A review of the research on policy and economy of natural gas distributed energy in China

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Abstract. This paper sorts out the relevant research on policy of natural gas distributed energy in China and establishes a policy research framework from three aspects: economic incentive policy, grid connected power generation policy and policy research method. And then it is discussed in detail. The economy of natural gas distributed energy is analyzed from three aspects: influencing factors, economic indicators and its research methods. Finally, relevant recommendations are proposed to promote the development of natural gas distributed energy in China.

1. Introduction

With the increasingly prominent problems of energy consumption and environmental pollution, all countries have taken energy efficiency, pollution emission reduction and green environmental protection as the focus of energy development [1]. Natural gas distributed energy is widely recognized by domestic and foreign governments because it is built on the user side and it can save energy and protect environment, it also has the superiority of cleanliness and high efficiency [2,3]. The government and relevant departments have successively promulgated a number of policies on natural gas source in DES.

The development of natural gas source in DES has attracted more attention of many scholars. Many scholars have proposed that the evolution of DES resource lies in policy [4], moderate policy incentives are the main means to accelerate the prosperity of the DES resource economic market [5]. Economy is also the key to the evolution of natural gas source in DES and a major manifestation of its development. The economy reflects the evolution of natural gas source in DES from the market perspective.

Combined with the above paragraph, this paper sorts and resolves those relevant references about the policy of natural gas distributed energy resource, constructs a policy research framework, and studies the policies of natural gas source in DES of economic incentive policies, grid connected power generation policies and policy research methods. The economy of NG source in DES is studied from influencing factors, economic indicators and its research methods.

2. Research on the policies of natural gas distributed energy

At the beginning of 1990, some scholars put forward the idea that attention should be paid to the development of distributed energy [6]. The countries which are overseas, like Europe and the USA, have basically formed perfect policy systems and mature technology systems [7-9]. The research on the policies of natural gas source in DES in China and its development and utilization are at a development stage. Therefore, this paper sorts out the existing research on the policy of natural gas
source in DES in China, and further explores the policy rules of its development to push forward the evolution of the natural gas source in DES industry.

2.1. Overview of the policy research framework
Governments at all levels in China have promulgated a lot of policies to push forward the development of natural gas source in DES. These policies involve many aspects. After reviewing these policies, Han Xiaoping [10] finds that the number of policies is large and involves a wide range of content, but these policies are lack of continuity, systematicness, coordination and integrity. Xu Qinhua et al. [11] also propose that the government should establish a unified and detailed policy system in terms of technical standards, fiscal and tax policies.

The continuous research on the policy of natural gas source in DES and the government's continuous improvement of the policy for natural gas distributed energy make the policy support gradually shift from macro policy to substantive and more targeted policies [12,13]. Based on the scholars' research on policies and relevant policies promulgated by the government, the policy research framework for natural gas distributed energy is constructed from economic incentive policies, grid connected power generation policies and policy research methods. Its specific frame diagram is shown in Figure 1.

![Policy research framework for natural gas distributed energy.](image)

In summary, when natural gas source in DES is increasingly valued, the policy contents and measures promulgated by China are gradually improving, and the scholars' research scope of the policy is becoming more and more extensive. This paper has established the policy research framework for existing research results and conducts detailed study and analysis.

2.2. Economic incentive policy
According to the research on current references, the policies of NG source in DES are still not perfect from the perspective of specific implementation. For relevant policies and projects in Guangdong Province, Tong Gang [14] proposes that the current policy support in terms of fiscal and tax, finance and price is still not perfect. Therefore, thinking from the economic level, energy price policy, subsidy policy and tax policy are analyzed for the research object.

2.2.1. Analysis of energy price policy. There are not many pilot cities for natural gas distributed energy projects, and their costs are high. Compared with other low-cost and large-scale traditional energy sources, the market competitiveness of natural gas distributed energy is inferior to that of traditional energy. Therefore, the price policy of natural gas distributed energy plays a decisive role in its development.

2.2.2. Analysis of subsidy policy. Many of the equipments of natural gas distributed energy systems in China rely on imports, and the overall cost of the system is expensive. At the same time, because in terms of price, natural gas is more expensive than traditional energy sources (such as coal), the
economic benefits of natural gas source in DES are poor. From the perspective of supporting the growth of natural gas source in DES, the implementation of subsidy policies is indispensable.

2.2.3. Analysis of tax policy. Energy tax policy in China is scattered in other policies, and there is no specific energy tax policy. With the development and attention of new energy and distributed energy sources, more and more relevant tax policies have been promulgated.

Based on three perspectives: price policy, subsidy policy and tax policy, this paper analyzes and studies the relevant references on natural gas distributed energy. The relevant views of the three aspects are shown in Table 1.

| Scholar (references) | Points |
|----------------------|--------|
| **Price policy**     |        |
| Qiao Zhenqi [15]     | Emphasize the importance of price, the state promulgates policy support |
| Paltsev S et al. [16]| Price reform: The complete market mechanism driven by the interaction of natural gas supply and demand |
| Hu A et al. [17]     | Price setting is closely related to the supply and demand of energy market |
| Qin Y et al. [18]    | The government should strive to move toward the pricing mechanism of the market |
| **Subsidy policy**   |        |
| Liu Qingrong [19]    | Adjust the subsidy policy for natural gas distributed energy |
| Dong R et al. [20]   | Impact of subsidy policies in two different cities on that growth of NG source in DES |
| He R M et al. [21]   | Subsidies for NG source in DES mainly include on-grid tariffs, technology research and development, investment, etc. |
| Ren Hongbo et al. [22]| Accelerates the formulation of specific subsidy standards in China |
| Pani M et al. [23]  | The impact of different incentives on subsidy policies |
| Wang Yanling et al. [24]| Analyze the issue of subsidy policy and propose a phased subsidy mechanism |
| **Tax policy**       |        |
| Xia B et al. [25]    | Tax policy has an important influence on the evolution of new energy industry in China |
| Ding Yun et al. [26] | Tax policy has played an important role in promoting new energy production and consumption, and environmental improvement. |
| Li Jing [27]         | At present, energy tax rate in China is unreasonable, and a tax system that support the growth of DES resource has not yet been formed. |
| Song Xiaojing [28]   | Distributed energy still has unreasonable and lagging phenomena in tax policies. |

In summary, a large number of researches and analysis have been done from three aspects: energy price policy, subsidy policy and tax policy. The formulation of energy prices is not only determined by the government, but also closely related to the supply and demand of the resource market. The formulation of subsidy policies needs to be detailed to determine the specific scope of subsidies (such as electricity/gas price subsidies, etc.) and subsidy standards (such as phased subsidy mechanisms). Tax policies need more attention in the growth of natural gas source in DES in China.

2.3. Grid connected power generation policy
Natural gas source in DES should be connected to public electrified wire netting to improve the economy and reliability of their operation. China has promulgated the regulations on "Distributed Power Access Grid Technical Regulations" and "Distributed Power Generation Grid Management Measures". Therefore, grid connected power generation is an indispensable stage at the growth of...
natural gas source in DES, it is also that focus of the growth of current natural gas source in DES in China.

2.3.1. Analysis from the technical field. Hua Ben [29] proposes that China should tap the potential of natural gas generate electricity and cooperate with large electrified wire netting to achieve win-win situation. Qian Jun et al. [30] introduce the research progress of distributed generation technology in detail and put forward relevant suggestions. Li Ping et al. [31] study the introduction of distributed generation technology into the distribution network and analyze its impact on the distribution network. Kakran S et al. [32] summarize the scholars’ solutions to the conventional grid problems in distributed energy generation, and propose that the focus should be placed on the connection between distributed energy generation and existing grids.

2.3.2. Analysis from the management field. Xu Jiexian et al. [33] propose that there are many problems between grid companies and distributed generation entities that need to be adjusted. He Runmin et al. [34] propose that the distributed power grid connected standard system lacks implementation rules and needs to strengthen policy support. Liu Manping [35] suggests that the relevant departments should lay down measures for managing distributed energy enter into the grid as quickly as possible, clarifies the application documents and approval procedures for grid connected power generation. Zeng M et al. [36] study the distributed energy grid connected management model, including operation management, organization management and grid connected incentive policies, and propose a coordination management mechanism. Bell K et al. [37] discuss regulatory and policy challenges for distributed energy and highlight the major challenges faced by policymakers in terms of marketplace and regulatory arrangements.

In summary, many scholars have conducted in-depth research on the grid connected power generation policy of natural gas distributed energy from the aspects of technology and management, which makes the technology and management more perfect. This has important practical significance for advancing the growth of natural gas distributed energy in China.

2.4. Policy research method

In the above research on the references of policy, the energy price policy and subsidy policy in the economic incentive policies are the key and play a decisive role. Therefore, the research method of policy is analyzed from two aspects: energy price and subsidy.

There are many research methods for energy prices and subsidies. Table 2 shows the different research methods and corresponding research purposes. In these studies, energy prices and subsidies are analyzed in depth through the construction of energy price models and subsidy models.

Table 2. Research methods and purposes of energy price and subsidy.

| Methods (References) | Purposes |
|----------------------|----------|
| Energy price         |          |
| Structural self-regressive model [38] | Analysis of the determinants of natural gas price |
| CGE model [39]       | Analyze changes in natural gas price and recommend differentiated price |
| Cost method, energy saving method [40] | Develop distributed natural gas on-grid tariffs |
| Dynamic game model [41] | The impact of natural gas price on power generation |
| Energy subsidy       |          |
| Price gap method [42] | Estimating the scale of natural gas price subsidies |
| Dynamic subsidy model [43] | Provide initial investment subsidies to the project |
| Optimization model of production decision [44] | Determine the optimal pricing by subsidy research |
| Price gap method, LMDI method [45] | Natural gas distributed energy subsidy and the impact of changes in subsidies |
In summary, the research methods for energy price and energy subsidy are analyzed separately, and the quantitative and concrete models of price and subsidy are established to analyze the determinants of natural gas price, and analyze the best price and subsidy through the existing data to further advance that sustainable growth of NG source in DES.

3. Economic research
The development of NG source in DES is not only driven by policies, but its economy is the basis of survival. And its economy will be affected by various costs and income factors from upstream and downstream (independent variables), such as natural gas costs, equipment costs, electricity sales prices, steam prices, and financial subsidies. Combined with some methods and models, any change in these factors will have an influence on the economy of natural gas source distributed energy system (such as net present value, project internal rate of return, and payback period). A block diagram of the economic research is shown in Figure 2.

3.1. Research on different influencing factors
Variation of different influence elements of natural gas distributed energy projects can have an impact on economy. By studying the different degrees of these influencing factors, we further analyze the focus factors that have an impact on economy.

Through the analysis of the references, it is found that there are many types of factors that affect the economy of natural gas distributed energy projects. Based on different influencing factors, scholars have done some related researches. For the study of single influencing factors, most of them are based on the natural gas price as an influencing factor, and the reasonable natural gas price is analyzed. In addition to analyzing reasonable prices, the study of various influencing factors usually analyzes the elements that have the most influence on those projects among the multiple influencing factors. Table 3 shows the different influencing factors and their appearance in the references.

| Influencing factor | References                  |
|--------------------|----------------------------|
| natural gas price  | [46,47,48,49,50,51,52]      |
| Electricity price  | [47,48,49,51,52]            |
| Steam price        | [47,49]                     |
| Subsidy            | [48,51]                     |
| Cost price         | [47,48,49,51]               |

In summary, there are many factors affecting the economy of NG source in DES projects, and that largest influential factor is the natural gas price. In the meantime, factors such as investment cost,
subsidy, steam price and electricity price will affect the economy of the project and the degree of impact will be different.

3.2. Research on different economic indicators

The economy is an important criterion for measuring whether a project is losing money or not. Different economic indicators reflect different angles of projects' economy. The economic indicators are classified as shown in Table 4. The time indicator mainly reflects the length of the investment recovery time of the project. The monetary indicator mainly reflects the cash flow changes of the project and draws the feasibility of the project. The efficiency indicator mainly reflects the utilization rate of the project and determines the direction of investment.

Table 4. Economic indicator classification.

| Indicator type     | Specific indicators                                    | References         |
|--------------------|-------------------------------------------------------|--------------------|
| Time indicator     | payback period, breakeven point                       | [47,48,49,50]      |
| Monetary indicator | net present value, present value of cost, annual value of cost | [46,47,50,51,51] |
| Efficiency indicator | net present value rate, internal rate of return, total investment yield, investment profit and tax rate | [48,49] |

In summary, economic analysis can be reflected by different economic indicators. These economic indicators reflect the economy of natural gas distributed energy projects from different perspectives, which helps investors understand the project from different angles and decides whether the project is feasible.

3.3. Research on different methods

For the economic research of natural gas distributed energy systems, different research methods are often used based on different research objectives (economic indicators). Table 5 shows the research methods corresponding to different economic indicators.

These models were created to optimize the economy of natural gas distributed energy projects. There are many indicators for measuring economy, and different models are established for different economic indicators. By establishing these different research methods, scholars analyze the economy of natural gas distributed energy projects for a given independent variable (influencing factors). Combined with the model, we analyze the economy of natural gas distributed energy projects from multiple angles and determine the optimal value of the influencing factors.

Table 5. Research methods corresponding to different economic indicators.

| Indicator type     | Methods (references)                                      |
|--------------------|-----------------------------------------------------------|
| Time indicator     |                                                           |
| Payback period     | Single and double factor sensitivity analysis [46]        |
| Breakeven point    | Single and double factor sensitivity analysis [46]        |
|                    | Economic benefit analysis model [50]                     |
| Monetary indicator |                                                           |
| Net present value  | Sensitivity analysis [47]                                |
|                    | Economic benefit analysis model [50]                     |
|                    | MILP model [51]                                          |
| Annual value of cost | Stochastic programming model [52]                        |
| Efficiency indicator |                                                   |
| Internal rate of return | Single and double factor sensitivity analysis [46]    |
| Return rate of investment | Technical economic evaluation method [48] |
In summary, for different types of economic indicators, a variety of research methods are given. The purpose of these research methods is to better study the relationship between independent variables (influencing factors) and dependent variables (economic indicators).

4. Conclusion
This paper reviews the research on policy and economy of natural gas distributed energy in China. In the study of policy, experts have conducted extensive and in-depth research on energy price policy, subsidy policy, tax policy and grid connected power generation policy, which has played a certain role in advancing the policy formulation on natural gas source in DES in China. In response to economic research, experts have carried on relevant researches based on the different influence factors and different economic indicators, pointing out the influencing factors and diversified economic indicators that should be focused on in their development. Based on the existing research results, the following suggestions are made:

1) Improve the policy system framework. Since the development of natural gas source in DES, it is necessary to continue to improve the part of its policy contents and measures. Its framework system should continue to improve in terms of finance (such as loan preferences, financing channels), administration (such as approval procedures), and the environment, and promote the growth of natural gas distributed energy.

2) Improve types of policy. At present, those policies of natural gas distributed energy in China have yet to be improved in terms of specific operational measures. Government departments should improve policies on tax incentives for natural gas distributed energy. In addition, Governments should consider the subsidy mechanism of natural gas distributed energy projects from multiple perspectives, such as installed subsidies and electricity/gas price subsidies.

3) Energy price formulation. Among the factors affecting the economy of natural gas distributed energy projects, natural gas price has received that highest attention as an influencing factor. Therefore, it is necessary to combine the actual project and the economic market to quantify the rationalization of prices and provide a reference for the government's pricing mechanism.

4) Project economic research. The economy of natural gas distributed energy is an important factor in determining its survival. The study of its economy should be combined with theory, evidence and methods.

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