Development of Highly Efficient H-80 Gas Turbine

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OVERVIEW: As global environmental problems have come under closer scrutiny in recent years, Hitachi has developed the new highly efficient H-80 dual-shaft gas turbine for the replacement market with the aim of reducing fuel consumption and CO_2 emissions by improving the efficiency of existing combined-cycle power plants. The new gas turbine commenced factory testing in January 2009 and tests were conducted up until June of the same year to confirm its reliability and ensure that there were no problems with the overall design. Further on-site testing was conducted to confirm factors such as the required performance and the reliability of the gas turbine when used in conjunction with other existing equipment that was not replaced in the upgrade. Having confirmed that these various requirements had been satisfied, the gas turbine commenced commercial operation on January 8, 2010.

INTRODUCTION

COMBINED-CYCLE plants constructed approximately 20 years ago using 1,100°C-class gas turbines have lower efficiency than the latest plants and declining utilization. Hitachi recognized the international movement toward reducing CO_2 (carbon dioxide) emissions and the need to improve the efficiency and reduce the CO_2 emissions of existing power plants, but because gas turbines able to meet these requirements did not exist, we decided to develop the H-80 80-MW-class, dual-shaft gas turbine specifically for the replacement market (see Fig. 1).

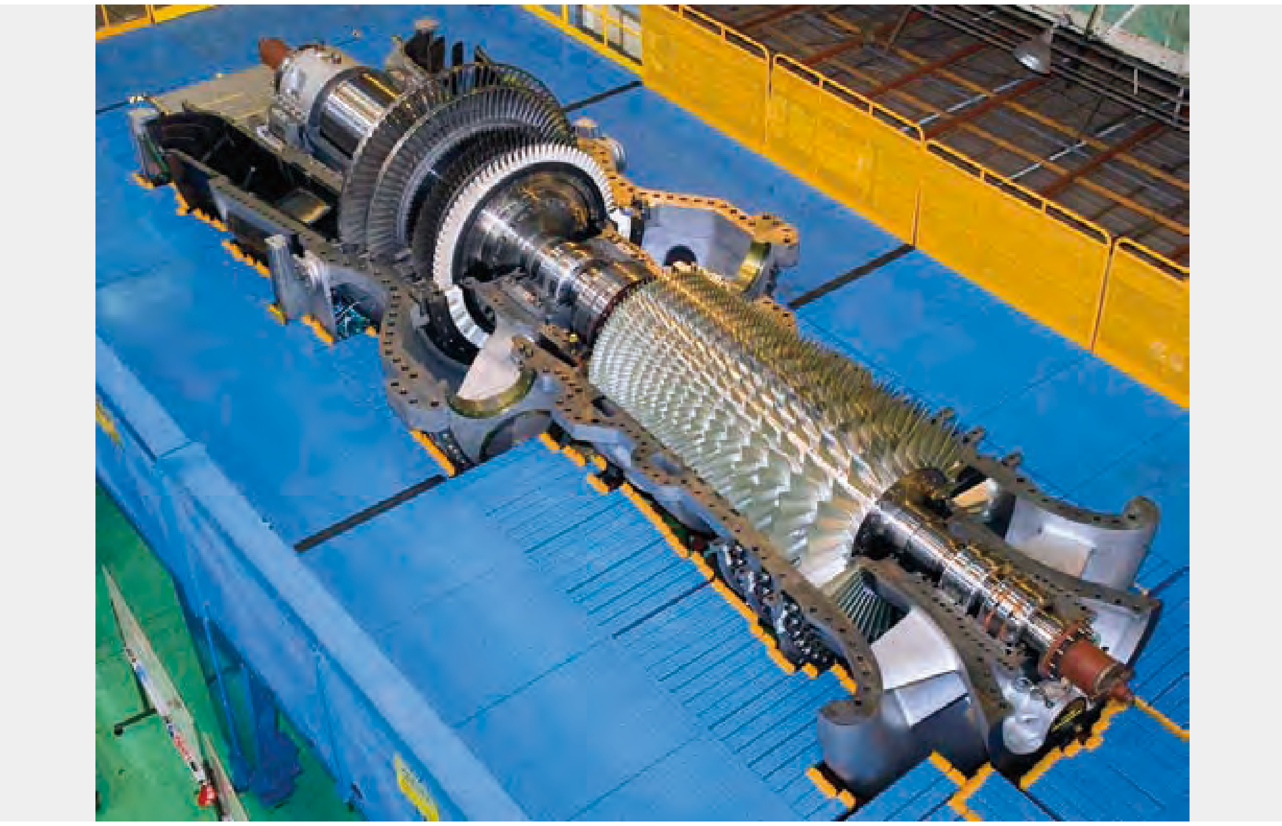

Fig. 1—H-80 Gas Turbine.
The H-80 gas turbine is aimed specifically at the replacement market and the first unit was supplied for turbine 4 at unit 1 of the Shin-Oita Power Station of the Kyushu Electric Power Co., Inc. and commenced commercial operation in January 2010.

The first H-80 commenced factory testing in January 2009 and performance and design verification tests were conducted up until June of the same year to confirm the validity of the overall design. This unit was then supplied for installation as turbine 4 at unit 1 of the Shin-Oita Power Station of the Kyushu Electric Power Co., Inc. and commenced commercial operation in January 2010.

This article describes the newly developed highly efficient H-80 gas turbine designed specifically for the replacement market.

REPLACEMENT GAS TURBINE SPECIFICATIONS

Design Concept

To improve the performance of the existing combined-cycle plant by a gas turbine upgrade alone, it was necessary to consider the following requirements: (1) keep the exhaust temperature and exhaust flow rate for the existing and new gas turbines largely unchanged to allow reuse of the existing equipment other than the gas turbine [HRSG (heat recovery steam generator) and steam turbine], and (2) ensure that the unit is small enough to fit in the available space[1].

The new gas turbine was designed to satisfy these two requirements based on the following concepts (see Fig. 2).

(1) Increase the pressure ratio for the compressor from 12 to 17 in order to raise the combustion temperature from the existing 1,100°C range to the 1,300°C range while keeping the exhaust temperature roughly the same as in the existing plant.

(2) The compressor speed specification was 4,580 rpm to match the exhaust flow rate.

(3) Although the generator needs to operate at a system frequency of 60 Hz (3,600 rpm), the installation did not allow scope for using a reduction gear and therefore a dual-shaft configuration was chosen in which the turbine was split into high-pressure and low-pressure sections with the high-pressure section running at the 4,580 rpm speed of the compressor and the low-pressure section running at the 3,600 rpm speed of the generator.

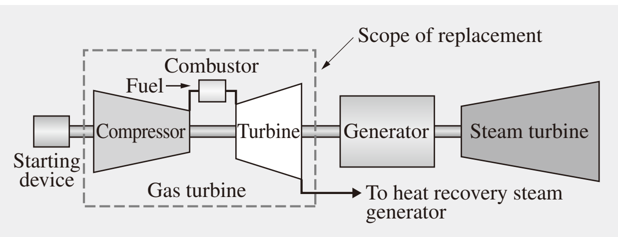

Fig. 2—Scope of Replacement.
The scope of the upgrade was kept to a minimum and involved replacing the gas turbine only with the objective of improving the efficiency and performance of the combined-cycle plant while continuing to use the other equipment.

TABLE 1. H-80 Gas Turbine Specifications
The efficiency of the H-80 is one of the highest for an 80-MW-class gas turbine.

	H-80
Gas turbine type	Open cycle, dual-shaft
Compressor	17-stage axial-flow
Combustor	Multi-can (10-can), dry low-NO*x* combustor
Turbine	4-stage axial-flow (2 high-pressure and 2 low-pressure stages)
Gas turbine output	89 MW
Gas turbine efficiency	38% (LHV)
Rated speed	4,580/3,600 rpm
Pressure ratio	17
Firing temperature	1,300°C-class
Exhaust temperature	530°C

LHV: lower heating value

Basic Gas Turbine Specifications

Table 1 lists the main specifications of the replacement gas turbine. The newly developed model is a heavy-duty dual-shaft gas turbine with a capacity among the world's largest and was based on the 30-MW-class H-25 gas turbine[2] of which more than 130 units have already been supplied around the world (see Table 2 and Fig. 3).

TABLE 2. Past Deliveries of Hitachi Gas Turbines
More than 130 H-25 gas turbines have been delivered (as of April 2010).

Model	Output	No. of units
H-15	16 MW	5
H-25	31 MW	135

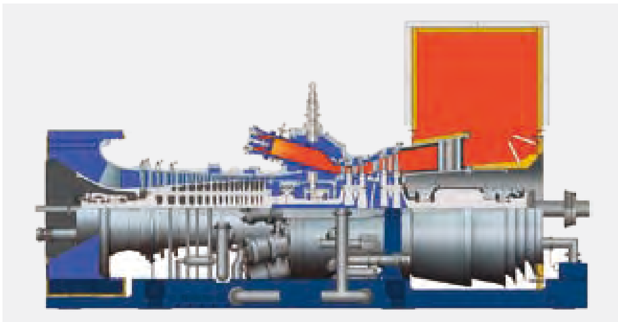

Fig. 3—H-80 Gas Turbine.
This heavy-duty dual-shaft gas turbine has a capacity among the world's largest.

The 17-stage axial-flow compressor has a pressure ratio of 17 and is capable of variable-speed operation at low load. The design of the high-temperature components (including the combustor and turbine) uses a similar structure to that of the H-25 gas turbine to ensure reliability and improve performance by adopting the latest technology. Based on environmental considerations, the H-80 also uses the dry low-NO*x* (nitrogen oxide) combustor that has already been proven in the H-25 gas turbine and elsewhere.

One of the issues specific to dual-shaft gas turbines is the comparatively large speed increase that occurs in the low-pressure turbine if the load is rejected. This is because, whereas the compressor in a single-shaft turbine uses the same shaft and therefore acts as a brake if the load is rejected, the low-pressure turbine in a dual-shaft configuration is not connected to the compressor shaft and is therefore prone to increase in speed. To deal with this problem and minimize the increase in speed, Hitachi fitted an exhaust line that can bleed off the air discharged from the compressor to reduce the flow of gas into the low-pressure turbine together with a control mechanism that rapidly bleeds off air and simultaneously throttles back the fuel system if a load rejection occurs.

Also, because the project involved replacing the gas turbine only, the design of the gas turbine ensured that it was similar in size to the existing unit so that it could be compatible with the existing auxiliary equipment.

Performance after Gas Turbine Replacement

Table 3 lists example performance improvements that were achieved using the newly developed gas turbine. The plant efficiency was improved by approximately 8% (relative).

TABLE 3. Example Performance Improvements after Replacement

The replacement of only the gas turbine achieved an improvement in efficiency of approximately 8% (relative).

Parameter	Unit	Unit 1 of Shin-Oita Power Station of the Kyushu Electric Power Co., Inc.	
		Before replacement	After replacement
Gas turbine output	MW	73.04	81.07
Gas turbine efficiency	% (HHV)	28.2	32.6
	% (LHV)	31.3	36.1
Gas turbine exhaust temperature	°C	533	510
Steam turbine output	MW	38.4	33.93
Plant output	MW	111.44	115.00
Plant efficiency	% (HHV)	43.0	46.3
	% (LHV)	47.7	51.3

HHV: higher heating value

VERIFICATION TRIALS

Factory Test Facility

Factory testing started in January 2009 to verify the performance and design. This involved a partial upgrade to Hitachi's test facility to allow full-load testing using a 90-MW-class axial-flow compressor. In addition to the standard instrumentation, several hundred special measurement points were also set up so that the operating status could be monitored continuously (see Fig. 4).

Fig. 4—Factory Test Facility.
A full-load test was conducted using Hitachi's test facility.

TABLE 4. Verification Test Items
The performance, mechanical reliability, and operation and control functions were confirmed in factory testing and on-site testing.

Test items		In-factory	On-site
Performance	• Output	○	○
	• Efficiency	○	○
	• NO*x* (nitrogen oxide)	○	○
	• Airflow rate	○	○
Mechanical reliability	• Shaft vibration	○	○
	• Metal temperature	○	○
	• Thrust load	○	○
	• Combustion stability	○	○
Operation and control functions	• Dual-shaft control	○	○
	• Startup and shutdown	○	○
	• Over-speed test	○	○
	• Load rejection	(○)	○

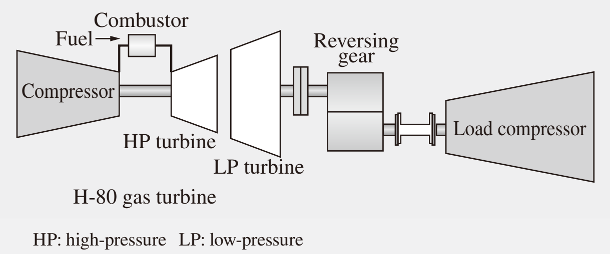

Fig. 5—Shaft Configuration for Factory Testing.
Full-load testing was achieved by using a load compressor to absorb the power.

Test Results

Table 4 lists the test items for factory and on-site testing and Fig. 5 shows the shaft configuration for factory testing. In factory testing, the output of the gas turbine was determined by measuring the power of the load compressor to confirm that the performance requirements were satisfied. Parameters from various parts of the gas turbine (including temperatures, pressures, and vibration) were measured in startup and speed-up tests, no-load tests, and load tests to confirm that the operational characteristics were in agreement with the design.

A test to simulate load rejection was conducted by replacing the coupling between load compressor and reversing gear with a coupling fitted with a shear pin. This confirmed that the behavior closely matched what was predicted by dynamics simulation and indicated that the increase in speed that would occur if a load rejection happened under on-site conditions would not be enough to cause any problems.

On-site Testing

On-site testing started in October 2009 and confirmed the plant's rated output of 115 MW and design performance of 46.3% or more. In terms of environmental performance, the level of NO*x* had been reduced significantly compared to before the replacement. The commissioning process included making adjustments to confirm that the new gas turbine worked correctly with the existing equipment (heat recovery steam generator and steam turbine) and testing confirmed the operational performance and reliability of the plant.

Load Rejection

Load rejection testing was the most critical point for the dual-shaft gas turbine and was conducted at a range of different loads from one-quarter to full load. The results confirmed that the increase in speed would not be enough to cause any problems and that the behavior closely matched what was predicted by dynamics simulation. The testing also confirmed that, even under transient conditions, there were no problems with combustion stability or other aspects of plant operation.

Having confirmed the performance, reliability, and functionality of the first H-80 gas turbine through this factory and on-site testing, the unit commenced commercial operation on January 8, 2010 as turbine 4 at unit 1 of the Shin-Oita Power Station of the Kyushu Electric Power Co., Inc. Table 5 lists the performance after the replacement.

TABLE 5. Performance after Replacement
The improvement in performance exceeded the initial plan.

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

CONCLUSIONS

This article has described the newly developed highly efficient H-80 gas turbine designed specifically for the replacement market.

Thanks to comprehensive backup starting at the early development phase from the Kyushu Electric

Power Co., Inc. which took delivery of the first unit, factory testing, installation (replacement), and on-site testing were completed without problems. In addition to proceeding with the replacement of the remaining five turbines, Hitachi is also planning the replacement of existing combined-cycle plant at other sites. The replacement of this gas turbine made maximum use of existing equipment and is anticipated to reduce the burden on the environment in ways that include reducing fuel consumption and CO_2 emissions.

Hitachi intends to continue improving the performance of the H-80, H-25, and other gas turbines to contribute to energy conservation and reducing CO_2 emissions.

REFERENCES

(1) M. Takase, "Upgrade to Highly Efficient Gas Turbine at Unit 1 of the Shin-Oita Power Station," Electrical Review (July 2009) in Japanese.

(2) O. Arai et al., "Characteristics and Applications of Hitachi H-25 Gas Turbine," Hitachi Review **57**, pp. 273-279 (Oct. 2008).

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