Introduction of Upgrade Work of Ultra-low NOx for Natural Gas-fired GTCC Power Plant of Taiwan Power Company

HIROFUMI OHARA[*1] ATSUSHI NAKANO[*1]
TAKASHI NISHIUMI[*2] NAOKI NAKATA[*1]
KAZUAKI KOJIMA[*3] MOTOYOSHI SHIMIZU[*3]

Gas turbine combined cycle-thermal power generation systems (hereinafter referred to as GTCC) are the most efficient and clean power generation systems using fossil fuels. New technology development is always moving forward to achieve higher efficiency and lower environmental impact. On the other hand, the operation of the latest high-efficiency GTCC power plants reduces opportunities for the operation of existing power plants, leading to deterioration in the profitability of existing power plant operating companies and a reduction in plant service life for existing power plants. To cope with this situation, Mitsubishi Hitachi Power Systems, Ltd. (MHPS) is retrofitting the technology developed for new types of GTCC power plants to existing power plants and is developing an upgrade menu to meet various requirements from existing power plant operating companies. In order to apply the latest gas turbine technology to existing power plants, it is necessary to upgrade and modify peripheral equipment associated with the power plants. MHPS is also involved in the design and construction of new plants as an EPC business and the development of control equipment. Taking advantage of its comprehensive capabilities, MHPS can propose an appropriate modification scope for the entire power plant and provide a comprehensive range of services, including construction and commissioning.

1. Introduction

Datan power plant Stage-I (6 units of M501F, 1,400MW) and Nanpu power plant (M501F, 250MW), both delivered by MHPS to Taiwan Power Company, have greatly contributed to power supply and demand in Taiwan since their commercial operation began in 2005 and 2003, respectively. In recent years, Taiwan has seen increased demand for electricity due to the shutdown of nuclear power plants, which is being compensated by improvements in availability of thermal power generation facilities. Reducing the environmental load of existing thermal power plants and increasing output are urgent needs. In order to respond to these needs arising from the power policy changes in Taiwan, it was decided to conduct power plant upgrade projects for these power plants, consisting of Ultra-low NOx conversion in addition to performance improvements through enhanced high-performance cooling turbine blades, which had already been prepared as an upgrade menu.

As for Ultra-low NOx, which is the main feature of this project, MHPS addressed the issue by retrofitting combustion technology proven in the latest M501/701J gas turbine to the M501F gas turbine. Power plant equipment necessary for the application of this latest combustion technology was also upgraded. In addition, taking advantage of MHPS's strength in handling both new power plant construction work as an EPC business and service work for the periodic inspection of existing power plants, MHPS carried out the first full turn-key construction work in Taiwan for service projects. In the area of control, MHPS applied not only the latest combustor control technology, but also MHPS-TOMONI®, a digital solution service of MHPS, to ensure long-term operational reliability after commercial operation started, and also to provide timely customer support. In order to extend power plant service life, MHPS also updated the control system including security improvements in the control device.

*1 Takasago Power Systems Service Department, Power Systems Service Headquarters, Mitsubishi Hitachi Power Systems,Ltd.
*2 Large Frame Gas Turbine Engineering Department, Gas Turbine Technology & Products Integration Division, Mitsubishi Hitachi Power Systems,Ltd.
*3 Chief Staff Manager, Control Systems Department, Project Management Division, Mitsubishi Hitachi Power Systems,Ltd.

In this paper, MHPS activities to improve plant availability for existing GTCC power plants are introduced, taking the example of the Ultra-low NOx conversion work that was carried out for Taiwan Power Company.

2. Ultra-low NOx Combustor

2.1 Ultra-low NOx Combustor

In addition to performance improvement through the use of high-performance turbine blades with enhanced cooling capability, which had already been prepared as an upgrade menu, one of the main purposes of this upgrade project is reducing NOx emissions. The NOx level of the combustor that has been in use since the start of commercial operation is 25 ppm, but the target after this upgrade is 9 ppm.

In order to achieve this, the 1,400°C class F-series combustor was developed by using technology proven in the 1,500°C class G series and 1,600°C class J series gas turbines. In the G and J series gas turbine, the plant thermal efficiency is improved by raising turbine inlet air temperature. Since a rise in turbine inlet air temperature leads to an increase in NOx, the latest combustion technology is employed to reduce NOx even at high turbine inlet air temperatures. The application of this latest technology to existing combustors enables the achievement of 9 ppm (**Figure 1**) .

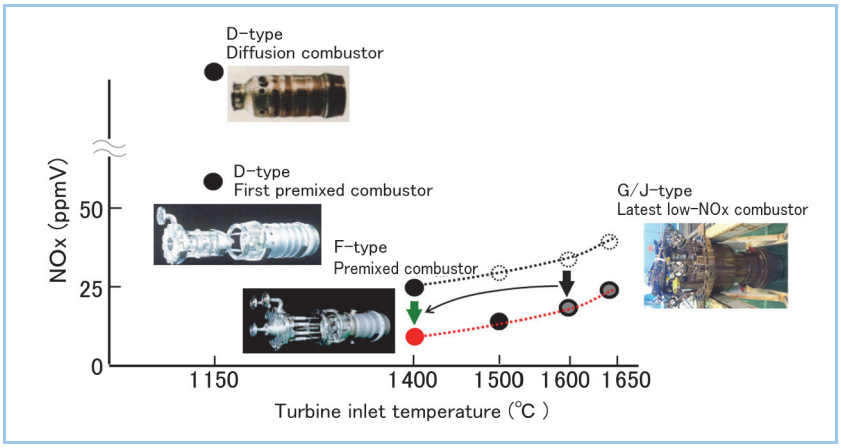

Figure 1 Transition of relationship between increase of T1T and development of combustor

One of the G and J series combustion technologies is “V nozzle”. This technology helps homogenize fuel and air mixture more, which lowers the peak flame temperature and reduces NOx while maintaining current the turbine inlet air temperature. Applying the advanced TBC developed for the J series gas turbine to the combustor basket and transition piece can also reduce the amount of cooling air while maintaining the reliability of combustor components and lowering flame temperature can reduce NOx (**Figure 2**) .

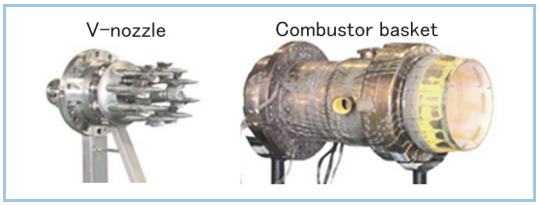

Figure 2 V-nozzle and gas turbine combustor basket

2.2 Modification of peripheral equipment

Ultra-low NOx with the latest combustor can be achieved by fuel staging, in which fuel gas is injected from multiple lines. Along with this, the fuel gas unit was newly manufactured and replaced the existing fuel gas unit. The power plant equipment was also upgraded with the application of the latest combustor, including an additional calorimeter to deal with fuel gas composition changes and a cartridge filter to remove foreign materials contained in fuel gas.

From a combustion control point of view, in order to minimize load changes when combustion pressure fluctuation occurs, the A-CPFM (Advanced Combustion Pressure Fluctuation

Monitoring Control) system, which monitors combustion pressure fluctuation and automatically adjusts parameters, was upgraded, and software modifications, such as the introduction of a control system that controls combustion parameters with higher accuracy, were applied.

2.3 Results of commissioning after application

Figure 3 illustrates the NOx emission value trend compared with gas turbine load in the first unit with the Ultra-low NOx combustor upgrade applied at the Datan power plant. As a result of applying the upgrade, it is found that the unit is being operated with a margin of 1 ppm or more against the initial development target of 9 ppm @ 15% O_2.

The plant has been in stable operation since the first unit commercial operation started in January 2019, and it has been proven that there are no issues from a long-term operational reliability point of view.

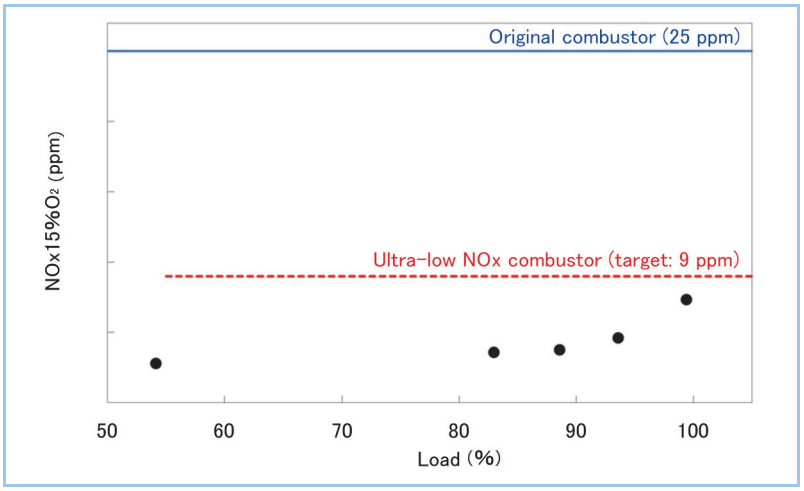

Figure 3 Trial operation result of Datan Power Plant

3. Construction

3.1 Outline of construction

As described in the previous section, this upgrade project was large-scale modification work that exceeds the normal work scope for regular periodic inspections, including modification work of plant-related equipment and gas turbine periphery components. Replacing the existing fuel gas unit with a new one and modifying gas systems including the installation of cartridge filters were the main items in plant portion. In the main unit portion, the replacement of the casing and the modification of peripheral piping for bleed air and cooling air were the main items of modification.

3.2 Details about major modification work

3.2.1 Replacement of fuel gas unit

According to the change of the fuel gas system through improvements in fuel staging, the existing fuel gas unit was replaced with a new one. Although we have no experience in the removal of existing fuel gas units, with careful preparation, interference removal, and the cutting of each pipe and conduit, the removal of the fuel gas unit was conducted without any problem.

In the installation of the new fuel gas unit, there was some concern about the connecting work between the piping in the new fuel gas unit and the existing piping since the new fuel gas unit was applied to a plant after long-term operation. However, by using the foundation of the existing unit as-is, they were connected without any problem (Figure 4).

Figure 4 Installation of new fuel gas unit

3.2.2 Combustor-compressor casing replacement work

In accordance with the application of the latest low NOx combustor, the shape of combustor-compressor casing was re-designed, and the casing was newly manufactured. Therefore, combustion-compressor casing replacement work was carried out as on-site modification work.

This was our first time replacing a combustor-compressor casing as on-site modification work. After identifying and examining concerns in advance and creating countermeasures, actual work on site was carried out.

First, there was concern that the oval-shaped deformation of the existing casing would make it difficult to lift up the combustor-compressor casing. As a countermeasure for this, fixing jigs were prepared to correct the oval-shaped deformation of the existing casing (**Figure 5**). The deformation of the existing casing was corrected using jigs, which allows the existing combustor-compressor casing to be lifted and the new casing to be installed without any problem.

There was also concern about alignment when the existing casing and the new casing were connected. In the same manner as the proven method used for new in-house machine manufacturing, alignment was carried out using a spigot ring that determines the position between casings, and assembly work was completed without any problems.

The effect of the new casing on clearance between the rotating section and stationary section was managed by installing all casings from the inlet casing to the exhaust casing temporarily, calculating the amount of movement of each casing, and adjusting the positions of each inner casings and turbine blade rings in order to maintain appropriate clearance between the rotating section and stationary section.

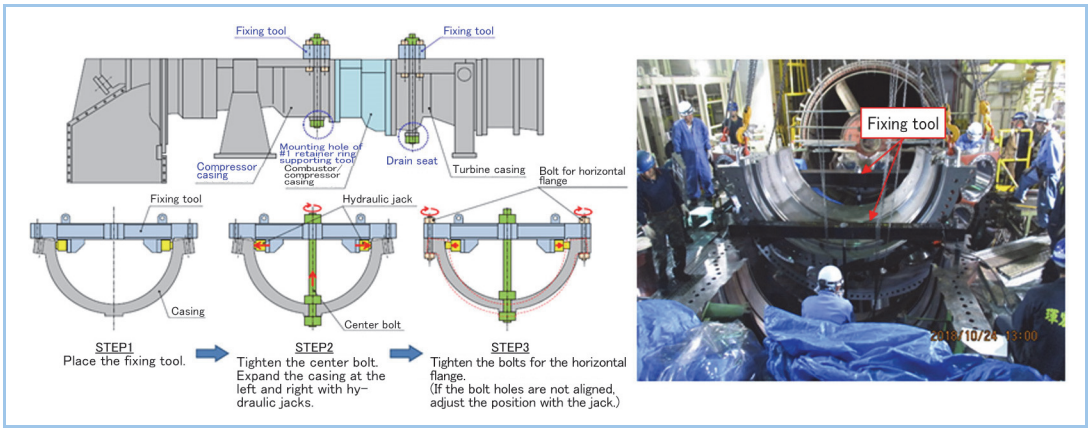

Figure 5 Fixing tool for correcting egg-shaped deformation of existing casing

3.3 Results

This was the first large-scale full turn-key modification work as a service project in which MHPS performed all the design, procurement, transportation and construction. The work schedule from the planning stage was strictly controlled and concerns about the gas turbine main unit and piping work were identified, countermeasures for these concerns were developed in advance, and on-site modification work was completed. As a result, there were no events leading to large schedule delays, and the construction work was carried out smoothly while ensuring quality, and

was completed in 65 days as scheduled.

4. Control device

4.1 Remote monitoring using MHPS-TOMONI®

The reduction of NOx emissions is the main feature of this upgrade project. MHPS adopted the Digital Solution Service MHPS-TOMONI® as one scope of this upgrade project in order to achieve a long-term NOx emission guarantee. A data transmission device with security functionality called Netmation® Secure Gateway (NSGW) was connected to the gas turbine control device (DIASYS Netmation®), and various gas turbine data are continuously transmitted to our cloud server. The operating condition of the gas turbine is monitored remotely for abnormalities using various monitoring software on the cloud. If the NOx level exceeds the specified value or when a major gas turbine alarm occurs, a notification e-mail is automatically sent from the cloud server to the relevant personnel at MHPS. At the same time, data with a higher sampling cycle rate than at normal times are collected and transmitted for smooth root cause investigation. Actions necessary to reduce NOx are immediately provided to the customer. NSGW has a one-way communication function, which prevents unauthorized access to the gas turbine control system from outside and prevents the unauthorized use of data by encrypting transmitted data and authenticating it with a cloud server using a digital certificate. System configuration related to remote monitoring is illustrated in **Figure 6**.

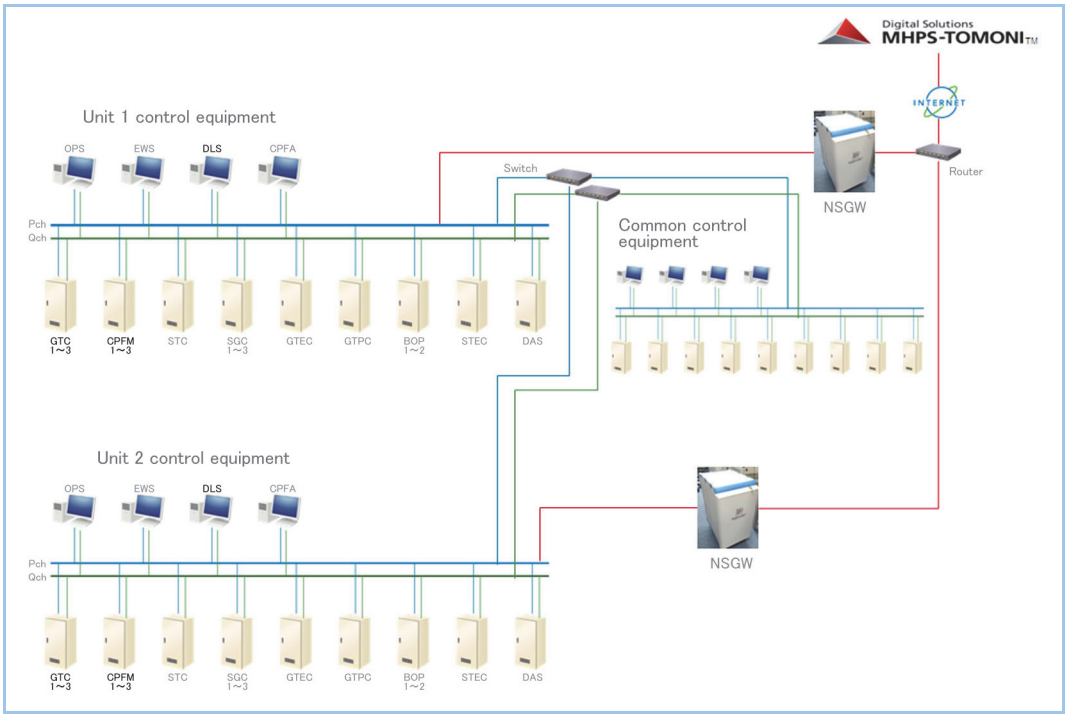

Figure 6 Remote monitoring system configuration diagram (Datan Power Plant)

4.2 Control system upgrade

n line with the adoption of MHPS-TOMONI®, MHPS upgraded the operating system (OS) of the gas turbine control system to improve maintainability and improve security functions. The existing control device was an architecture based on Microsoft® Windows 2000. However, due to end of OS support and difficulty in obtaining and maintaining computers that can use the OS, a Windows 10-based system was adopted. In addition to the OS, the computer equipment and DIASYS Netmation® control software were both upgraded to the latest version for Windows 10. With this upgrade, Applocker anti-malware software can be applied, and the security functionality of the entire gas turbine controller was improved by limiting the installation and execution of applications. Security functions applicable to the upgraded system are shown in **Table 1**. In addition, in this upgrade, the application of the control system is run in a virtual OS launched in the host OS on the host computer, and it is designed in consideration of maintenance convenience in the future.

Table 1 List of applicable security functions

#	Security Countermeasure	Windows			
1	Network segmentation with firewall, DMZ	NT/ 2000	XP	7	10
2	Physical access block	✓	✓	✓	✓
3	Separate PC (DFPC) for data collection	✓	✓	✓	✓
4	Disable media auto play	✓	✓	✓	✓
5	Block unnecessary firewall ports and service settings	✓	✓	✓	✓
6	Anti-malware white list function			✓	✓
7	Access restriction by Secure Manager			✓	✓
8	Rapid Backup/Recovery			✓	✓
9	USB-type virus checker		✓	✓	✓
10	Central Windows account management			✓	✓
11	All devices log management tool			✓	✓
12	Regular security patch application			✓ (Until 2020)	✓

5. Conclusion

The Ultra-low NOx conversion project for Taiwan Power Company introduced in this paper started commercial operation of the first unit of the Datan Power plant in January 2019. As of May 2019, the construction and commissioning of 5 units has been completed, with commercial operation starting one after another. This construction effort was a large-scale plant modification project, including peripheral equipment and control equipment, with a focus on low NOx, which contributed greatly to the improvement of the operating rate of existing plants. Such plant-wide upgrade can only be proposed by MHPS, which handles all the design, construction and service work of the main equipment, plant and control devices.

MHPS will continue to work on the project to complete the upgrade work for Nanpu Power plant, which will be the final unit of the project. MHPS will also continue the development of an upgrade menu to meet the needs of various customers.

References

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