

Research Progress and Suggestions on Natural Gas Industry Technology Revolution in the Context of Energy Revolution

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Abstract: The energy revolution is an important driving force for the progress of productivity and civilization in human society. As a big country in global energy consumption and carbon emission, promoting the energy revolution is a strategic choice to ensure the sustainable development of China's energy industry, which is in line with China's national conditions of the construction of modern energy system. Based on the strategic background of the energy revolution, this paper combines China's natural gas production capacity and consumption demand in the context of national conditions, and from the perspective of technological revolution, we have sorted out the research results of relevant scholars on the natural gas industry and the technological development of the whole industry chain of "production, supply, storage and marketing", and discussed the technological development of China's natural gas industry in the context of the energy revolution. The results of the study show that: (1) the innovative technology of natural gas industry is diversified, low-carbon and green development, but from the dimension of safety, stability and economy, the performance is relatively weak. (2) The overall synergistic development of the whole industrial chain technology is uneven, the gap between supply and demand is increasing, and the degree of information and intelligence is low. And then for the development of China's natural gas industry technology puts forward proposals: (1) to promote innovative natural gas technology breakthroughs, integration of new areas of technology, to achieve the dual objectives of low-carbon economic development and environmental protection; (2) to increase natural gas exploration and development efforts, breakthroughs in the integration of the digital transformation of traditional exploration technology, and continue to support the increase in storage and production; (3) to accelerate the upgrading of natural gas supply and demand, and the establishment of a synergistic, intelligent, diversified pipeline network system. (4) Boost the construction of gas storage system, pay attention to the standardized gas storage management system, and play the role of valley cutting and peak leveling; (5) Build a new comprehensive energy service system, and build a multi-species, multi-link intelligent technology integration to create a new service system.

Keywords: Energy Revolution, China's Natural Gas Industry, Countermeasures Suggestions.

1. Introduction

Throughout the history of human development, there have been three energy revolutions. The energy revolutions have contributed to the industrial revolution, increased social productivity and promoted the progress of human civilization. The "13th Five-Year Plan" clearly puts forward to further promote the energy revolution, focus on promoting changes in the way of energy production and utilization, optimize the energy supply structure, improve the efficiency of energy utilization, and build a modern energy system that is clean, low-carbon, safe and efficient. Natural gas as one of the major energy sources, but also as the structure of energy consumption from high-carbon fossil energy to renewable energy development of the transition fuel, by 2060 to achieve the goal of carbon neutrality can't be separated from natural gas.

Carbon neutrality is a carbon-reducing energy revolution. China is the second largest economy in the world, and at the same time a major global energy consumer and carbon emitter. At present, the primary energy consumption structure in China is dominated by coal, and energy diversification. Under the goal of "double carbon", natural gas energy as the importance of excessive energy, vigorously increase the demand for natural gas and control carbon emissions is China's current carbon emission reduction is the primary

focus.

Driven by the energy revolution, the domestic energy structure is accelerating its transformation towards a diversified structure, and natural gas energy will make a great contribution in low-carbon energy [1]. Combined with the challenges and opportunities of the current energy revolution, how to green China's natural gas industry, this paper studies the iterative development of natural gas energy technology from the perspective of the technological revolution.

2. Natural Gas Industry Technology

2.1. Desulfurization Technology

Natural gas contains a certain amount of hydrogen sulfide, with the increase in demand for natural gas and awareness of environmental protection, natural gas desulfurization technology plays an important role in the energy industry. Natural gas desulfurization technology is widely used nowadays. Foreign scholars' study natural gas desulfurization technology including adsorption desulfurization, biological desulfurization, oxidative desulfurization and permeation gasification desulfurization. American Sulfatreat Company takes the iron oxide method to remove mercaptan by using granular iron oxide as desulfurizing agent. France IFP and LGI jointly developed a new liquid-phase oxidative desulfurization process on high-pressure kinda buzz its

desulfurization. And domestic scholars focus more on dry and wet desulfurization technology. Jing Caiyang from the physical properties of the medium used in the desulfurization technology is divided into wet desulfurization and dry desulfurization [2]. At the same time, along with the creation of industrial technology, the new desulfurization method is more innovative, the innovation of technology to control the loss of energy consumption, and effectively guarantee the efficiency of natural gas purification.

Desulfurization technology is very critical to the storage and transportation of the natural gas industry chain, but the current desulfurization technology is more complex and costly, making it difficult to promote on a large scale [3]. Combined with the increasingly stringent requirements under the current dual-carbon goal, the country should continue to promote the research of natural gas desulfurization technology, and effectively guarantee the safety, stability and economy of natural gas transportation and use.

2.2. Hydrogen Doping Technology

Natural gas hydrogen doping technology is one of the current low-carbon technologies in pursuit of cleanliness and environmental protection. Under the energy revolution to promote the energy transition process, the research and application of domestic natural gas hydrogen doping technology has also achieved certain development. Currently, the domestic natural gas hydrogen doping technology can be divided into two ways: one is the direct mixing of hydrogen and natural gas, and the other is the hydrogen storage and mixing technology [4]. The main manifestations of the two ways include thermal deconstruction reaction, hydrogenation reaction and substance-mediated hydrogen absorption reaction such as adsorbent membrane. By changing the technology, it is obvious that natural gas hydrogen doping technology can improve the energy utilization efficiency of natural gas, reduce carbon emissions, and achieve carbon neutrality more quickly. However, Li Linhong et.al agreed that natural gas hydrogen doping technology is green and clean, but also pointed out that the current hydrogen doping technology needs to be further solved in terms of the cost of the technology, safety and the source of hydrogen [5].

3. Natural Gas Industry Chain Technology

Natural gas industry chain refers to a collection of upstream, midstream and downstream industries linked by the output, transportation or consumption of natural gas and its by-products [6]. Generally speaking, natural gas exploration and development are collectively called upstream, natural gas storage and transportation facilities are called midstream, and natural gas consumption and utilization are collectively called downstream. From the data, China's natural gas production is much lower than the consumption, the corresponding production growth rate is also lower than the consumption growth rate, the gap between supply and demand is increasing, and at the same time, the industry development with the uncertainty of the external environment to increase the risks and challenges. Therefore, it is necessary to analyze the development of technology from the perspective of the whole natural gas industry chain, establish and improve industrial risk prevention and protection, and promote the smooth operation of the whole natural gas industry chain.

3.1. Natural Gas Exploration and Development Technology

At present, the exploration and exploitation level of natural gas resources in China is relatively low and is in a period of rapid development. Natural gas exploration and exploitation technology is also developing and achieving some new results. According to the data released by the National Bureau of Statistics of the People's Republic of China and other data, in 2023, China's natural gas production continued the trend of steady increase in recent years. China's annual incremental natural gas production has risen each year from 2014 to the present. In line with the current effectiveness of natural gas exploration, it reflects to a certain extent that natural gas production technology is also in the stage of continuous development.

In the field of natural gas extraction, the traditional extraction technology methods in the energy loss and extraction efficiency performance are poor. In the context of energy reform and upgrading "carbon peak, carbon neutral" strategy, scholars explore the optimization of natural gas extraction technology. Jin Gang and Huang Xin summarized that the extraction technology should be combined with the environmental characteristics of natural gas fields, the scientific use of hydrochloric acid treatment process, plunger gas lift drainage gas extraction process, electric submersible pump injection process can effectively improve the natural gas extraction efficiency, reduce energy consumption, and reduce the adverse impact on the environment [7]. Guo Tianchao and Liu Bo et al. put forward a systematic exploration process system, i.e., to create an integrated technical process of exploration and development, and advocate multi-technology combinations for exploration [8]. In the upstream of the industrial chain, natural gas extraction investment decision-making.

It can be seen that the innovative breakthroughs in natural gas industry technology in exploration and extraction have provided important support for the rapid growth of natural gas production, and some of the new energy technologies are even at the forefront of the world. And for the comprehensive utilization, multi-energy complementary energy technology is still in the weak field, the future exploration and extraction technology and other information technology automation technology combined use will promote the further development of the natural gas industry.

3.2. Natural Gas Pipeling Transportation Technology

At present, many scholars at home and abroad have conducted in-depth research on natural gas pipeline network technology, including the use of algorithms to optimize the operating parameters of the pipeline network, so that it can meet the specific optimization objectives and complete the natural gas transmission and supply safely, reliably and economically. The strategy of one nationwide network integrates domestic natural gas resources and market consumption into the pipeline network system for unified analysis. However, the original Excel-based pipeline-by-pipeline balance analysis is increasingly not adapted to the business requirements, and more comprehensive and systematic analysis methods and models need to be developed. 2014, Chen Zhenghui studied the optimization and allocation model of natural gas inter-provincial sales by using the linear programming method [9]. In 2020, Li Zhenbing et al. realized

the optimization of natural gas supply under the multi-competitive market by establishing mixed-integer quadratic programming and mixed-integer linear programming models, and combining particle swarm algorithms to solve the model [10]. Foreign scholars study the optimization problem of transmission system more from the combination of mathematical model and software platform. Ali Azadeh further considered the environmental impact of greenhouse gases generated in the process of natural gas production and transportation, and regarded the parameters of natural gas demand, storage tank capacity and cost as fuzzy parameters, and set up a dual-objective fuzzy linear programming model aiming at the minimization of economic cost and the minimization of the cost of greenhouse gas emission. . ULSTEIN N L et al. established a corresponding production planning optimization model with maximizing the production efficiency of offshore gas fields as the objective function, taking production, transmission, processing and marketing links as physical constraints, and considering natural gas quality constraints in the transportation link [11]. BARTON P I established a production and transmission planning model for the natural gas value chain, which increases the consideration of the gas wells, pipelines, the pressures and flow rates in the pipeline nonlinear constraints between them [12].

In summary, the literature at home and abroad focuses more on the use of modeling algorithms to solve the problem of natural gas industry chain supply based on specific environmental constraints, and the limited application environment tends to increase the difficulty of modeling in the strategic goal of pipeline network. The overall optimization of energy supply from a systemic perspective is rarely considered. Therefore, it is of great significance to carry out research on natural gas supply technology that meets the conditions of multiple environments.

3.3. Natural Gas Storage Technology

Natural gas storage is an important part of natural gas transmission and distribution system, which is an important project for seasonal safety peak adjustment and ensuring continuous and smooth gas supply, and the construction of gas storage to improve the natural gas pipeline network is an important measure to ensure the safe supply of natural gas. China's construction of reservoirs later than developed countries, and based on the complexity of the domestic hard conditions, foreign mature oil and gas reservoirs and salt cavern type reservoirs and other theoretical technologies can not effectively guide the domestic. With the relevant state ministries and commissions intensively issued documents, requiring all-out efforts to do a good job in the construction of natural gas production, supply, storage and marketing system, to make up for the short board of insufficient gas storage capacity. Nowadays, it has gradually formed an important breakthrough in the theoretical system and technical system of "site selection, design, construction and operation" of gas storage.

The dynamic airtightness of the gas storage reservoir structure is the primary issue of site selection evaluation, the current domestic dynamic airtightness evaluation technology integrates the principles of rock physics, geomechanics, fluid mechanics and other multidisciplinary principles, to solve the dynamics of the whole life cycle of the gas storage reservoir. In the design of gas storage reservoirs, it is difficult to accurately describe the reservoir capacity due to the problem

of high-speed injection and extraction seepage mechanism in medium and low permeability reservoirs, so the high-speed unsteady seepage mechanism is established to characterize the reservoir capacity equation [13]. The design of supporting well shape and wellbore, as well as the strengthening of drilling, cementing, and well completion supporting technologies have been researched to improve the construction technology of gas storage reservoirs. In the monitoring and operation, in the face of technical constraints, the environment is complex and variable gas storage project, should establish gas storage reservoir formation - wellbore - ground "trinity" real-time monitoring and early warning system and is a digital information management platform, to achieve the storage of static data storage, management and application of gas storage reservoir. It should realize the storage, management and application of static data of gas storage reservoirs.

Domestic gas storage development started late, but after more than 20 years of development, the demand increases, the number of reservoirs increased, and formed a certain scale of gas storage, China's gas storage technology and standard system framework has been initially established. However, the key technology reserves for complex address conditions are still weak, for the specific long-term gas storage reservoirs of high-speed alternating gas injection and gas extraction, should still pay attention to its potential risks.

3.4. Big Data Technology for Natural Gas Downstream

For the downstream of the natural gas industry, oil and gas enterprises using traditional management and operation methods face the following two problems: one is to master comprehensive and detailed customer sales data information but it is difficult to utilize the information to mine, the ability to process large amounts of information is weak, and it is difficult to establish an effective sales information model; the other is that it is difficult to meet the actual production and operation needs of enterprises based on the traditional statistics and economic indicators to analyze the predicted market price. The other is that the predicted market price based on traditional statistics and economic indicators can hardly meet the actual production and operation needs of enterprises. With the energy reform promoting oil and gas system reform and energy transformation, natural gas sales enterprises are transforming from resource-centered sales-oriented enterprises to customer-centered value-added service-oriented enterprises. Currently, scholars mainly tap the potential value of data through the rational application of big data technology to provide stronger technical support for the downstream of the industry.

The natural gas market in Europe and the United States has matured earlier, and many foreign companies already have more mature forecasting software, which can output specific data such as the number of existing users, the industry to which they belong, and various index parameters into price-related forecasts through models. For example, the Gas Load Forecaster natural gas forecasting software developed by the British ESI company inputs the historical price of natural gas, price differences and other data, and effectively forecasts the need for natural gas for a period of time in the future through the software. With the continuous maturation of the domestic natural gas market, some scholars have also carried out sales volume forecasting research on the differences in consumption characteristics of different customers. The

further utilization of big data by enterprises will inevitably improve the quality of service to customers, and under the increasing maturity of artificial intelligence technology, various intelligent algorithms will improve the prediction accuracy of enterprises, however, the current research results are more focused on different types of customers according to the specific conditions of the information to give predictions, but the model is difficult to be dynamically adjusted according to the actual situation, which often makes it difficult to implement the decision.

In recent years, on the price forecasting of natural gas, domestic scholars have used practice series forecasting models to analyze and forecast natural gas price changes. However, due to the limited effective data in the domestic market, the forecasting effect of the existing literature on the market is still unsatisfactory. The forecasting method of time series still has large limitations in the domestic market application. With the rapid rise of artificial intelligence, various artificial intelligence methods are obviously better than traditional forecasting methods, but the technology is still in its infancy in the natural gas downstream market, and more real data should be available to verify the feasibility of its application.

4. Future Prospects

4.1. Promoting Innovative Technologies for Natural Gas Industry

The current natural gas industry has entered a brand new era, and will become the protagonist of domestic fossil energy in the future. As the demand for natural gas increases year by year, it promotes breakthroughs in natural gas technology innovation and realizes the dual goals of low-carbon economic development and environmental protection. Although China has abundant natural gas resources, but the original natural gas sulfur compounds greatly affect the economic value of natural gas, encourage the diversified development of desulfurization technology, improve the desulfurization technology, and effectively protect the natural gas transmission and use.

At present, the integration of domestic natural gas and hydrogen energy development has a corresponding foundation, the future should further promote the deep integration of natural gas and hydrogen energy industry chain, to realize the natural gas industry in the upstream hydrogen production, midstream hydrogen doping, downstream hydrogen pattern, natural gas and hydrogen as an important carrier linking traditional energy and new energy sources, to accelerate the integration of natural gas and new energy sources, to promote the synergistic development of intelligence, greening and to build a new type of energy system. It will accelerate the integration of natural gas and new energy, promote intelligent, green and synergistic development, and build a new development pattern under the new energy system where natural gas and new energy complement each other.

4.2. Increase Natural Gas Exploration and Development

China's natural gas exploration in general is in the early-mid stage, and in the future, it is still possible to explore and develop atmospheric fields, with a high potential for rising production. Facing the huge development opportunities and challenges in the future, technology research and

development and equipment manufacturing should be comprehensively upgraded to form a multifaceted comprehensive utilization and multi-energy complementary energy technology in terms of devices, materials, software and manufacturing. With the maturity of drilling technology of 10,000-meter extra-deep wells and the efficient development of deep, low-permeability, offshore, and unconventional hydrocarbons, it is necessary to increase the digital transformation of the traditional exploration technology and deeply integrate intelligent technology into various fields of engineering technology to form a new generation of artificially intelligent exploration and development technology.

4.3. Optimization of Natural Gas Supply

Upgrading domestic natural gas pipeline facilities, laying out the national pipeline network, expanding imported pipelines, and establishing a synergistic, intelligent and diversified pipeline network system, so as to effectively guarantee the safety and efficiency of natural gas supply. As the scale of development of the natural gas industry continues to expand and the degree of information intelligence continues to improve, continuous supporting construction of pipeline network facilities should be increased. At the same time, we should innovate natural gas pipeline gathering and intelligent pipeline network technologies, continue to promote the interconnection of regional pipeline networks, systematically optimize the domestic energy supply, overcome the impact of complex environments and improve the strategic pattern.

4.4. Boosting Gas Storage System

Gas storage plays a key role in the natural gas industry chain, but based on the complex geological conditions in China and the late start of development, "storage" is also a relatively weak link in the whole natural gas industry chain. Although Europe and the United States in the gas storage technology is more mature, but the complexity of the domestic unique conditions of the construction of the reservoir is difficult to refer to foreign technology, in the current storage capacity and infrastructure constraints, the future should pay attention to the gas storage risk warning technology, improve the risk assessment system, and achieve standardization. At the same time, we should improve the risk management and control of the whole life cycle of gas storage reservoirs, create an intelligent management system, and maximize the regulating role of gas storage reservoirs in "cutting down the valley and leveling the peak".

4.5. Building New Integrated Energy Service System

Digital information technology is changing the global energy system, and digitalization has the potential to build a new architecture of interconnected energy systems. Currently, technologies such as 5G, IoT cloud computing, big data, artificial intelligence and block chain are gradually being applied to electric power, natural gas and other fields, which are changing the mode of energy production, operation and transmission, and are gradually forming a new type of integrated energy service system. Although there are few natural gas companies in China that use information for management, there are still drawbacks in the information processing capability of the system as well as the synergistic capability between systems. In the future, we should continue

to study coal, oil and gas, electric power and other technology pathways, build a smart technology system, and try to achieve synergy between horizontal “electricity, heat, cold, gas, water” multiple energy varieties and vertical “source, network, load, storage” multiple supply links.

References

- [1] DU Xiangwan. Energy Revolution for Sustainable Future [J]. Journal of Beijing Institute of Technology (Social Sciences Edition), 2014, (5): 1-8.
- [2] JING Caiyang. Research and Application of Natural Gas Desulfurization Technology [J]. China Petroleum and Chemical Standards and Quality 2021.10.3969/j.issn.1673-4076.2021.24.068 (in Chinese)
- [3] WANG Shengli. Analysis of research status and development trend of natural gas desulfurization technology [J]. Science and Technology Prospect, 2016, 9.
- [4] SHEN Dandan, YAO Talent, LIU Jingjing. Application and key technology of natural gas hydrogen doping in the context of carbon neutrality [J]. Shanghai Energy Conservation, 2022, 3: 277-282.
- [5] LI Linhong Zheng Shujing Chen Jisheng Li Xuehua. Research on the development strategy of China's hydrogen energy heating industry [J]. Thermal Power Generation, 2022, 51(11):56-64.
- [6] LIU Dingzhi, ZHANG Yuantao, LIANG Yan. Natural gas industry chain system optimization technology and its outlook [J]. Chemical Automation and Instrumentation, 2023, 50(5):632-643.
- [7] JIN Gang, HUANG Xin. Exploration of natural gas extraction process technology [J]. China Petroleum and Chemical Standards and Quality, 2023.
- [8] GUO Tianchao, LIU Bo, DENG Ming. Research on natural gas exploration and development [J]. Shanxi Chemical Industry, 2022(006):042.
- [9] Chen Zhenghui. An optimization model of the provincial natural gas sale allocation based on the profits of suppliers [J]. Natural Gas Industry, 2014, 34(12):152-155.
- [10] LI Zhengbing, LIANG Yongtu, XU Ning, et al. Optimization of pipeline natural gas supply chain considering market competition [J]. Oil and Gas Storage and Transportation, 2021, 40(1): 113.
- [11] Ulstein, N. L., Nygreen, B., & Sagli, J. R. (2007). Tactical planning of offshore petroleum production. European Journal of Operational Research, 176(1), 550-564.
- [12] Barton P I, Selot A. A production allocation framework for natural gas production systems[M]//Computer Aided Chemical Engineering. Elsevier, 2007, 24: 539-544.
- [13] ZHANG Gangxiong, ZHENG Dwen, ZHANG Chunjiang, et al. Development and application of information data management platform for underground gas storage [J]. Oil and Gas Storage and Transportation, 2015, 34(12):4.