ISSN 2616-5767 Vol.8, Issue 4: 42-46, DOI: 10.25236/AJETS.2025.080405

Preliminary Design Analysis of the CCGT Power Plant in Western Kazakhstan

Lin Kan, Jiang Jian

Southwest Electric Power Design Institute Co., Ltd., Chengdu, Sichuan Province, 610021, China

Abstract: *Kazakhstan, with rich in oil and gas resources, is an important partner in the Belt and Road Initiative. Based on the preliminary design experience of combined-cycle gas turbine (CCGT) power plant projects in western Kazakhstan, this paper analyzes the distribution of energy resources, the current situation and problems of the power system in the region, as well as the preliminary design characteristics of new CCGT power plant projects. It provides a useful reference for investing in or constructing CCGT power plant projects in western Kazakhstan.*

Keywords: *Kazakhstan; western region; combined-cycle gas turbine power projects; natural gas; design characteristics; preliminary experience*

1. Introduction

Kazakhstan is the largest landlocked country in the world, located in the hinterland of the Eurasian continent and rich in oil and gas resources. On September 7, 2013, President Xi proposed the Belt and Road Initiative during his visit to Astana . Under the strategic guidance and joint efforts of both countries, China and Kazakhstan have established close and effective trade and economic cooperation. Investing in or undertaking combined-cycle gas turbine (CCGT) power plant projects in Kazakhstan not only aligns with China's Belt and Road Initiative and the strategic plans of both China and Kazakhstan, but also enjoys a favorable macro-environment, which is conducive to consolidating bilateral cooperation between the two countries. However, currently there are few CCGT power plant projects invested in or undertaken by Chinese companies in Kazakhstan, and the market for gas turbine projects in Kazakhstan is still in need of further development.

2. Distribution of Energy Resources

Kazakhstan's primary energy supply structure currently remains heavily reliant on traditional energy sources: oil, natural gas, and coal. Although in recent years Kazakhstan has begun to focus on developing new energy sources, such as wind energy and solar energy, the proportion of new energy currently remains at a relatively low level (less than 5%). Kazakhstan has a high level of energy self-sufficiency. While its oil and gas resources meet domestic demand, they also serve as one of the country's main sources of foreign exchange income through exports[1].

Kazakhstan has approximately 176.7 billion tons of coal reserves, accounting for about 4% of the world's total reserves. It ranks eighth in the world after China, the United States, Russia, Australia, India, South Africa, and Ukraine. The country's coal resources are mainly distributed in the northern and central regions. In the north, the Pavlodar Region is the primary area, while the central region is dominated by the Oblast of Karaganda. The coal reserves in these two areas account for more than half of the total national reserves.

The distribution of oil fields in Kazakhstan shows a pattern of being more concentrated in the west and less in the east. The western part of Kazakhstan, especially the Caspian Sea region, is the main area where oil and gas resources are concentrated. The country's oil reserves are among the top in the world rankings, following the Middle East, Russia, the United States, and some Latin American countries. At present, the proven oil reserves on land in Kazakhstan are 4.8 billion to 5.9 billion tons, and the proven natural gas reserves are about 3.5 trillion cubic meters，of which more than 1 trillion cubic meters are recoverable. In the Caspian Sea region, Kazakhstan's proven oil reserves are approximately 8 billion tons.

The distribution of thermal power projects in Kazakhstan is closely related to their resource distribution and power production structure, with most of the existing natural gas power generation

ISSN 2616-5767 Vol.8, Issue 4: 42-46, DOI: 10.25236/AJETS.2025.080405

located in the western region of Kazakhstan.

3. Power System in the Western Region

3.1 Major Issues with Kazakhstan's Power Grid

a) Imbalanced development of power resources, with more severe power shortages in the western and southern parts of Kazakhstan.

The distribution of power resources in Kazakhstan is uneven. The northern regions, including Akmola Oblast, Kostanay Oblast, and Pavlodar Oblast, host the main large power plants. The electricity generated in these plants is primarily used to supply the central part of the country and for export to Russia. Over 70% of the country's electricity generation is concentrated in the central and northern regions, while the western and southern oblasts face power shortages and have to import electricity from neighboring countries such as Kyrgyzstan. In recent years, the situation of power shortages has become increasingly severe due to the rising prices of coal, increased electricity prices, growing electricity demand, and political factors.

The imbalance of the development of Kazakhstan's power resources is mainly caused by the uneven distribution of the coal resources. Considering the convenience of transportation and cost savings, the construction of large thermal power plants in Kazakhstan is generally located in the central and northern regions where are close to the coal-producing areas.

Moreover, the structure of power generation in Kazakhstan is characterized by an imbalance between thermal power and hydropower. In the southern part of Kazakhstan, coal resources are relatively scarce, while water resources are more abundant. However, the region has not fully utilized its hydropower potential, which is also one of the factors contributing to the local power supply tension.

b) The power transmission network system is weak, and the reliability of production equipment is prominent

Kazakhstan's power industry developed relatively late, gradually establishing an independent power system only in the mid-1960s. After nearly four decades of operation, most of the power generation facilities remain outdated, resulting in low production efficiency. At the same time, many transmission and distribution lines are aging and frequently experience malfunctions, resulting actual productivity being less than half of the installed capacity in the country. Additionally, the renewable energy generation projects currently under construction are likely to further impact the already fragile transmission and distribution system.

3.2 Power System in the Western Region

Kazakhstan's power system is divided into three major regions: the northern region, the southern region, and the western region. The northern and southern regions are connected by three 500kV transmission lines, while the western region's power system is not directly connected to the main national grid within the country's territory. The western region includes West Kazakhstan Oblast, Atyrau Oblast, and Mangystau Oblast, and part of its electricity supply currently relies on imports from abroad.

Figure 1 Schematic Diagram of the Power System Interconnection Project in Western Kazakhstan

ISSN 2616-5767 Vol.8, Issue 4: 42-46, DOI: 10.25236/AJETS.2025.080405

From Figure 1, we can see that, to achieve direct connection of the western region's power system to the unified national grid within Kazakhstan's territory and to enhance the reliability of power supply in the western region, Kazakhstan has planned an interconnection project for the western region's power system. This project involves constructing a new 500kV transmission line between the Karabatan substation and the Ulke substation, with a total length of 600 kilometers. It is reported that the project is currently in the feasibility study stage and is planned to be put into operation in 2027.

According to statistics from the Ministry of Energy of Kazakhstan, the maximum electricity load in the western region is projected to be between 2,598 and 3,470 MW from 2024 to 2030. After accounting for necessary power reserves, the total electricity demand is estimated to be between 3,081 and 4,106 MW. Considering the additional power from reconstructed, expanded, and newly built power plants, the available power generation capacity is expected to be between 2,519 and 3,252 MW. Therefore, there will be a power deficit of 237 to 855 MW in the western region's power grid from 2024 to 2030.In terms of regulating power, the system will require a regulating power capacity of 332 to 437 MW from 2024 to 2030, while the available regulating power capacity is only 42 to 62 MW. As a result, there will be a regulating power deficit of 276 to 375 MW in the western region's power grid during this period. Therefore, constructing a gas turbine project in the western region of Kazakhstan can help meet the electricity demand of the region, stimulate local economic development, and fully leverage the local natural gas resource advantages. It will also promote the development of clean and low-carbon energy, enhance the power grid's peak regulation capability, and complement renewable energy sources such as wind and solar power. This aligns with Kazakhstan's power development strategy.

4. Preliminary Design Features of New Gas Turbine Projects in the Western Region

Based on the author’s own project experience,the following preliminary design features for CCGT power plant projects in the western region of Kazakhstan are summarized as below.

4.1 Topography, Landform, and Foundation Selection

Although Kazakhstan's terrain is complex, its western and southwestern regions are mainly composed of plains and lowlands, with the land sloping gradually downward toward the Caspian Sea. The lowest-lying area in Kazakhstan is the coastal region along the Caspian Sea. From Figure 2, most areas in the western region of Kazakhstan have relatively stable geological conditions. In the author’s experience with projects in Atyrau Oblast and Mangystau Oblast, the local seismic intensity was low. New projects can determine whether to use a natural foundation based on the geotechnical characteristics in the local survey report.

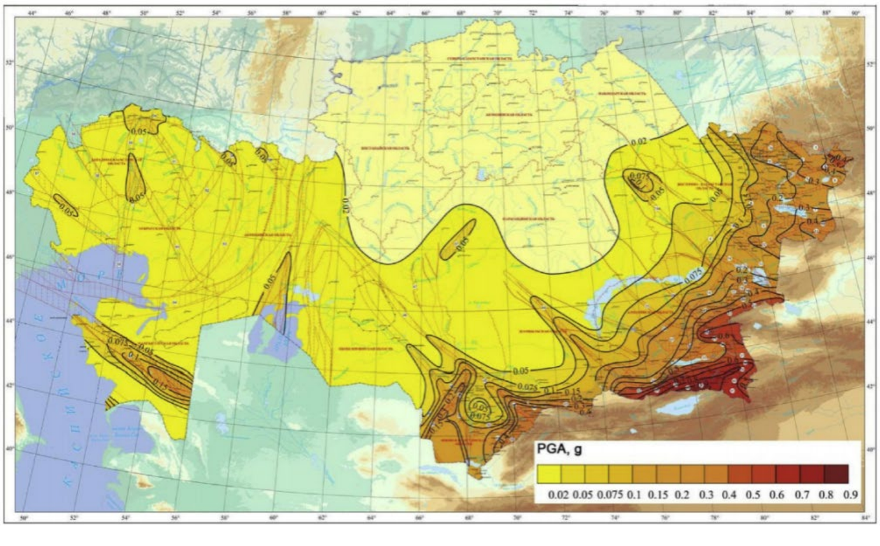

Figure 2 Seismic Zone Map of Kazakhstan [2]

4.2 Climate and Heating

In the cold season in western Kazakhstan, the air mass from the Western Branch of the Siberian anticyclone is dominant, while in the warm season, the tropical air mass from the Central Asian River and the Iranian desert dominates. Under the influence of these air masses, an extremely arid continental climate was formed. It is characterized by warm and dry summer, sunny weather for most of the time, long winter, little snow, windy and partly cloudy.

The winter temperature in western Kazakhstan is relatively low, and the extreme minimum temperature for many years often reaches below minus 40 degrees. Therefore, CCGT power plant projects must take into account the heating system. A heating station can be set in the main building to provide hot water for the whole plant. When the unit is in normal operation, the heating source can come from the hot water at the tail of the heat recovery steam generator (HRSG) or low-pressure steam extraction. When the unit is shut down, the heating source can come from the start-up boiler.

In addition, it is recommended that HRSG adopt a tight, enclosed layout with a single layer of profiled steel sheet on the outer layer, combined with insulation materials, and a single layer of profiled steel sheet on the inner layer to meet the heating requirements during winter.

To prevent icing of the gas turbine intake filters in winter, a gas turbine anti-icing system should be considered, such as extracting air from the compressor to heat the intake air and prevent icing. All other process systems should also incorporate anti-freezing and insulation measures for the winter season.

4.3 Water Source and Steam Turbine Cooling Method

Kazakhstan has more than 11,000 rivers of various sizes, most of which are inland rivers and seasonal streams. Despite the large number of rivers, the country is still classified as water-deficient. The main rivers in the western region of Kazakhstan include the Syr Darya, Ural River, Emba River, Ili River, Irtysh River, and Ishim River, which are important water sources for the area. Additionally, the Caspian Sea, which partially belongs to Kazakhstan, provides a vast water area for the country.

When the proposed site of the project is near the Caspian Sea, seawater can be considered as the circulating cooling water source. Due to the strict protection policy of the Kazakh government on the Caspian Sea, if once-through seawater cooling (OTSC) system is to be used, it is necessary to conduct environmental impact assessments in advance in accordance with regulations such as the Environmental Protection Law of Kazakhstan and the Water Code of Kazakhstan, and obtain the relevant permits issued by the government. In addition, according to the author's experience, the local environmental protection department generally requires that the temperature rise of water intake and drainage in the Caspian Sea should not exceed 5°C, and the maximum drainage temperature should not exceed 30°C. Therefore, the circulating water ratio of OTSC system may be higher.

If there are other available water sources near the proposed project site, and after a technical and economic comparison, wet cooling tower system (WCTS) can be another alternative solution.

When the proposed project site is located in an area with scarce water resources, and the water consumption of WCTS cannot be met, an air cooling system can be considered. This option conserves water resources, but compared to wet cooling methods, it involves higher investment costs and results in higher turbine back pressure. Some of the existing CCGT power plant projects in the western region of Kazakhstan have adopted air cooling systems.

4.4 Interrelation between Installed Capacity Scale and Main Equipment Selection

Given that Kazakhstan's current power transmission and distribution system is relatively weak and most of the existing generating units are relatively old, the author concludes that in the western region of Kazakhstan, before the successful upgrade of the power grid in the coming years, new CCGT power plant projects will mainly fall into two categories: (1) Constructing small-to-medium units around existing main substations and transmission lines to meet the growing electricity load demand in the western region. (2)Constructing new units based on the existing old generating units to fill the capacity gap caused by the actual reduced output of the old units. It is recommended that new CCGT power plant projects adhere to the principle of being economical and practical. In the coming years, market opportunities for small-to-medium units may be higher than those for large units.

According to the author's experience, the local government may put forward dual fuel requirements for new CCGT power plant projects to improve the operation reliability of power plants. In addition to conventional natural gas, gas turbines may also be required to adapt to other fuels such as light diesel or ethane. This is not common in China. In recent years, with the development of gas turbine equipment technology, the trend has been towards more refined designs in pursuit of greater capacity and higher efficiency. Currently, most of the latest and advanced gas turbines are typically designed for single-fuel use, specifically natural gas. Gas turbines that are suitable for dual-fuel applications are often models that have been mature for many years. If dual-fuel capability is required, the subsequent selection of the main equipment will be significantly limited, and both the production cycle and equipment cost will be greatly affected. According to the author's investigation, the dual-fuel requirement is not mandatory in Kazakhstan. Unless the local government can give sufficient subsidies or other commitments, investors are advised to consider it carefully.

In addition, Kazakhstan's natural gas is usually symbiotic or associated with oil, and the oil associated gas usually contains more impurities, including sulfide, soluble oil, etc; Moreover, the gas supply pressure of some existing natural gas pipelines in Kazakhstan is low, and some are even lower than 2.0MPa(g). At present, most mainstream gas turbine models have high requirements for fuel quality, so it may be necessary to properly pretreat the natural gas transported by the natural gas pipeline network before entering the gas turbine to remove impurities. If the natural gas supply pressure cannot meet the gas turbine inlet requirements, it is also necessary to consider setting a supercharging device to meet the requirements of gas turbine use.

4.5 Utilization Hours, Gas Prices, and Grid-connected Electricity Price

According to the statistical data from the 2023 Kazakhstan Power System Annual Report, the average annual utilization hours for gas-fired power plants nationwide are approximately 5,352 hours. If a power plant is located near a large chemical industrial park with stable electricity demand, the utilization hours of the power plant would be even higher. The western region of Kazakhstan is situated at the source of natural gas, where the price of natural gas is much lower than that in China. For example, in Mangystau Oblast, where the author has experience, the gas price is about 0.35 Yuan/Nm^3, while in Atyrau Oblast, the gas price is even lower than 0.2 Yuan/Nm^3. Kazakhstan's gas-fired power plants adopt a two-part tariff system for grid-connected electricity, consisting of capacity pricing and energy pricing. It is suggested that the investor should strive for favorable on grid price and higher annual utilization hours in the early negotiations to improve the economic benefits of the project.

5. Conclusion

In summary, Kazakhstan, as an important node of the Belt and Road Initiative, is rich in energy resources and has great development potential. However, the country faces challenges such as imbalanced power resource development, severe power shortages, and a weak power transmission and distribution network, which pose significant difficulties for new gas turbine projects. Currently, there are few gas turbine projects in Kazakhstan invested in or undertaken by Chinese companies.

By analyzing the local resource conditions, power demand, and the current status of the power grid, and combining the author's own experience, this paper has proposed a series of characteristics and considerations for the preliminary design of new CCGT power plant projects in the western region of Kazakhstan. In the future development of gas turbine projects in the western region of Kazakhstan, the preliminary design experience put forward in this paper can be referred to, and specific analysis and decision-making should be carried out in combination with the local actual situation to further explore the market for gas turbine projects in Kazakhstan.

References

[1] Investment and Cooperation Guide for Countries and Regions: Kazakhstan (2023 Edition)
[2] Probabilistic Seismic Hazard Assessment of Kazakhstan and Almaty City in Peak Ground Accelerations, N.v. Silacheva, U.K. Kulbayeva, N.A. Kravchenko, 2018.