meet noise regulations could affect the project schedule and spoil the site landscape. Therefore, taking the appropriate, balanced measures is needed. Preliminary simulations were conducted using environmental noise simulation software (SoundPLAN) to determine facility specifications that meet these requirements.

Simulation results are shown in **Figure 2**. In addition to individual noise reduction measures for each piece of equipment, a noise barrier wall was installed on the north side where predicted points outside the site were relatively close to effectively control noise. Based on the results of preliminary examinations, noise reduction measures were then taken. All values were confirmed to comply with the noise regulations by a noise test after construction of the power plant.

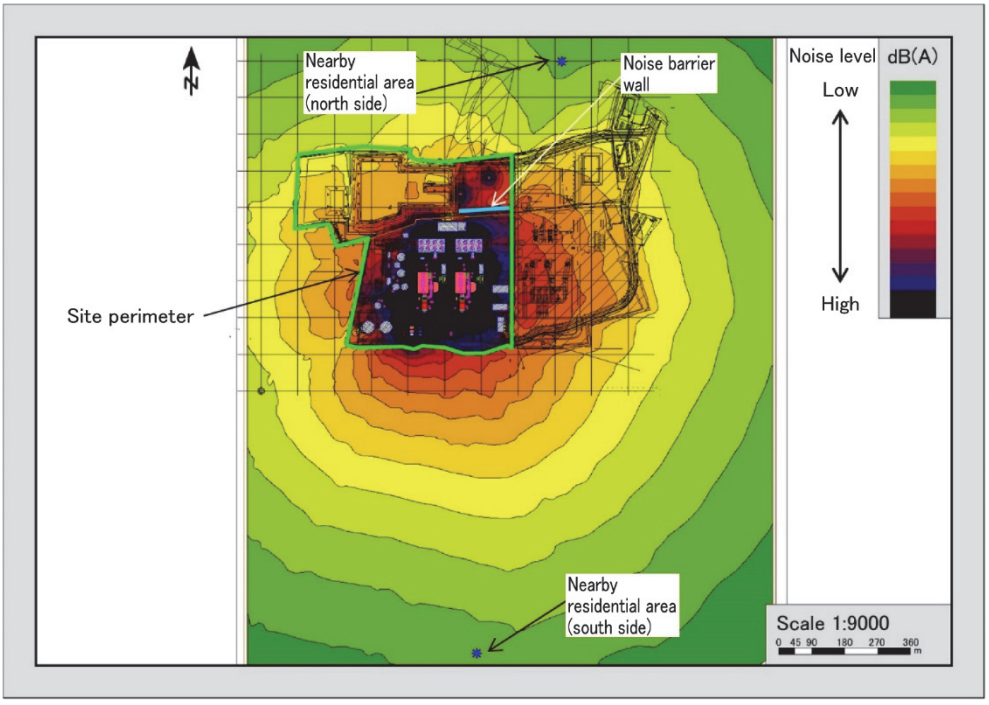


**Figure 2 Noise simulation results (HKP)**

# 3. Features of main equipment

## 3.1 Gas turbine

Advanced technologies have been applied to MHI's proven J-series gas turbine to develop M701JAC, MHI's cutting-edge gas turbine. Turbine inlet gas temperature has been increased to the 1650°C class for improved plant efficiency. Specifically, the following technologies were used (**Figure 3**).

(i) Enhanced air cooled combustor was installed for lower NOx emissions
(ii) Thicker advanced TBC was applied for improved reliability
(iii) A high-load, high-efficiency compressor was installed to control exhaust gas temperature increase
(iv) Turbine clearance control was applied to ensure high efficiency and operability

In addition, the combustor was demonstrated to be capable of oil-fired operations without compromising performance in gas-fired operations

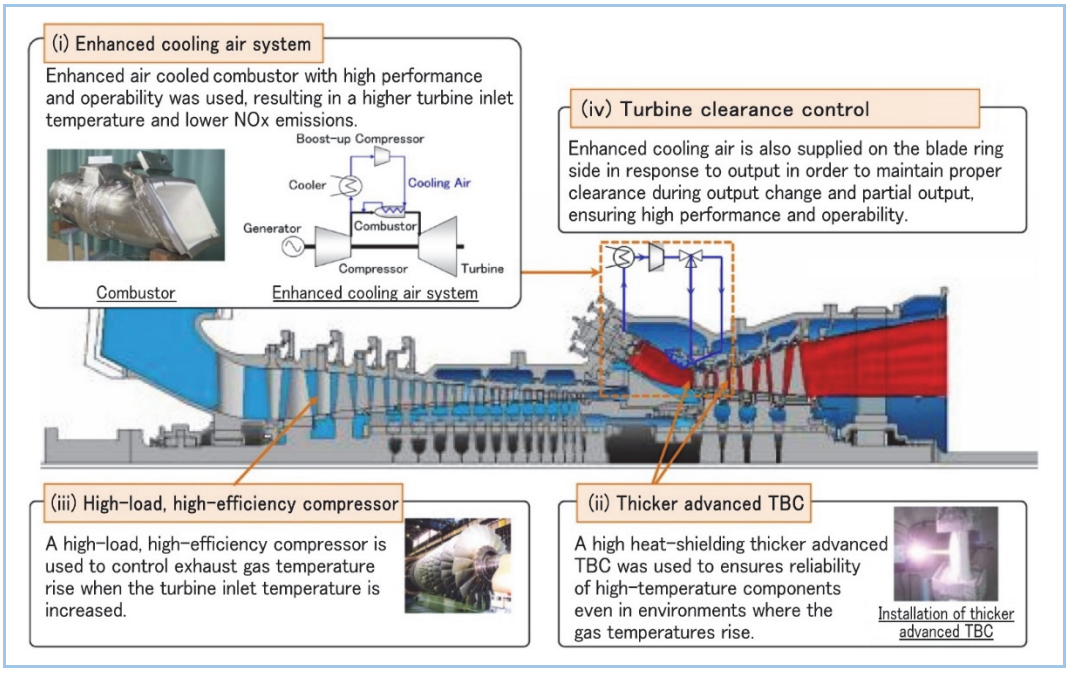


**Figure 3 Technologies used for M701JAC gas turbine**

## 3.2 Steam turbine

A two-casing steam turbine, which is suitable for the steam flow rate generated by the heat recovery steam generator, was employed. The turbine was developed using MHI's latest technologies, such as high-efficiency reaction blades and seal structures designed by the latest three-dimensional flow analysis, for improved turbine efficiency.

GSRC/GPD: Next-generation high-pressure and intermediate- and low-pressure axial-flow exhaust turbines were used to improve efficiency. Compared to conventional downward exhaust systems, the axial-flow exhaust allows for a reduction in building height. In addition, the pier foundation structure, where foundation pillars are erected only where needed for the main components loading area, was adopted instead of the conventional lattice structure where foundation pillars are connected by foundation beams. This led to a reduction in costs (**Figure 4**).

HKP: Based on high- and intermediate-pressure and low-pressure side-exhaust turbines have been incorporated with the most advanced technologies which have been verified at the MHI plant demonstration test facility, achieving improved efficiency and reliability. Main advanced technologies that have been incorporated are as follows.

(1) Vertical position control of casing using electric heater (**Figure 5**-(1))

The high- and intermediate-pressure turbine casing can be raised by heating the casing support from the attached electric heaters. This ensures a clearance margin inside of turbine casing when the upper clearance between the casing and the rotor decreases during transient

periods such as startup. As a result, design clearance could be narrowed, thereby improving the efficiency.

(2) Reduced leakage from blade row seal (Figure 5-(2))

Inclined seal fins improve flow contraction effect and reduce leakage from the blade row seal area.

(3) Advanced low-pressure turbine

By adopting the latest 40.5-inch last blades, the improved shapes of the shroud and the blades, the improvement of efficiency and reliability could be achieved (Figure 5-(3)). In addition, reliability could also be improved by modifying the support structure and rib structure of the inner and outer casings.

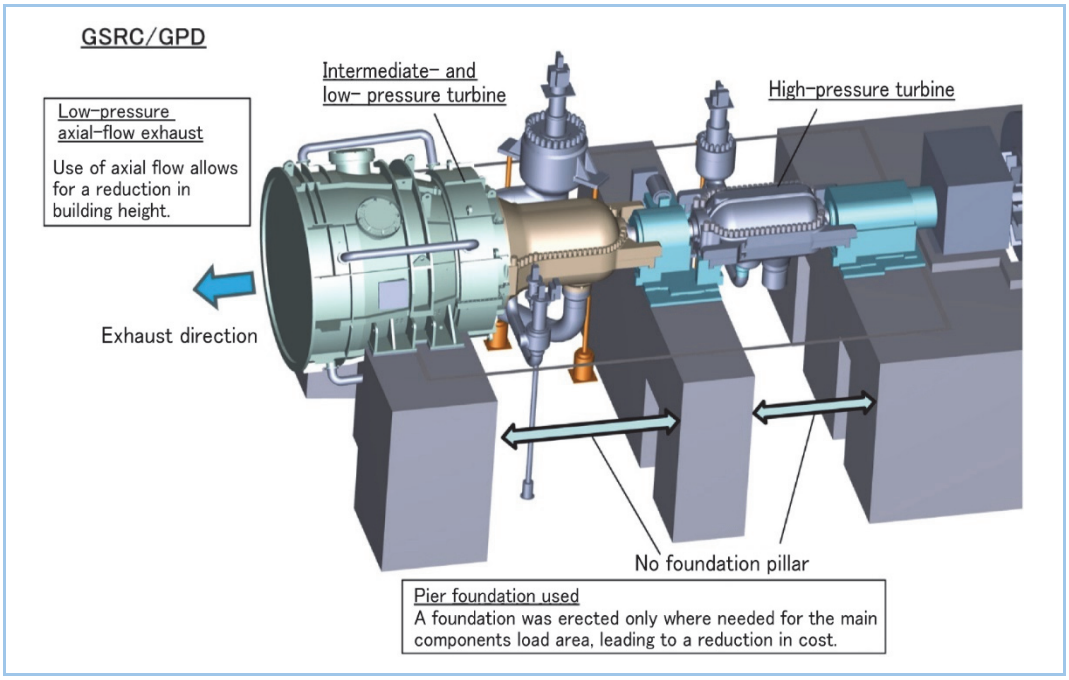


**Figure 4 Features of steam turbine for GSRC/GPD**

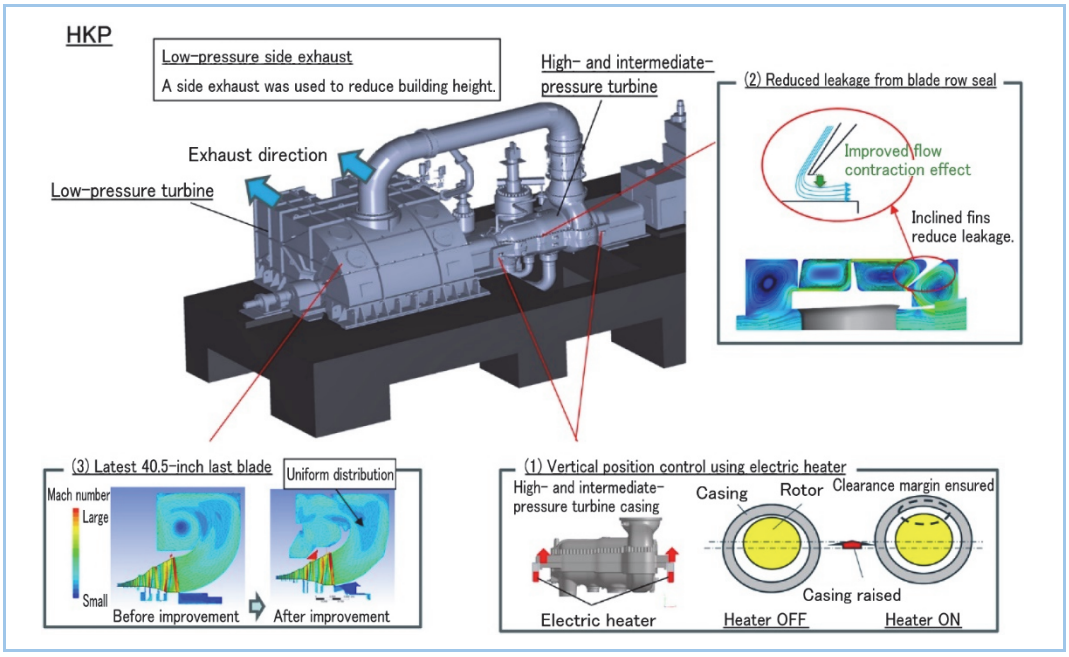


**Figure 5 Features of steam turbine for HKP**

# 4. Project implementation

## 4.1 Project schedule

The schedule of major processes of the project are shown in **Table 3**. During the project period, the COVID-19 pandemic caused delays in equipment shipments and entry restrictions into Thailand for the on-site technical advisors. However, MHI identified priority construction activities, and could avoid project schedule delays by implementing various measures such as adjusting site work schedule and proactively coordinating with the customer. While all other projects and construction works were delayed, this is the only project in Thailand which could complete all units on schedule and start commercial operation.

- Secure supply chain (emergency procurement of auxiliary boilers, chemical injection equipment, air compressors, etc. from local sources)
- Commissioning of auxiliary equipment using alternative means (temporary power supply, etc.)
- Maximized use of remote supervise via the Internet.

**Table 3 Project schedule of main processes**

| GSRC | | GPD | | HKP | |
|---|---|---|---|---|---|
| Feb. 2018 | Award of contract | Feb. 2018 | Award of contract | Sep. 2020 | Award of contract |
| Dec. 2018 | Start of construction | Mar. 2020 | Start of construction | Mar. 2022 | Start of construction |
| Mar. 2021 | Block-1 commercial operation start | Mar. 2023 | Block-1 commercial operation start | Mar. 2024 | Block-1 commercial operation start |
| Oct. 2021 | Block-2 commercial operation start | Oct. 2023 | Block-2 commercial operation start | Jan. 2025 | Block-2 commercial operation start |
| Mar. 2022 | Block-3 commercial operation start | Mar. 2024 | Block-3 commercial operation start | - | - |
| Oct. 2022 | Block-4 commercial operation start | Oct. 2024 | Block-4 commercial operation start | - | - |

## 4.2 Project Management

This project was undertook by MHI as a full-turnkey project. MHI was executed the entire scope of the power plant, including equipment supply, transportation, civil and construction, and commissioning. For on-site construction works, MHI formed a consortium partnership with Sino-Thai Engineering and Construction Public Company Limited, a major general contractor in Thailand. Continuous Q (quality), C (cost and risk), and D (delivery date) were carefully managed throughout the project period, and all units could be completed with high-quality on time. In addition, on-site construction management was carried out with safety as priority, and a total of 55 million safety man-hours could be achieved at the three sites.

# 5. Conclusion

MHI completed construction of highly efficient GTCC power plants which use state-of-the-art gas turbines (M701JAC type) with a total output of 6,700 MW and completed all ten units on schedule. This was a large-scale project requiring approximately seven years from the contract award until start operation of the final unit. All parties involved, including the customer, partners, and MHI unitedly worked together as ONE TEAM based on trust and good communication to complete the project despite facing various difficulties, such as the COVID-19 pandemic. The GTCC power plants have continued to safely operate since the start of operations and have demonstrated high reliability. MHI is confident that they will continue to respond to Thailand's energy demand and contribute to further economic development of the country.

In light of these achievements, not only was GSRC awarded the "Power Plant of the Year 2023" at ENLIT Asia, the largest power and energy exhibition in ASEAN, it has also received high praise from parties outside of MHI.