Re-powering of Thermal Power Plant with Low NOx Emission, Heavy-Duty Type Gas Turbines

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For the issues of increasingly stringent environmental regulations, the requirements for low emissions of NOx and other pollutant from both new and existing thermal power plant have grown. SaskPower's Queen Elizabeth Power Station(QEPS) owned two 66 MW steam turbines, had been operated with oil or natural gas firing boiler, were re-powered with combined cycle technology because of the considerations of plant emission regulation, plant efficiency and increasing power demand. Six Hitachi H-25 gas turbines with Low NOx Combustors are installed into this re-powering system. NOx emissions from H-25 gas turbine can be maintained below specified 25ppm at rated load. The gas turbine power output and efficiency also showed satisfactory results. In addition, the operability and reliability of gas turbines at extreme cold ambient temperature at -45℃ are verified by operating results at QEPS.

1. Introduction

SaskPower's Queen Elizabeth Power Station (QEPS) had generated power with two 66 MW and one 100 MW steam turbines operated by oil or natural gas firing boiler.

To address the issues of increasingly stringent environmental regulations, plant efficiency and increasing power demand, SaskPower decided to re-power existing two 66 MW steam turbines with combined cycle technology.

For this re-powering system, six Hitachi 25 MW class gas turbines, named H-25 gas turbine, are supplied. These incorporate Low NOx Combustors (LNC) to meet specified 25ppm NOx emissions.

The commissioning was completed successfully, and the renewed QEPS started commercial operation in June 2002, and have been operating smoothly ever since.

This newly installed re-powering system provides improvement of over all plant efficiency and power output, now can generate up to 225 MW at 46% efficiency with reduction of 80% NOx and CO emissions as well as green house emissions.

2. Outline of Re-powering System

2.1. System Configuration The overview of QEPS with re-powering system is shown in Fig.1 and the re-powering system configuration is shown in Fig.2.

(a) Existing steam turbine plant (back) and newly installed re-powering system (front)

(b) Six H-25 gas turbines in gas turbine hall

Fig. 1. Overview of Queen Elizabeth Power Station and Inside of gas turbine hall.

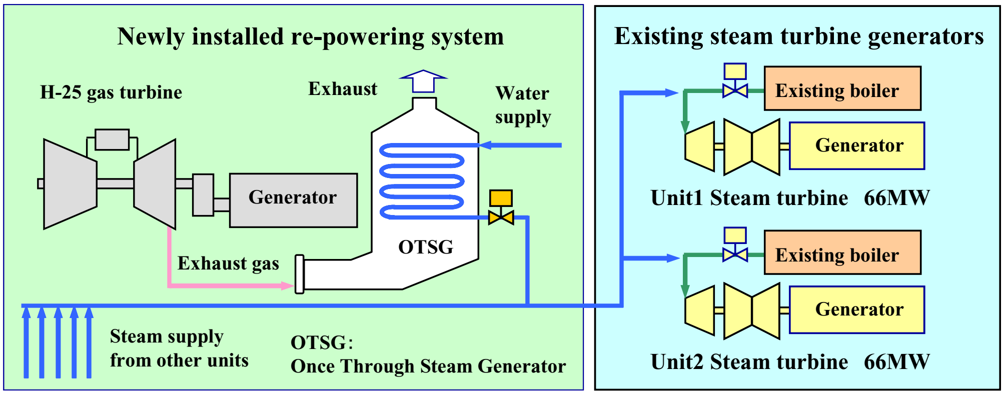

Fig. 2. Re-powering system configuration.

The newly designed re-powering system consists of six Hitachi H-25 gas turbines and six Innovative Steam Technologies once-through steam generators (OTSG). Steam lines from OTSGs are gathered and connected to existing steam line for two 66 MW steam turbines without eliminate existing boilers for two 66 MW steam turbines.

Since high temperature and high strength Incoloy 800 and Incoloy 825 alloy materials are applied for boiler tubes, the OTSGs can duct the exhaust gas without water flowing. Therefore, gas turbine can be operated continuously as a simple cycle machine even when the steam turbines are not in service.

In addition, in this system, boilers for two 66 MW steam turbines have been kept operable condition as an emergency back up.

Because of the reasons mentioned above, this re-powering system has operation flexibility for any situations.

Furthermore, multiple gas turbine system allows the plant to maintain nearly full load efficiency throughout a 40 to 225 MW output range.

In full load condition, the re-powering system has capacity to produce 225 MW power output at 46% efficiency.

Six H-25 gas turbines generate 24.21 MW each with 304,000 kg/h and 546℃ exhaust gas at 15℃ ambient temperature. NOx emissions can be maintained below 25ppm with LNC.

OTSGs can produce 40,000kg/h, 54.1bar and 482℃ superheated steam for the steam turbines.

Most of equipments have been installed inside gas turbine hall not to be exposed to extreme cold ambient temperature. Only OTSGs are packaged for outdoor installation as shown in Fig.1.

Table 1. Major contractors and equipment suppliers for QEPS re-powering system.

Project Development	SaskPower
Project Management	SNC-Lavalin
EPC Contractor	Marubeni Canada
Construction	Graham Industrial
OTSG	IST
Gas Turbine Generators	Hitachi

IST: Innovative Steam Technologies

Working with Marubeni Canada, Hitachi, SNC-Lavalin and SaskPower had developed this re-powering system. The major contractors and equipment suppliers are listed in Table 1.

2.2. H-25 Gas Turbine H-25 gas turbine is one of high efficiency and high reliability heavy duty type gas turbine in the power generation industry.

Utilizing the latest metallurgical technology and advanced cooling system, H-25 gas turbine can be operated at 1260℃ firing temperature and 14.7 pressure ratio condition. This gas turbine has capacity of 27.5 MW power output and 33.8% efficiency at ISO condition.

The H-25 gas turbine is an open cycle, single shaft machine with a 17stage axial compressor, a 3stage axial impulse turbine and 10 can reverse flow type combustors.

Inlet guide vane (IGV) is applied at compressor inlet to improve efficiency at partial load in combined cycle operation and to operate LNC in stable.

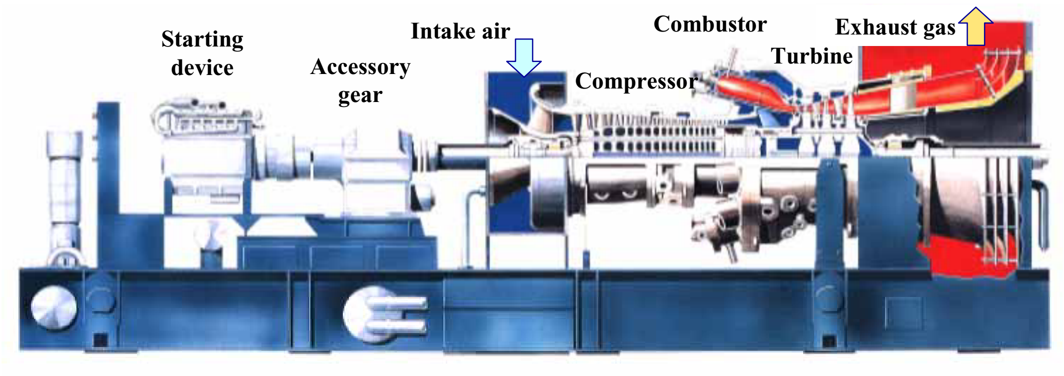

Fig.3. Structure of H-25 gas turbine.

H-25 gas turbine rotating speed is 7280rpm and this speed is reduced to 3000 or 3600rpm for 50 and 60Hz generator with reduction gear.

Structure of H-25 gas turbine is shown in Fig.3 and its specifications are listed in Table 2.

Table 2. H-25 gas turbine specifications.

Fuel	Natural gas	Light oil
Power output (MW)	27.5	26.3
Efficiency (%)	33.8	32.6
Rated speed (rpm)	7280	
Intake air flow (kg/s)	88.0	
Exhaust gas temp. (℃)	555	
Pressure ratio (-)	14.7	
Compressor	17stage axial flow type	
Turbine	3stage axial flow type	
Combustor	10can multiple type	

2.3. Low NOx Combustor(LNC) From the viewpoint of environmental issues, the requirements for low NOx emissions for gas turbines have been enhanced, even for medium size gas turbines.

To meet this requirement, Hitachi developed Low NOx Combustor for H-25 gas turbine. State-of-the-art emission control technology is applied for H-25 gas turbine LNC. Lean premixed stable

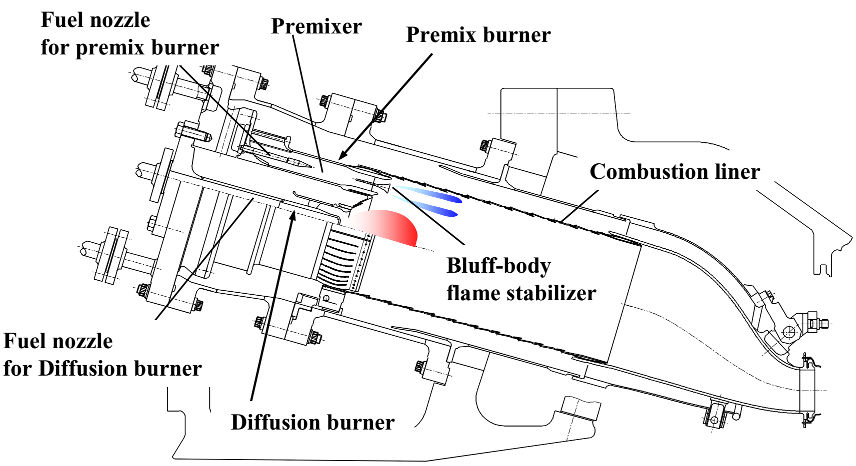

Fig.4. Structure of Low NOx Combustor for H-25 gas turbine.

combustion is the key technology for emission control. This lean premixed combustion technology is applied for H-25 gas turbine LNC for accomplishment of lower NOx emissions.

The diffusion combustion, which has the benefit of very good stability, is also applied to cope with wide fuel flow turndown ration in over all gas turbine operation from ignition, acceleration up to entire load range.

Bluff-body type flame stabilizer is applied to hold lean premix combustion flame. This premixed combustion with bluff-body type flame stabilizer attains high combustion stability and outstanding characteristics concerning lower NOx emissions and load operation. Swirling flow type flame stabilizer is utilized for diffusion combustion. The diffusion burner is located at the core of the combustor and the premixed burner is located at its periphery in the form of a ring.

Structure of the H-25 gas turbine LNC is shown in Fig.4.

The LNC for QEPS re-powering system is modified to accommodate the site conditions of extreme cold ambient temperature at -40℃ and the natural gas fuel properties with higher Nitrogen content which is inert gas, to maintain the high performance throughout the operating range.

3. Considerations

3.1. Fuel gas properties The natural gas supplied to QEPS mainly consists of Methane and a certain amount of inert gas such as Nitrogen, whose concentration fluctuates chronically. Fuel gas density also fluctuates according to the inert gas concentration. Inert gas, such as Nitrogen, in fuel gas influences the combustion stability. For stable operation, inert gas influence must be considered in combustion control for gas turbine combustor, especially for LNC.

Because of the sensitivity of the LNC system, the flow rate of fuel gas injected into the combustors must be controlled carefully in accordance with the fluctuation of Nitrogen concentration in the fuel gas.

3.2. Ambient Temperature QEPS is located at a latitude of 52degree and an elevation of 501 meters. The year around temperature ranges from +36℃ in summer to below -40℃ in winter. The gas turbine must keep the stable operation without any problem for a wide range of ambient temperature mentioned above. The reliability must be also maintained.

At design stage, the following metallurgical and operational issues were considered for the QEPS model H-25 gas turbines especially.

a) LNC operational stability
b) Compressor and turbine characteristics
c) The strength of materials at extreme cold temperature

4. Results and Discussion

4.1. Operating results for fuel properties The structure of combustor is optimized to fit QEPS fuel gas properties. In addition, fuel combustion control adjustment system is applied for the LNC system because the combustion stability must be maintained throughout the operating range by combustion control optimization, even if Nitrogen concentration in the fuel gas fluctuates. The combustion control is adjusted according to Nitrogen concentration in the fuel gas to make a combustion condition the optimum for the concentration. Nitrogen concentration is detected by chromatograph installed in fuel supply line and fuel flow control is adjusted based on this analysis result. This system configuration is shown in Fig.5.

With the optimization of combustor structure and

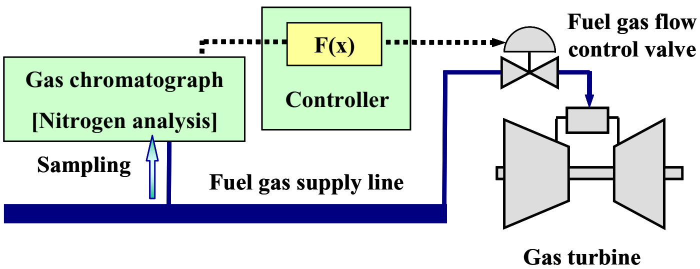

Fig.5. Outline of fuel gas control adjustment system for Nitrogen concentration.

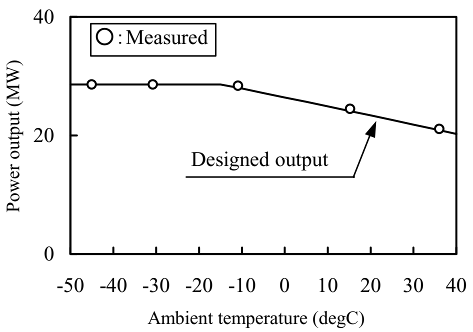

Fig.6. H-25 gas turbine full load power output versus ambient temperature.

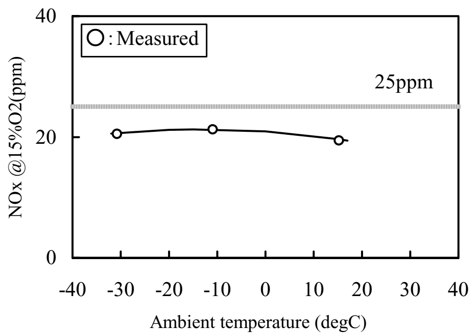

Fig.7. H-25 gas turbine LNC NOx emissions at rated load versus ambient temperature.

combustion control for the fuel gas properties, the gas turbine can be operated stably while keeping its performance and operability.

4.2. Operating results for ambient temperature Fig.6 shows the full load out put versus ambient temperature at QEPS till April 2004.

Ambient temperature ranged from 36℃ down to -45℃ till April 2004. At any ambient temperature, H-25 gas turbine can generate designed power output without any problem.

This result verifies H-25 gas turbine and LNC operability and reliability for a wide range of ambient temperature.

The power output and efficiency at the rated load can also satisfy the designed specifications.

4.3. NOx emission performance results The commissioning results concerning the NOx emission characteristics of H-25 gas turbine LNC at rated load are plotted versus ambient temperature in Fig.7. This shows that at each ambient temperature, NOx emissions are maintained below 25ppm at 15%O2 which is specification for H-25 gas turbine QEPS models.

The 25ppm NOx emissions are achievable from 70% load up to rated load. NOx emission characteristics for gas turbine load are shown in Fig.8.

4.4. Commercial operation and gas turbine inspection results The first unit was commissioned in January 2002 and each of the remaining five units were commissioned at one month intervals following. Following commissioning, the turbine plant has

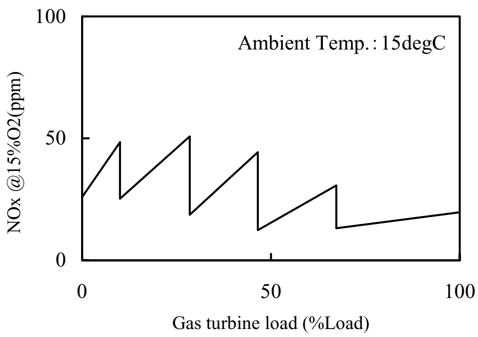

Fig.8. H-25 gas turbine NOx emissions versus gas turbine load.

been operated on a dispatchable basis with no operational or performance problems.

Regular interval inspection was carried out from October 2002, and the inspection results revealed that there is no damage to combustors and gas turbines. These satisfactory results proved the reliability of H-25 gas turbine hardware.

From now on, the installed H-25 gas turbines will be maintained under a long-term contract agreement covering parts and services.

5. Conclusion

The re-powering system installed in SakPower's Queen Elizabeth Power Station has significantly improved overall plant efficiency, power output and operational flexibility while dramatically reducing the plant's environmental impact. H-25 gas turbines with LNC can also contribute the plant performance.

H-25 gas turbines outstanding operability, performance and reliability are also verified by H-25 gas turbine with LNC successful operation results at QEPS.

With the successful operating results of the re-powering system at QEPS, we believe that the technology and system can be applied for both re-powering existing plants and new power plants in worldwide power generation market to achieve the more environmental friendly industry.

References and Notes

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