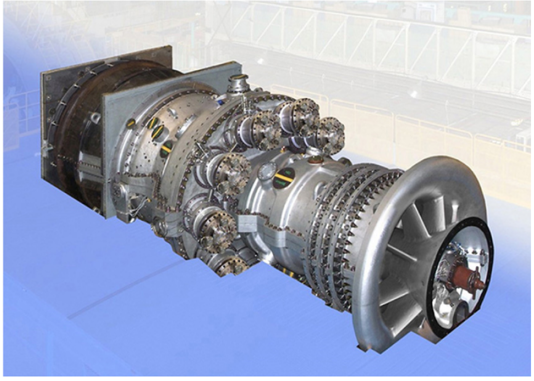
World's Largest Class High-efficiency Dual-shaft H-100 Gas Turbine



Hitachi Gas Turbine Engineering Department, Gas Turbine Products Headquarters

Power Systems Project Engineering Department, Power Systems Project Management Division

Mitsubishi Hitachi Power Systems, Ltd.

The H-100 gas turbine, appreciated for its high efficiency, has been used by customers aiming for improved efficiency of power generation plants as a replacement for older existing gas turbines. Due to its dual-shaft configuration, the H-100 is also suitable for purposes other than power generation including driving machinery, and application to large LNG plants is under examination. Recently, the attainment of further efficiency has allowed the H-100 to widely meet user expectations as a product for new power generation, replacing existing facilities, and driving machinery. The H-100 was called the H-80 in replacement projects of existing plants because the permitted operation output was about 80MW, and now the name has been changed to the H-100, which is derived from the gas turbine rated output of 100MW class.

1. Introduction

To replace 1100°C-class gas turbines that were built approximately 20 years ago, the H-100 gas turbine was developed in order to improve efficiency and reduce the CO_2 emissions of existing power generation plants, and the first unit started commercial operation in 2010. As of March 2015, ten H-100 gas turbines have started commercial operation and the total operating time has attained 207,000 hours. In addition, its development is continuing for the purpose of meeting customer needs for the further enhancement of efficiency and output, as well as the diversification of fuel. In addition, due to its dual-shaft configuration with separate high-pressure and low-pressure rotors, the H-100 is also suitable for use in driving machinery, and this application to large LNG plants is under examination.

2. Development of H-100 gas turbine

In the development of the H-100 gas turbine, it was necessary to consider the following conditions in order to attain performance enhancement of existing combined plants just by replacing the gas turbine.

(1) The exhaust temperature and exhaust flow rate must be equivalent to existing values because the existing heat recovery steam generator (HRSG) and steam turbine were to be reused.

(2) The size must be equal to or smaller than the installation space of the existing gas turbine in order to minimize the replacement work as much as possible.

To satisfy the conditions above, the new gas turbine was designed under the following concepts.

(1) The combustion temperature was raised from the 1,100°C class of the existing gas turbine to 1,300°C for the enhancement of performance, while the pressure ratio of the air compressor was changed from 12 to 17 in order to maintain the same exhaust temperature as the existing facility.

(2) The design of the air compressor was expanded proportionally based on the existing model. Because the exhaust flow rate was required to be equivalent to the existing value, the rotating speed was set to 4,580 rpm to achieve the same amount of air.

(3) The generator was required to be set to the system frequency of 60 Hz (3,600 rpm). The layout did not allow the use of a reduction gear, however, and therefore the dual-shaft configuration with separate high-pressure and low-pressure turbines was used. The high-pressure side is set to 4,580 rpm, the same as the air compressor, and the low-pressure side is set to 3,600 rpm, the same as the generator.

Figure 1 shows the scope of this replacement.

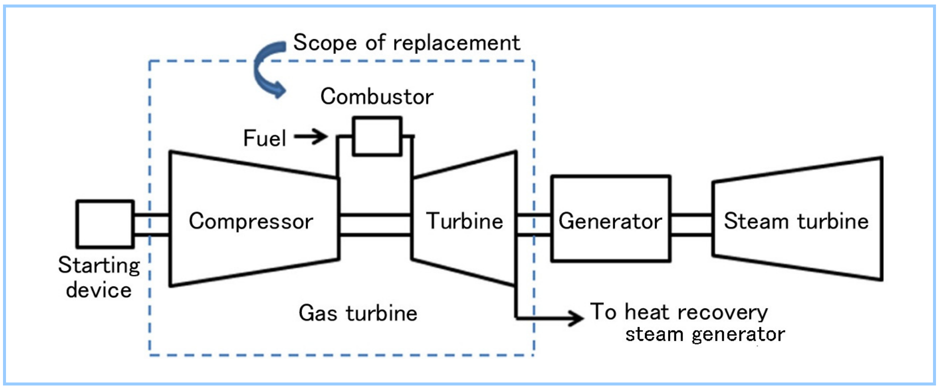


Figure 1 Scope of replacement
Improving the efficiency and performance of the combined plant by modifying the minimum scope of only the gas turbine facility and reusing other equipment.

The H-100, a heavy-duty dual-shaft gas turbine with the world's largest capacity, was designed based on the proportional expansion of the 30MW-class H-25 gas turbine, which has seen the delivery of more than 150 units worldwide.

The air compressor is a 17-stage axial flow air compressor that has pressure ratio 17 and enables variable speed operation in a low load range. The high temperature components such as the combustor and the turbine are designed based on the proportional expansion of the H-25 gas turbine using a similar structure so that reliability can be ensured. At the same time, the latest technologies are applied for the improvement of performance.

The eco-friendly combustor is a multiple can type with ten cans and uses a dry-type low NOx combustor that has been used successfully for H-25 gas turbines. The combustion temperature is 1,300°C class.

The turbine is an axial flow type with a four-stage (two for the high pressure side and two for the low pressure side) dual-shaft configuration.

The output is 101.1MW. The efficiency of the gas turbine itself attains 37.7% (LHV), which features the top-class efficiency of a heavy-duty gas turbine in the class. **Figure 2** shows a cross sectional view of the H-100 gas turbine and a photograph of the opened upper-half casing.

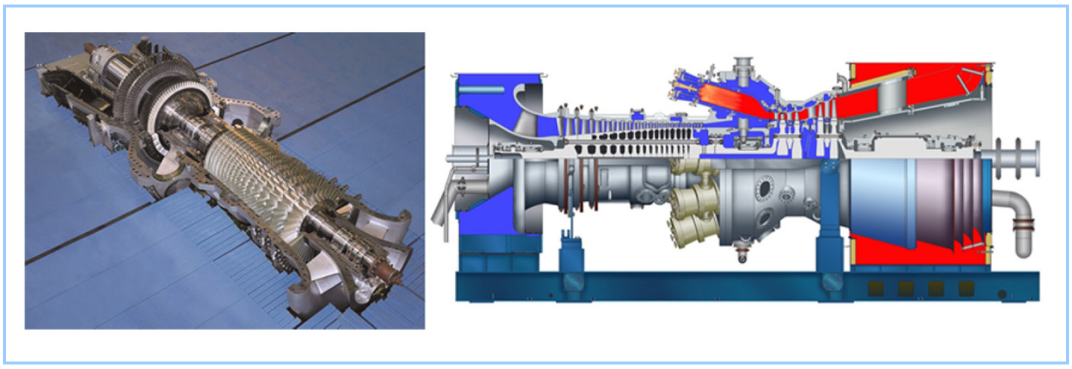


Figure 2 H-100 gas turbine
The H-100 is a heavy-duty dual-shaft gas turbine with the world's largest capacity.

From January 2009, the H-100 was factory-tested for the verification of the performance and design. In October 2009, on-site commissioning started and a relative value improvement in plant efficiency of about 8% compared to the existing model was verified. With regard to the environmental performance, NOx emissions were significantly reduced in comparison with the existing level. The compatibility with the existing reused equipment, including the steam turbine and the heat recovery steam generator, was confirmed and adjusted, and it was verified that there were no problems with the operation and reliability of the whole plant.

Table 1 shows the performance of the plant after replacing the gas turbine, which showed improvement beyond what was initially planned.

Table 1 Plant performance after replacement

	Before replacement	After replacement	
	Design	Design	Actual
Plant output	115MW (7°C)	115MW (28°C)	116.53MW (28°C)
Increase of output	Base	+13.5% (relative)	+15.0% (relative)
Plant efficiency	43.0%HHV 47.7%LHV (at 15°C)	46.3%HHV 51.3%LHV (at 15°C, 115MW)	46.4%HHV 51.4%LHV (at 15°C, 115MW)
Increase in efficiency	Base	+7.7% (relative value)	+7.9% (relative value)

HHV: Higher Heating Value, LHV: Lower Heating Value

3. Improvement of output, enhancement of efficiency, and diversification of fuel

The H-100 series consists of the H-100 (100) and H-100 (110), and the respective basic specifications are shown in **Table 2**. The H-100 (100) described in Section 2 was developed and has established successful operational achievements in replacing gas turbines mainly in the 60 Hz area. Today, we are proceeding with development in order to meet customer needs for the replacement of 1,100°C-class gas turbines in the 50 Hz area, and improve output and efficiency further in the 150 to 300MW GTCC class. For 60 Hz units, the H-100 (110) attains about 15% improvement in the rated output to 116.2MW, and about 3% relative value improvement in the simple cycle efficiency to 38.8% (LHV) in comparison with the H-100 (100). This is due to the enhancement of the air compressor flow rate and the combustion temperature, as well as the optimization of the low-pressure turbine blade. This is the top-class efficiency in the 150 to 300MW combined cycle class.

We plan to start a factory test of the H-100 (110) to verify its performance and reliability from the end of 2015. According to the results of a trial calculation, the plant efficiency will improve by approximately 10% when the H-100 (110) replaces a 1,100°C-class 50 Hz gas turbine of the same capacity class.

The H-100 (100) was delivered in 2014 for the Osaki CoolGen Project, and its on-site commissioning will commence in 2016. The Osaki CoolGen Project is an oxygen-blowing IGCC project where coal gas with a high hydrogen concentration is burnt in a gas turbine. The conventional technology reduces NOx by using a diluent such as nitrogen, water, or steam for the diffusion combustor, but a multiple cluster combustor, which can reduce NOx without the use of a diluent, is adopted for this project.

Table 2 H-100 series gas turbine basic specifications

Item		H-100 (100)		H-100 (110)	
		50Hz	60Hz	50Hz	60Hz
Type		Heavy-duty dual-shaft gas turbine			
Compressor		17-stage axial-flow			
Combustor		Multi-can (10-can)			
Turbine		4-stage axial-flow (2 high-pressure and 2 low-pressure stages)			
Output		99.1MW	101.1MW	112.4MW	116.2MW
Efficiency		36.7% (LHV)	37.7% (LHV)	38.2% (LHV)	38.8% (LHV)
Rated speed		4,580/3,000 rpm	4,580/3,600 rpm	4,580/3,000 rpm	4,580/3,600 rpm
1 on 1 combined cycle performance	Output	143.2MW	143.5MW	157.0MW	163.7MW
	Efficiency	53.5% (LHV)	53.9% (LHV)	54.4% (LHV)	55.1% (LHV)
2 on 1 combined cycle performance	Output	288.1MW	288.7MW	317.3MW/ 322.8MW*	330.4MW/ 337.0MW*
	Efficiency	53.8% (LHV)	54.2% (LHV)	55.0% (LHV)/ 55.9% (LHV)*	55.6% (LHV)/ 56.7% (LHV)*

* Triple pressure reheat specification

4. Application to driving machinery

The H-100 is a dual-shaft gas turbine, and therefore can also be used for purposes other than power generation including driving machinery. In particular, the speed of the low-pressure turbine working as a driving shaft is variable from 70% to 105%, and its application to driving the compressor in the main cooling system of an LNG plant is currently under examination.

Typically, a 5,000,000 tons production/year-class large LNG plant, which is the H-100 application target now being examined, has a configuration where an 80MW-class single shaft gas turbine supplied for power generation is adopted to drive the compressor of the main cooling system, and an 8 to 20MW helper motor is used to compensate for any deficiency in output. If the H-100 is applied to this configuration, the 100MW-class output characteristics allow the elimination of the helper motor and its related electrical equipment such as the switch gear, inverter, transformer, etc., as well as the reduction of the capacity of the gas turbine power generation equipment for supplying electric power to the helper motor, and as a result, the simplification of the configuration, space saving, and the reduction of the installation and operating costs can be expected. **Figure 3** shows the system configuration of the main cooling system compressor.

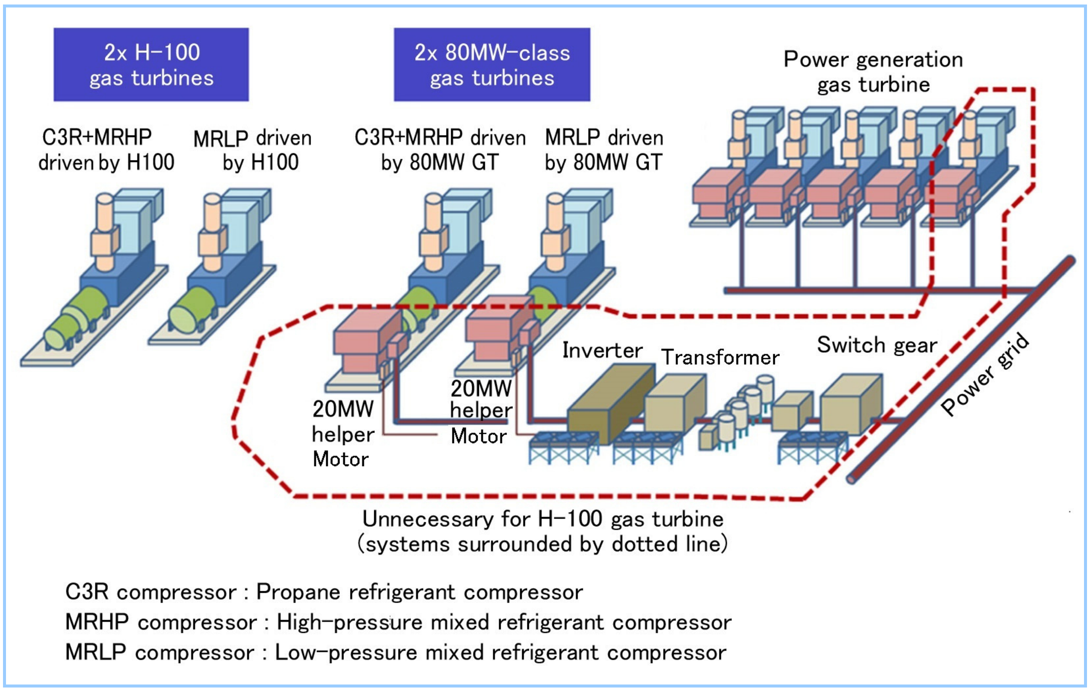


Figure 3 System configuration of main cooling system compressor for 5,000,000 tons production/year-class LNG plant

The application of a dual-shaft turbine for driving the compressor of the main cooling system is advantageous in that the capability of operation at the wider rotation speed range (70% to 105%) in comparison with a single shaft turbine can reduce the risk of emergency stops of the plant caused by the lowering of the rotation speed. As another advantage, restarts from emergency stops can be performed without reducing the refrigerant pressure in the main cooling system, thereby shortening the starting time. The starting torque characteristics have been verified using a locked rotor test implemented with our test equipment.

LNG plants are required to have availability higher than that of power generation plants. In order to reduce down time for maintenance, we will therefore provide various options such as a whole gas turbine replacement method for aero-derivative gas turbines. **Figure 4** shows a conceptual diagram for replacing a turbine module.

When the main cooling system compressor for LNG plants is provided by Mitsubishi Heavy Industries Compressor Corporation, the gas turbine, compressor unit, auxiliary equipment, control device and their interconnection can be arranged collectively by the Mitsubishi Heavy Industries group. This also allows customers to deal with a single representative.

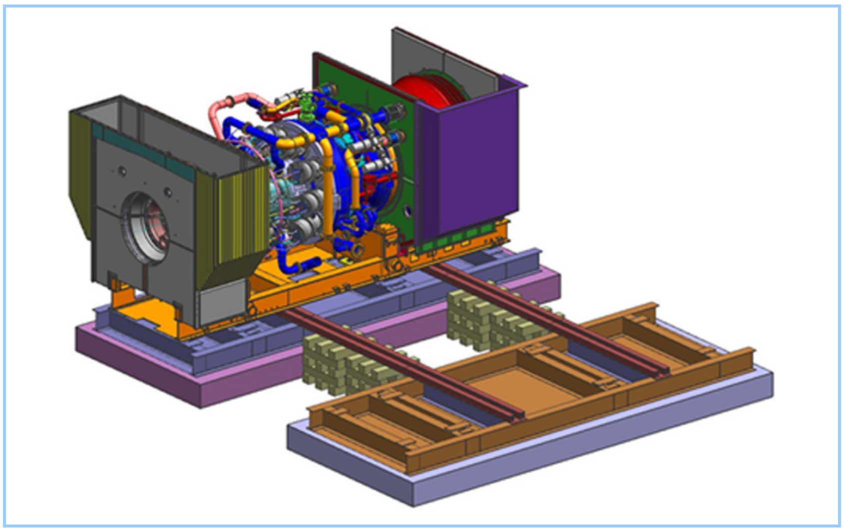


Figure 4 Conceptual diagram for replacement of H-100 turbine module

5. Future prospects

The H-100 gas turbine series, which was developed for the purpose of meeting customer needs for the further enhancement of efficiency and reliability, as well as the diversification of fuel, has attained excellent performance as targeted in the development phase. We believe that the H-100 can gain customer satisfaction in wide application including new power generation, replacing existing facilities, and driving machinery.