Summary of Gridding-based Planning Method for Electric Energy Substitution Supporting Network

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Abstract. Electric energy substitution technology is of great significance for optimizing the final energy consumption structure, promoting energy conservation and emission reduction, and preventing air pollution. This paper aims to review the current research status of electric energy substitution technology and related fields, summarize the planning methods of electric energy substitution supporting network, and provide reliable network support for large-scale promotion of electric energy substitution. Firstly, the connotation, strategic significance and characteristics of electric energy substitution technology are summarized, and the basic structure of electric energy substitution technology is proposed. Then, the characteristics of network planning and gridding planning ideas are integrated into the gridding planning framework under the background of electric energy substitution is proposed. Finally, the development challenges of gridding planning methods in the current electric energy substitution background in terms of technology, mechanism and infrastructure are summarized, and looking forward to the development direction of the electric energy replacement supporting network plan under the background of the 14th Five-Year Plan and the new round of power system reform.

1. Introduction
Since the 13th Five-Year Plan, government at all levels in China have attached great importance to the prevention and control of air pollution, issued various environmental protection policies, and continuously tested, strengthened and enriched air pollution control measures[1-8]. In May 2016, the eight national ministries and commissions jointly issued the Guiding Opinions on Promoting Electricity Substitution, taking electric energy substitution(EES) technology as one of the important means to prevent and control environmental pollution, thus building a higher level and broader range power consumption market[9], to promote the sustainable development of energy and the construction of the global energy internet.

The current research on EES is mostly focus on qualitative analysis of EES potential, brief introduction of EES technology, development analysis of EES technology in the context of energy internet and power sales side reform, and comprehensive evaluation model of EES transformation projects. Literature[10] conducted a comparative analysis on the potential and development trend of EES in different scenarios and different industries. Literature[11] simulated the influence of factors such as population, economy, technical level and government support on the potential of EES.
Literature[12-13] summarized the current status of EES implementation at home and abroad, and proposed the construction basis, system architecture and level division of the EES standard system. Literature[14] constructed a calculation model for the critical electricity price of EES in the field of new energy, and proposed an overall model and economic evaluation method to promote the substitution of new energy electric energy. Literature[15] constructed a comprehensive evaluation index system for the benefit of electric energy substitution projects based on the external environment, company profitability, and social environment involved in the implementation of Tianjin EES projects. Therefore, the lack of EES planning research on related technical means and model tools has made it difficult to transform electric energy alternative technology from demonstration-oriented to large-scale and diversified implementation.

This paper aims to review the current research status of EES technology and related fields, summarize the planning methods of EES supporting gridding, and provide reliable network support for large-scale promotion of EES. Firstly, the paper summarizes the connotation, strategic significance and characteristics of EES technology, and proposes the basic structure of EES technology. Then, propose a distribution network planning framework under the background of EES, based on the temporal-spatial distribution characteristics of the typical EES load and incorporating the gridding planning concept. Finally, summarize the current development challenges of gridding planning methods in terms of technology, mechanism and infrastructure under the background of power substitution, and look forward to the development direction of the electric energy replacement supporting network plan under the background of the 14th Five-Year Plan and the new round of power system reform.

2. Overview and analysis of electric energy substitution technology

2.1. Connotation and significance of electric energy substitution technology

EES strategy mainly includes new energy consumption models such as replace coal with electricity, replace oil with electricity, and electricity from afar\(^{[16]}\). Substituting electricity for coal mainly converts coal used in industrial boilers and residential heating lamps into electricity to promote the electrification of rural households and alleviate the resulting air pollution. Substituting electricity for oil mainly reduces dependence on oil by vigorously developing electric vehicles, electrified rail transit and rural electric irrigation. Electricity comes from a distance means using transmission instead of coal, and transmitting electricity from west to east through the high voltage power grid to optimise the energy consumption structure of the central and eastern regions, thus achieving the optimal allocation of resources on a larger scale.

2.2. Characteristics of electric energy substitution

a. Mutual independence

There is no strict correlation or functional complementarity between different EES technologies, and different types of EES loads are independent of each other. In other words, according to different functional requirements, multiple EES technologies are allowed to exist in the same power consumption area, and when analysing the impact of EES load on the regional power network, all EES loads in the same area can be linearly overlay.

b. Easy to mesh

Each EES technology has a unique application range according to its function, characteristics and scale. For example, distributed electric heating is mostly used in residential buildings, schools and hospitals. Heat pump is mainly used in office buildings, commercial buildings, villas. Cold storage air-conditioner is mostly used in shopping malls, restaurants, dairy products processing, beer industry and other fields\(^{[16]}\). This feature is conducive to gridding planning of power distribution areas where EES is implemented based on urban functional zoning and urban planning.

c. Efficient and clean emissions
Traditional industrial boilers, residential heating, and coal for rural households use scattered coal with low efficiency and serious pollution. The efficiency of civilian stoves is about 20%, and the efficiency of small-tonnage coal-fired boilers is about 50%. The coal used in power plants has been fully transformed due to the dust removal, desulfurization and denitrification of coal-fired units. The proportion of desulfurization transformation has reached 99%, and the proportion of out-of-stock has reached 92%. Not only the efficiency can reach more than 90%, but the pollutants produced are less and relatively concentrated, the difficulty and cost of processing are very low.

**d. Flexible characteristics**

With the continuous improvement of V2G (electric vehicle access to the network) technology, the electric vehicle load with V2G function has shown flexible characteristics. That is, charging when the system load is low, and smoothing the total load curve. When the system fails or the power supply is tight, the electric vehicle is used as a backup power source to supply power to the network in order to reduce the system pressure, thus realizing the two-way flow of information and energy between the electric vehicle and the network under a controlled state\[17\].

### 2.3. Basic architecture of electric energy substitution technology

As shown in Figure 1, EES technologies are mainly divided into three types, *replace coal with electricity*, *replace gas with electricity*, and *replace oil with electricity*, and are widely used in various fields of residents, industry, commerce, and agriculture.

![Electric Energy Substitution Technology](image)

**Figure 1. Basic architecture of electric energy substitution technology**

### 3. Distribution network planning under the background of electric energy substitution

#### 3.1. Difference from traditional distribution network planning

Traditional distribution network planning is a complex multi-decision variable and multi-constraint optimization problem in mathematics\[18\]. The temporal and spatial distribution characteristics of EES load determine that there are obvious differences in planning ideas and planning methods in...
distribution network planning under the background of EES.

a. Different planning ideas

The traditional deterministic planning method does not consider the environmental changes after planning, but chooses an expected environment that is considered to be the most likely to be realized as the future scenario, and finds the economic, reliable and safe optimal solution to meet the environmental constraints\textsuperscript{[19]}. Distribution network planning under the background of EES needs to consider the promotion policy, implementation status and development trend of EES technology in the short and medium term. And seek for a more flexible and more adaptable planning plan to actively respond to possible future policy changes and technological changes, and strive to minimize the compensation investment of the planning plan.

b. Different planning methods

The traditional distribution network planning mainly divides the power supply area based on the saturated load density and the urban functional partition, and uses the principle of hierarchical partition and voltage division for planning. Distribution network planning under the background of EES needs to divide the power supply grid and power supply units according to the temporal and spatial distribution characteristics of the EES load, and comprehensively consider factors such as land use, load density, load maturity and voltage level. And carry out distribution network planning for each grid and unit to give full play to the rich capacity of existing network equipment and improve the precision of gridding planning.

c. Different planning key issues

The foundation and core of traditional distribution network planning is electricity demand forecasting. The main difficulties of distribution network planning in the context of EES lies in the lack of historical load statistics and the fact that it is difficult to accurately estimate the superimposition effect produced by the cross-application of electric energy substitution technology. The former difficulty can be solved by analysing the load characteristics and adaptability of the EES load, and the latter can be solved by carrying out gridding-based EES distribution network planning.

3.2. Characteristics and adaptability analysis of electric energy substitute load

At present, the more mature EES technologies mainly include 7 types of distributed electric heating, heat pumps, industrial electric boilers, cold storage air conditioners, household electrification, electric vehicles and agricultural electric drainage and irrigation. The characteristics of various EES loads are strongly related to their application fields. For example, the load characteristics of industrial electric boilers are basically the same as traditional industrial loads, the EES load characteristics of residents and agriculture are consistent with the laws of residents' lives and agricultural production.

\[\text{Figure 2. Heat pump cooling network load}\]
Fig. 2 shows the influence of a regional heat pump cooling load on the summer daily load characteristics of the regional power network under different permeability. Fig. 3 shows the influence of distributed electric heating on the daily load characteristics of the regional power network in winter under different permeability. It can be seen from the figures that the heat pump load and the distributed electric heating load have a strong correlation between the summer cooling demand and winter heating demand in this area.

4. Development challenges and directions of electric energy substitute network planning

4.1. Development challenge

a. Electric energy substitution supporting technologies and methods are not perfect

The current research work of EES mainly involves the analysis and calculation of the potential of a single type, economic evaluation, the alternative solution of a single project and the exploration of the standard system, and policy simulation. At the same time, the planning method for EES has not been perfected, and the planning plan does not have a set of unified standards. As a result, the construction of its supporting network is not included in the distribution network project library. The work is only carried out through the green channel, and the construction requirements are relatively random.

b. Energy support mechanism is not perfect

The development of EES is accompanied by huge changes in the final energy consumption structure and rapid growth of electricity, which has had a strong impact on the existing energy supply mechanism. It has become an urgent need for the whole society to improve the country's energy supply capacity and tap the energy supply potential. Although the country's new energy resources have great potential for development, the wind energy and solar energy are mainly distributed in the Three Norths and other areas with relatively backward economic development, while the load centers are concentrated in the economically developed central and eastern regions. Moreover, a large number of wind, solar, and water abandonment phenomena occur, and problems such as waste of power generation and insufficient power generation at certain moments happen frequently in areas with relatively backward economic development.

c. Restrictions on the construction of electric energy substitution supporting network infrastructure

Residential and commercial EES equipment integrates a large number of smart electricity technology and the flexible characteristics of EES technology, which not only requires the network to monitor, collect and analyze users' electricity consumption information in real time, and provide power companies with more refined load samples and different time-regional load distribution. At the same time, users need to receive the dispatch strategy and electricity price information fed back by the network in real time, adjust the electricity consumption behavior in real time, and feed back electricity to the network in time. However, the supporting non-intrusive intelligent load monitoring system is
still in the research and development or experimental stage, and it will take some time before large-scale use and promotion, which has become a potential resistance to the development of EES.

In addition, the V2G charging technology of electric vehicles makes it have the characteristics of flexible load. Although the current time-space randomness of electric vehicle behavior is relatively rich, they are in the stage of theoretical research or mathematical modeling, and lack a lot of reliable statistical data to prove the correctness and accuracy of the results. Moreover, the flexible load dispatch mode and control strategy are not yet mature, and it is difficult to implement on a large scale, which severely restricts the development of electric vehicles, and it is also difficult to play its role in improving the stability of the power network and cutting peaks and valleys.

d. The gridding planning method is not perfect

The gridding division standard is too broad At present. Specifically, a unified grid division standard is used in cities and rural areas, as well as areas with different economic development levels, population densities, and social development speeds. In underdeveloped areas with relatively low levels of development and large rural distribution, the area covered by functional grids is too large, which brings difficulties to planning, operation and maintenance.

In addition, the current gridding planning workload is too large and time-consuming, while urban planning changes rapidly, resulting in a gridding process that does not match the urban development speed, and investment waste often occurs. At the same time, the functional grid 35kV and 110kV network power supply capacity evaluation standards still use the capacity ratio as a consideration indicator, and the margin left in the short-term planning is too large, resulting in an excessive gap between the actual load level and the maximum power supply capacity, and producing a large amount of unnecessary investment.

4.2. Development direction

In the context of implementing energy-saving emission reduction and EES strategies across the country, EES is widely recognized as a new energy consumption concept in line with the country's national conditions. Various EES technologies have matured at the technical level. During the 14th Five-Year Plan period, the EES strategy is bound to usher in a period of rapid development.

(1) Accelerate the upgrading of existing EES technology, make it develop in the direction of higher efficiency, lower transformation cost, and more intelligence, and continuously expand the field of EES to cover all aspects of social production and life.

(2) The wide-scale promotion of EES technology will definitely have a huge impact on the planning and transformation of the existing distribution network. The existing gridding planning methods are not enough to support the implementation of the EES strategy. It is necessary to improve the network gridding panning method under the background of EES, and analyze the impact of EES on the distribution system of different regions and different voltage levels one by one. In the process of advancing the EES strategy, the existing power distribution network will be reconstructed and planned from the bottom up, and strive to produce the greatest benefits with the least time and cost.

(3) The lack of historical data for electric energy replacement load brings greater difficulties to load forecasting on this basis. It is possible to combine the analysis of the characteristics of EES load with the modeling and simulation of EES technology, and to combine factors such as the government's planned substitution of electric power, population growth, and social and economic development to propose a load forecasting method in the context of EES.

5. Conclusion

EES technology is of great significance for optimizing the final energy consumption structure, promoting energy conservation and emission reduction, and preventing air pollution. Based on the current research status of electric energy substitution technology and related fields, the construction and operation of demonstration projects, this paper summarizes the connotation, strategic significance and characteristics of EES technology, and proposes the basic structure of EES technology. Then, the characteristics of network planning and gridding planning ideas are integrated into the gridding
planning framework under the background of EES is proposed. Finally, the development challenges of gridding planning methods in the current EES background in terms of technology, mechanism and infrastructure are summarized, and looking forward to the development direction of the electric energy replacement supporting network plan under the background of the 14th Five-Year Plan and the new round of power system reform.

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