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The Solution from China for Gas Turbine Combined Heat and Power Generation in the Astana Region of Kazakhstan

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Abstract

This paper takes the Phase II expansion project of a thermal power plant in the Astana region as a specific case study, which deeply investigates and proposes a comprehensive modernization solution for combined heat and power (CHP) generation centered on China's advanced 9F-class gas-steam combined cycle technology. Through detailed engineering design and technical comparative analysis, this solution systematically elucidates its comprehensive advantages in system integration, comprehensive energy efficiency, deep emission reduction, and operational peak-shaving flexibility. Research combined with specific engineering data indicates that the Chinese solution can not only meet the urgent electricity and heating load demands of the Astana region but also highly aligns with Kazakhstan's national strategy for energy modernization transition and "green economy" development. It provides a technical path and engineering exemplar with high feasibility, economic viability, and foresight for upgrading similar aging energy infrastructure in Central Asia.

Keywords

Gas Turbine Combined Heat and Power (CHP); Combined Cycle; Chinese Technical Solution; Astana; Energy Efficiency

1. Introduction

In the fields of heavy-duty gas turbines and combined cycle CHP, China, through long-term technology introduction, digestion, absorption, and re-innovation, has formed a full industrial chain capabilities covering R&D design, equipment manufacturing, engineering construction, operation, and maintenance, and has accumulated rich domestic and international project experience. Against this background, this paper takes the upgrade and expansion of a typical aging gas-fired power plant in the Astana region as the specific research object and engineering carrier. It aims to deeply analyze the technical bottlenecks of the existing system and, based on detailed preliminary engineering design, systematically demonstrate the technical superiority, economic rationality, and implementation feasibility of adopting the advanced Chinese combined cycle CHP solution. This is intended to provide valuable engineering reference and technical insights for deepening China-Kazakhstan energy cooperation, Kazakhstan's sustainable energy development, and similar projects in countries along the "Belt and Road" initiative.

2. Overview of Chinese Gas Turbine CHP Technology

The core of the Chinese technical solution lies in pursuing the maximization of cascaded energy utilization and optimal system integration. Gas-steam combined cycle CHP technology embodies this philosophy: natural gas is efficiently combusted for power generation in the gas turbine (primary power generation, producing about 2/3 of the combined cycle's electricity); subsequently, the exhaust gas at around 600℃ is not wasted but directed into a heat recovery steam generator (HRSG) to produce multi-parameter steam at high, medium, and low pressures; this steam then drives a steam turbine for secondary power generation (producing about 1/3 of the combined cycle's electricity); finally, a portion of the steam that has performed some work, with suitable parameters, is extracted from between the intermediate and low-pressure cylinders of the steam turbine for external heating. This process scientifically achieves energy grade matching of "high-grade for power generation, medium/low-grade for heating," fully utilizing the energy value of a single fuel [1]. This integrated design philosophy is recognized as a benchmark for achieving ultra-high system efficiency in modern cogeneration projects [2]. It can increase the comprehensive energy utilization rate to around 80%, far exceeding the traditional separate heat and power production mode.

Simultaneously, the Chinese solution highly emphasizes the synchronous design of environmental performance. Domestically in China, gas turbines commonly employ Dry Low-NOx (DLN) combustors, and efficient denitrification technologies such as Selective Catalytic Reduction (SCR) have become standard configurations, ensuring deep reduction of nitrogen oxides under various loads. This complete and advanced technological system provides a solid and reliable technical foundation and diverse choices for the modernization and expansion of aging power plants in the Astana region.

3. Overall Chinese Modern CHP Solution for Astana

For this project, we have tailored a complete modern CHP expansion solution based on China's mature technological reserves and rich engineering experience.

3.1 Construction Scale and Overall Layout

The project plans to construct one new 500MW-class (9F type) "one-on-one" multi-shaft gas-steam combined cycle CHP unit. The plant site is located in the northern part of Astana city, adjacent to urban roads and next to the existing Phase I power plant. The available site area is sufficient, with flat and open terrain. The project construction period is 48 months.

The overall plot plan fully considers the connection with the Phase I power plant, the smoothness of the process flow, the convenience of construction and operation & maintenance, and the possibility of future expansion. Main facilities include the gas turbine building, steam turbine building, HRSG area, central control building, electrical distribution device, chemical water treatment workshop, circulating cooling facilities, natural gas pressure regulating station, etc. The plant water source is tentatively set to use the nearby municipal water supply network.

3.2 Selection and Technical Parameters of Major Equipment

According to the project's fuel characteristics, heating demand, and grid peak-shaving requirements, the selection of major equipment follows these principles: advanced and mature technology, high reliability, excellent comprehensive energy efficiency, good environmental performance, flexible operation, and economic rationality.

a. Gas Turbine: A 9F-class heavy-duty gas turbine is adopted. At this stage, consideration is temporarily based on the M701F4 model jointly produced by China's Dongfang Electric Group and Mitsubishi. This model has a unit power of about 327MW (ISO conditions) and efficiency exceeding 40%, with a large number of successful operational records in China and globally, and its reliability is fully verified.

b. Heat Recovery Steam Generator (HRSG): A horizontal, natural circulation, triple-pressure reheat HRSG matched with the 9F gas turbine is selected. This type of boiler maximizes the recovery of exhaust heat to produce high, medium, and low-pressure steam. Given that this thermal power plant is located on the urban fringe and bears the responsibility of providing heating to the urban core area, its geographical location dictates relatively stringent environmental requirements. Therefore, the boiler must synchronously install a high-efficiency Selective Catalytic Reduction (SCR) denitrification device, with a designed denitrification efficiency of not less than 70%, ensuring that the NOx emission concentration under combined cycle operation is stably below the strict standard of 40 mg/Nm3, to minimize the impact on the urban environment. Additionally, the solution considers the possibility of installing a supplementary firing system in the HRSG to temporarily increase heating capacity or ensure steam supply stability under specific operating conditions.

3.3 Main Performance Indicators of the Whole Plant

Based on the above major equipment selection and system design, the estimated main performance indicators of this solution under annual average meteorological conditions are as follows:

a. Power Generation Output: About 495.8 MW in pure condensing mode; about 438.36 MW in heating mode (can be increased to about 472.71 MW after supplementary firing).

b. Power Generation Efficiency: Combined cycle pure condensing power generation efficiency can reach 59.6% (LHV).

c. Heating Capacity: Rated extraction steam flow of 300 t/h, corresponding to an external heating capacity of not less than 822.53 GJ/h (approximately 192.7 Gcal/h), which can effectively meet urban heating load growth demand.

d. Comprehensive Energy Utilization Rate: As high as 78.53% under heating conditions.

e. Main Gas Consumption Indicators: Under heating conditions, the specific gas consumption for power generation is about 0.1492 Nm3/kWh, and for heating is about 29.19 Nm3/GJ.

Compared with the old plant's "separate production of heat and power" mode, the new solution can save at least 20% of natural gas consumption while outputting the same amount of electricity and heat, resulting in extremely significant energy-saving and economic benefits.

4. Process System Design

4.1 Thermal System

a. The thermal system adopts a unit system design, completely separated from the old plant, ensuring operational safety and flexibility.

b. Main Steam and Reheat Steam Systems: The system is configured with 100% capacity high, medium, and low-pressure bypass systems to meet the requirements for rapid unit start-up/shutdown, load rejection, and matching steam temperature and pressure during start-up.

c. Feedwater System: Each unit is equipped with 2×100% capacity electrically driven variable-speed high-pressure feedwater pumps and 2×100% capacity intermediate-pressure feedwater pumps. The system is equipped with minimum flow recirculation to protect pump safety.

d. Condensate System: Configured with 2×100% capacity condensate pumps (one operating, one standby). The system includes a gland steam condenser and is equipped with a minimum flow recirculation pipeline to the condenser.

e. Auxiliary Steam System: To meet the demand for gland sealing steam and deaerator heating during unit start-up, and considering the reliability of in-plant heating in extremely cold regions, it is proposed to install two start-up boilers, each with a capacity of 15 t/h. After normal operation, the auxiliary steam source switches to low-temperature reheat steam.

4.2 Fuel Supply System

4.2.1 The fuel for this project is pipeline natural gas

a. Natural Gas Pressure Regulating Station System: As the incoming pipeline gas pressure (about 1.2 MPa) may be lower than the gas turbine's required inlet pressure (M701F4 requires about 3.6-4.2 MPa), a natural gas pressure regulating station needs to be set up within the plant. The station includes filtration, metering, pressurization (if needed), pressure regulation, safety venting, and other units to ensure that the natural gas supplied to the gas turbine meets stringent requirements in pressure, temperature, and cleanliness.

b. Gas Front-End Module: Integrally designed by the main equipment island supplier, it typically includes performance heaters, fine filters, gas pressure control valves, flow control valves, etc., and is the core front-end of the gas turbine combustion system.

c. Backup Fuel Storage System: Given that this project serves as a core urban heating source, the reliability of its operation is directly related to livelihood security and social stability. Therefore, a highly reliable backup fuel system must be established. For this purpose, an LNG storage tank with a capacity of not less than 30,000 cubic meters and supporting regasification, pressurization, and transportation facilities are planned to be constructed about 10 km outside the plant. When the main natural gas pipeline supply is interrupted or fails, a quick switch to the LNG backup fuel source can be made to ensure continuous power plant operation and guarantee urban heating security. Global energy security analyses increasingly highlight the strategic value of diversified fuel supply and on-site storage for critical urban energy infrastructure [3].

4.3 Flue Gas and Environmental Protection System

a. Flue Gas System: The gas turbine exhaust enters the HRSG for heat exchange and is then discharged into the atmosphere through the tail-end flue duct and chimney. The system is equipped with a bypass chimney. When the gas turbine operates in simple cycle, or the HRSG is under maintenance, the flue gas is directly discharged through the bypass chimney, further improving the operational reliability of the power plant.
b. Environmental Protection System: The core is the SCR denitrification system integrated into the HRSG flue duct. Selective Catalytic Reduction technology is used, with the reducing agent being ammonia gas produced through the urea pyrolysis (or hydrolysis) process. The design ensures that under combined cycle operation, the NOx emission concentration at the chimney outlet is stably controlled at ≤40 mg/Nm3, meeting and surpassing stringent environmental standards. The gas turbine itself employs DLN low-NOx combustion technology to control NOx generation at the source.

4.4 Civil and HVAC

a. Structure: Based on local Kazakh standards, the site is in a non-seismic zone. According to preliminary geological survey data, the foundation soil layers are mainly clay. General or light building structures can use natural foundations, while important building structures can use pile foundations. The specific approach will be determined after a detailed investigation.
b. HVAC: In response to Astana's extreme climate (winter heating design temperature -30.1℃, summer ventilation design temperature 26.6℃), mechanical ventilation systems are installed for the gas turbine hall and steam turbine hall. The heating source for the main powerhouse and other buildings comes from the start-up boilers during unit shutdown. During normal operation, it primarily utilizes hot water from the tail section of the HRSG, with any shortfall supplemented by low-pressure steam exchange, ensuring high reliability of the heat source. Air conditioning systems are installed for electronic equipment rooms, the central control room, offices, etc.

5. Technical Performance Comparison and Advancement Analysis

To quantify the upgrade benefits of the modern Chinese gas turbine CHP solution compared to the old plant system, an in-depth comparative analysis is conducted from multiple dimensions.

In terms of energy utilization efficiency, the difference before and after the upgrade is revolutionary. The comprehensive energy efficiency of the whole plant under the old "separate production" mode is less than 60%. In contrast, this Chinese solution, through deep coupling of gas-steam combined cycle and CHP, achieves cascaded energy utilization. The pure condensing power generation efficiency alone is nearly 60%, and the comprehensive energy utilization rate, including heating, can reach 78.53%. If a higher-grade H-class gas turbine is used, the comprehensive energy utilization rate of this solution can reach around 80%. While outputting the same amount of electricity and heat, the new solution can save at least 20% of natural gas consumption compared to the old plant, resulting in extremely significant energy savings and economic benefits.

In terms of environmental emission reduction, the contrast is more intuitive and significant. The old plant units lack efficient denitrification facilities, with NOx emission concentrations at levels of 100-200 mg/Nm^3 or even higher. The new solution integrates gas turbine DLN combustors for source control and end-of-pipe efficient SCR denitrification systems, enabling stable control of NOx emission concentration below 40 mg/Nm^3, achieving an emission reduction range of over 60%. Such deep emission cuts are critical for meeting the stringent air quality standards increasingly adopted in urban development plans [4]. This has major practical significance for improving air quality problems in Astana caused by high heating demand and poor diffusion conditions in winter.

In terms of operational flexibility and reliability, the new solution achieves fundamental improvement. The old plant's electricity and heating systems were isolated, with slow adjustment, struggling to adapt to fluctuations in modern power grids and heating networks [5]. This enables the power plant to not only operate as an efficient baseload power source but also respond quickly and smoothly to grid peak-shaving instructions, becoming a flexible resource supporting regional grid stability. The rapid ramping and wide load-following capabilities of modern combined-cycle plants are proven assets for integrating variable renewable energy into power systems [6]. Simultaneously, by configuring a backup LNG fuel system and considering backup heat sources, the energy supply reliability of the thermal power plant as an urban lifeline project is greatly enhanced.

6. Conclusion

Looking forward, with the deepening connection between the "Belt and Road" initiative and Kazakhstan's "Bright Path" new economic policy, such high-quality energy cooperation projects integrating Chinese technology, equipment, standards, and construction experience will usher in broad prospects in Kazakhstan and the wider Central Asian region [7]. Regional economic cooperation strategies explicitly identify the modernization of energy infrastructure as a cornerstone for sustainable growth and resilience [8]. China's mature, reliable, economical, green, and efficient integrated gas turbine CHP solution will undoubtedly continue to contribute indispensable Chinese wisdom and strength in assisting countries along the route in their energy transition and upgrading, and in jointly building a green and low-carbon regional energy future.

References

[1] Government of the Republic of Kazakhstan. National project "Modernization of energy and utilities"; 2024.

[2] Ministry of Energy of the Republic of Kazakhstan. Electricity sector development plan of the Republic of Kazakhstan until 2035; 2021.

[3] International Energy Agency (IEA). World energy outlook 2022. Paris: IEA Publications; 2022.

[4] Jin H, Lin R, Wang B, et al. Review of high-efficiency cogeneration technology for gas-steam combined cycles. Electr Power Constr. 2023;44(1):1-10.

[5] Li W, Zhang Q, Wang S. Economic and environmental assessment of retrofitting coal-fired CHP plants to natural gas combined cycle in cold regions. Energy Policy. 2022;160:112678.

[6] Asian Development Bank (ADB). Central Asia Regional Economic Cooperation (CAREC) energy outlook 2030. Manila: ADB; 2023.

[7] Siemens Energy. Siemens Energy combines technologies to stabilize the Irish grid; 2023.

[8] International Gas Union (IGU). Global gas report 2023: navigating to a secure and sustainable energy future; 2023.