Study of Nature Gas Distributed Energy System development space

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Abstract. Distributed natural gas energy plays an important role in the world low-carbon energy system. The development prospect of global distributed natural gas energy is considerable. And the installed capacity of natural gas distributed energy system (NG-DES) in China is increasing year by year. It’s urgent to clarify the development space of NG-DES for further healthy development. From the perspective of demand supply, China’s natural gas distributed energy development space is affected by social energy demand and other energy development levels. The application scenarios of NG-DES can be divided into commercial complex, industrial park, residential building, Internet data center and other application scenarios. This study summarizes the installed capacity of natural gas distributed energy in different projects under different scenarios, and calculates the new development space of natural gas distributed energy in China in 2020-2025. The results provide a reference for the rational and orderly development of distributed natural gas energy in China.

1. Introduction

Nature gas distributed energy system (NG-DES) is an efficient way for local energy supply. There are many progresses on the technology of NG-DES [1]. The shale gas revolution has brought substantial increase in natural gas supply [2]. In China, since the implementation of the National Energy “Thirteenth Five-Year Plan”, NG-DES installed capacity has been growing rapidly. It’s urgent to calculate the development space of NG-DES and clarify the growth space of installed capacity.

There are many researches discussing the feasibility of NG-DES projects. According to Ma et al’s sensitivity analysis, with the increase of feed-in tariff, and the decrease of local grid tariff and natural gas price, the economic performance of distributed energy system (DES) will become better.[3]. Alanne and Saari listed obstacles that restrict the development of small-scale DES and gave some solutions to increase their potential in Europe [4]. Liu analyzed the constraints of NG-DES development from the aspects of government rules and regulations, technology, and market, and then put forward some policy recommendations [5]. Xiao et al. proposed a method of predicting and analyzing the development potential of DES, and then analyzed the development potential of DES in Yunnan Province as an example [6].

Existing research qualitatively analyzed the feasibility and development obstacles of NG-DES. And it is urgent to put forward methods to measure the development space of NG-DES.
2. Analysis of NG-DES development space

2.1. Factors influencing the development of NG-DES
There are many influencing factors of NG-DES development space. And the relationships among the factors are complex, as shown in figure 1. In figure 1, the tail element of the blue arrow line promotes the element pointed by the arrow, that is, the increase of the former promotes the increase of the latter; on the contrary, the tail element of the red arrow line hinders the element pointed by the arrow, that is, the increase of the former causes the decrease of the latter.

![Figure 1. Influence factors network of NG-DES development space.](image)

The influence factors in the network mainly are social energy demand and the development of energy utilization projects. From the perspective of energy supply and demand, social energy demand can be supplied through renewable energy, thermal power and NG-DES projects, and there is a competitive relationship among various energy supply modes. Moreover, under the influence of energy conservation and emission reduction policies, the development of conventional thermal power projects is restrained to some extent, while in the long run, the development of renewable energy projects and the development of NG-DES are encouraged.

In addition, the relationship between renewable energy project development and NG-DES development space is complex: on the one hand, the development of renewable energy projects reduces the demand space for the development of NG-DES projects; on the other hand, due to the intermittence of renewable energy, the increase of renewable energy leads to the increase of the demand for energy supply reliability auxiliary services, which in turn will promote the development of NG-DES projects.

2.2. Typical application Scenarios of NG-DES
The typical application scenarios of NG-DES include commercial complex, industrial park, residential building and internet data center (IDC). The use of distributed natural gas energy brings various benefits, as summarized in table 1.

| Scenarios             | Benefits of using distributed natural gas as an alternative                                                                 |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------|
| Commercial complex    | reduce investment in facilities; adapt to load demands at different time periods and in different energy consumption areas; operate efficiently |
| Industrial park       | concentrate the operation and maintenance work of equipment; improve the overall operation efficiency and reduce management and maintenance costs |
| Residential building  | provide intensive energy supply for residential buildings                                                                   |
| Internet data center  | get rid of the dependence on power grid; realize local power consumption and comprehensive energy utilization; guarantee energy supply reliability |
3. Calculation process of development space for NG-DES

The remarkable feature of NG-DES is to promote the comprehensive utilization efficiency of energy, which requires high load matching. Thus, the development of NG-DES must closely integrate the characteristics of energy demand in specific application scenarios. Calculation process of development space for NG-DES is as follows:

(a) Divide NG-DES application scenarios and obtain the growth data $S_i$ of energy consumption area / rack in each scenario;

(b) Obtain the NG-DES capacity $P_i$ that can be installed for per energy consumption area / rack from existing projects;

(c) Calculate the development space $Q$ for NG-DES by equation (1):

$$ Q = \sum (k_i \times S_i \times P_i) $$

In the equation, $k_i$ is the reduction coefficient of application scenarios, indicating the proportion of power demand for each energy usage scenario to be satisfied by NG-DES. As a result of the limitation of natural gas supply, poor project economic performance, and other obstacles, the energy demand that is satisfied by NG-DES only accounts for a small part of the total energy demand [6]. Considering the installed capacity of natural gas fired power plants, gas electricity generation and total electricity consumption of the whole society in China, the value of $k_i$ for all the scenarios in this study is 0.0147.

4. Calculation of NG-DES development space

4.1. Growth data in typical application scenarios in China

The forecast for growth data is based on the data obtain from the National Bureau of Statistics and "Report of Market Prospective and Investment Strategy Planning on China IDC Industry (2019-2024)". The predicted results of growth data in 2020-2025 are shown in table 2.

| Scenarios            | Per energy consumption area / rack installable capacity |
|----------------------|--------------------------------------------------------|
| Commercial complex   | 7.387W/m²                                               |
| Industrial park      | 17.127W/m²                                              |
| Residential building | 0.144W/m²                                               |
| IDC                  | 3.083kW/rack                                            |

Table 2 shows that in the period of 2020-2025, among the four typical application scenarios, the new energy-consuming areas of industrial parks and residential buildings are large, reaching 13.1728 billion m² and 16.2273 billion m² respectively, and the new energy-consuming areas of commercial complexes are the smallest, only 1.3373 billion m². The number of new racks in IDC reaches 616155.

4.2. NG-DES installed capacity for per energy-consumption area / rack

Through existing projects, the installation data of NG-DES is obtained, and the NG-DES installed capacity for per energy consumption area / rack are summarized in table 3.

| Scenarios            | Per energy consumption area / rack installable capacity |
|----------------------|--------------------------------------------------------|
| Commercial complex   | 7.387W/m²                                               |
| Industrial park      | 17.127W/m²                                              |
| Residential building | 0.144W/m²                                               |
| IDC                  | 3.083kW/rack                                            |

Table 3. Per energy consumption area / rack installable capacity for typical application scenarios.
residential buildings, due to the lack of relevant data, we mainly refer to the NG-DES application case for hot water supply in hospital.

4.3. Development space for NG-DES in China
According to the data in table 2 and table 3, and using equation (1), the development space of China's NG-DES in 2020-2025 is calculated. The results are as shown in table 4.

| Development space | Commercial complex | Industrial park | Residential buildings | IDC |
|-------------------|--------------------|-----------------|----------------------|-----|
|                   | 145.216            | 3316.475        | 34.350               | 279.242 |

According to table 4, China's NG-DES development space in 2020-2025 is 3375.283MW. Among the four typical application scenarios, industry parks have the greatest development space is 3316.475MW. The development space of IDC ranks second, with the high scheme as 447.802MW, the low scheme as 110.682MW, and the difference as is 279.242MW. Commercial complex scenario ranks third, at 145.216MW. The development space in residential buildings for NG-DES is especially small, just 34.350MW.

4.4. Analysis for NG-DES development space in China
Based on the demand estimation of different scenarios, this study measures the potential of NG-DES in China in 2020-2025. The results are analyzed as follows:

Firstly, the developing space for NG-DES is limited and the development pace of new projects should be appropriately slowed down. According "13th Five-Year Plan" of Energy Development for China, the installed capacity of gas power generation will reach 110 million kW in 2020. If the proportion of NG-DES to gas power generation is similar to that of 2018, NG-DES installed capacity will reach 28,390 MW, with an increase of 6,890 MW over 2018, which is sufficient to meet future demand growth in 2020-2025.

Secondly, the development space is quite different under four typical application scenarios. There are two reasons, one is the different service orientation and industrial composition for both scenarios, the other is the positioning of NG-DES in energy supply. Thus, it is important to innovate the business models, which aims to improve NG-DES's construction and operation, and match different energy supply strategies.

5. Conclusion
NG-DES is cleaner, more efficient, flexible and reliable than traditional energy supply mode. The implementation of energy conservation and emission reduction policies will promote the development of NG-DES. According to the forecasting results, among the four typical application scenarios, industrial park has considerable demand, which is suitable for large-scale development. There is a little demand in commercial complexes and IDCs, and economic performance should be fully considered in the development of projects in these two scenarios.

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