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Energy Consumption under the Influence of Industrial Structure Change based on Smart Grid

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Abstract: This paper analyzes the impact of the industrial structure(IS) change of smart grid(SG) on energy consumption(EC). The supporting system of SG and the main control signals in different stages are analyzed, and the general law of EC and energy economic effect coefficient are discussed; Analysis algorithm of the impact of IS change on EC, and then analyzes the impact of IS change of SG on energy efficiency; Through statistical testing, decomposition of energy intensity and analysis of carbon emission characteristics of regional intelligent distribution network in recent 10 years, it is concluded that the change of IS of intelligent distribution network has a great impact on EC. SG uses intelligent interaction to promote real-time communication between supply and demand sides, so as to improve power efficiency and save EC.

1. Introduction

As the input of the economic system, energy has always provided the material basis for economic activities and social production, but at the same time, it restricts the economic development. SG is an extremely complex system engineering. Different countries have formed their own SG development models through continuous research and practice according to their national conditions and the characteristics of the power industry. The reverse distribution of power supply and demand in China objectively requires large-scale and long-distance transmission in order to improve the efficiency of power utilization. This paper focuses on the impact of IS changes based on SG on EC.

Based on the impact of the IS change of SG on EC, many scholars at home and abroad have studied it. Syed D proposed a new distribution transformer level STLF deep learning method based on hybrid clustering, which has enhanced scalability. The gain in training time and accuracy when clustering based deep learning modeling is used in STLF is studied. Clustering is based on K-medoid algorithm, and the prediction model is generated for different load distribution clusters. The clustering of distribution transformers is based on the similarity of EC curves. This method reduces the training time because it minimizes the number of models required by many distribution transformers [1]. Manxi studied the dynamic demand response in SG to control EC. Since the energy state of each user in the SG can be described based on differential equations, the goal of EC control is constructed based on differential games. The concept of power sharing is introduced to realize the load transfer of main users from high price hours to low price hours. Nash equilibrium is given based on Hamilton equation, and numerical simulation results verify the effectiveness of the model [2].

This paper discusses and analyzes the impact of the IS change of SG on EC. With the beginning of industrialization, industry has gradually become the leading industry in society. Economic growth is mainly extensive. Relying on the growth mode of high input and high consumption, it drives the substantial increase of energy demand. The amount of energy required per unit of GDP increases, and the energy intensity increases accordingly, so as to allocate electric energy efficiently and reasonably; Widely absorb different types of power generation in order to use clean energy and reduce environmental pressure; Promote the interaction between the supply and demand sides, give play to the enthusiasm of users, guide rational consumption, and achieve the goal of energy conservation and environmental protection [3-4].

2. Influence of IS Change based on SG on EC

2.1. Supporting System of SG

SG technology has basically realized the collection of multi-dimensional data information covering six links of power generation, transmission, transformation, distribution, utilization and dispatching in China. It makes the interaction between the power system and the outside world more and more frequent. Through big data, we can coordinate the needs and functions of each participant in the power system, determine the accurate power supply mode, integrate different power supplies, and activate power supply while ensuring the reliability and stability of the whole system. The energy efficiency and safety level of power supply, while increasing the supply of clean energy, controlling EC, reducing EC, reducing pollution and greenhouse gas emissions, and improving our living environment. Figure 1 shows the structure of main control signals in different stages of China's power grid [5-6].

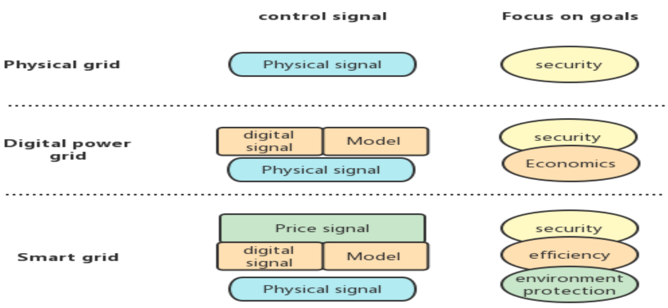

Figure 1. Main control signals in different stages of power grid

The characteristics of SG are: strong self-healing, stable and reliable; High security and strong ability to resist attacks; Good compatibility; The interaction between supply and demand is the new normal; Strong power market coordination; Optimize resources and improve energy efficiency; High quality service, high power quality and high degree of information integration [7]. Intelligent application system refers to the integration of power flow, information flow and business flow, so as to promote the safety, reliability, efficiency, economy, low carbon and other capabilities of the power system. The supporting system of China's strong SG is shown in Figure 2.

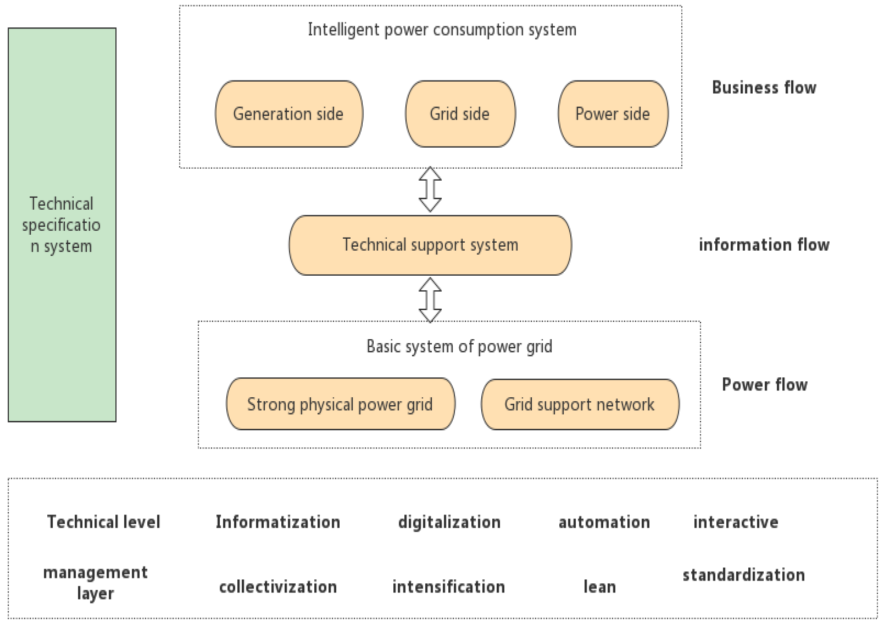

Figure 2. Support system of SG in China

The basic system of power grid refers to the physical network structure, which is the basis for realizing the "strength" of SG. In the technical support system, all kinds of advanced power generation technology, transmission technology, communication technology, dispatching technology, energy storage technology, measurement technology and demand side management technology cooperate with each other to provide support for SG to promote the development of low-carbon power system. At present, SG involves many advanced technologies. However, due to the different maturity of various advanced technologies and their different impact on the low-carbon level of the power grid, the role of these technologies in promoting the low-carbon of the power system is also different. To build the technical support system of China's strong SG, we should focus on the reality of China's power grid, reasonably judge the development importance and order of various technologies, and give priority to the development of key technologies suitable for China's strong SG, so as to promote the efficient construction of a strong SG [8-9].

With the support of the standard planning system, the construction and operation of a strong SG will be more standardized. At present, China's SG is still in the initial stage of construction, and relevant standards or specifications should be scientifically and reasonably revised and corrected in a timely manner according to the actual situation of the development and changes of China's SG, so as to ensure the timeliness and effectiveness of the standard planning system in guiding the construction and development of a strong SG [10].

2.2. General Rules of EC

2.2.1. Energy Economic Effect Coefficient (Energy Efficiency)

Energy economic effect coefficient is the economic benefit brought by unit energy and the reciprocal of EC coefficient. Their role is mainly reflected in the following aspects: calculate energy efficiency and energy conservation, and calculate the total energy conservation capacity; Predict the energy demand of different parts of the national economy through energy allocation. According to the power share, the potential economic development can be calculated and the economic growth rate can be predicted. The elasticity coefficient of EC can not only reflect the efficiency level of EC, but also reflect the relationship between open source and energy efficiency in EC. The lower the elasticity coefficient of EC, the higher the efficiency of EC in economic development, and the lower the economic dependence on energy. When the elasticity value of elasticity is greater than 1, it indicates that the growth rate of energy potential is greater than the speed of system development, and it is necessary to completely rely on open source to solve the energy demand development of the system [11-12]. When the elasticity coefficient of EC is greater than 0 and less than 1, open source and energy conservation must work together to meet the energy demand of economic development. The improvement data of the relationship between system development and energy use may come from the long-term trend, but in different periods of economic development, due to different influencing factors such as economic level, IS and EC structure, the elasticity coefficient of EC is not constant, and there is no exact conclusion on what proportion relationship should be maintained between energy growth and economic growth [13].

Generally speaking, in the initial stage of economic development, economic development is highly dependent on energy, the demand for energy is very large, and the utilization efficiency of energy is very low. EC rises rapidly with economic development, and the economic system is a resource intensive economy; In the higher stage of economic development, the economic development is mainly driven by the improvement of technical level. The energy utilization rate is greatly improved, the dependence of economic growth on energy is gradually reduced, and the rising rate of EC slows down with economic development. At this time, the economic system turns into a low-energy economy. The relationship between EC indicators and economic development in different countries and regions will be inconsistent. Generally speaking, the rate of increase in EC is inversely proportional to the economic level [14-15].

2.3. Impact of IS Change of SG on Energy Efficiency

The EC structure reflects the IS to a certain extent. In the composition of China's EC, coal accounts for a high proportion, which is precisely due to the massive use of coal, oil and other energy in the production of the secondary industry. Under different levels of economic development, people's demand structure is different. When people are in a low-income state, Engel's coefficient is large, and consumption is mainly to meet the problem of food and clothing. At this stage, agriculture and textile industry account for a large proportion of the IS; When the income level increases, people's demand turns to a more advanced stage, and they are more inclined to buy durable consumer goods. At this time, the manufacturing industry accounts for a large proportion in the IS; When the economic level continues to develop, people are in the stage of high income, material life is extremely rich, and more turn to the demand stage of pursuing personality and fashion, which promotes the rapid development of high-tech industries such as finance and insurance, information service industry and the continuous improvement of the tertiary industry in the IS [16]. Therefore, different stages of economic development have different ISs. Through economic development, we can promote the continuous adjustment and upgrading of IS, and then affect EC.

In terms of the direction of energy development, especially the characteristics of renewable energy power generation, the massive use of distributed power generation and energy storage equipment will increasingly weaken the natural monopoly of SG, so as to eventually eliminate its natural monopoly in the terminal retail market and move towards a free competitive market.

Specifically, the role of SG in promoting energy efficiency is mainly reflected in four aspects: first, improve the utilization rate of power grid. The SG uses two-way communication, advanced sensors and distributed computers to optimize the transformation and use efficiency, improve the transportation capacity and operation control flexibility of the power grid, so as to improve the comprehensive utilization and reliability of the power grid. The second is to improve the efficiency of peak shaving. SG has developed from a traditional power grid to a new platform for optimizing the allocation of power resources, with significant benefits of peak staggering and peak shaving networking [17-18].

3. Analysis Algorithm of the Impact of IS Change on EC

This paper uses input and output functions to illustrate the impact of IS changes on EC: input and output are expressed by the following functions:

$$B = P(a_1, a_2, ..., K, H) \tag{1}$$

Where, K refers to capital input and H refers to labor input; AI (i=1,2,..., n) refers to the input of other resources; B is the maximum output. According to the form conversion of Cobb Douglas production function, the function can be converted into:

$$B = GK^{\lambda} H^{\delta} a_1^{\gamma_1}, a_2^{\gamma_2}, ... a_n^{\gamma_n} \tag{2}$$

Where, a refers to certain technical conditions: λ,δ,γ They are the output elasticity coefficients of capital, labor and other resources. Then, the full differential of equation (2) can be obtained:

$$dB / B = \lambda(dk / k) + \delta(dH / H) + \sum_{i=1}^{i=n} (da_i / a_i) \tag{3}$$

From this equation, we can see that there are three ways to reduce the input of resources other than capital and labor (i.e. da1/a1): the first is to reduce the economic aggregate (db/b); The second is to increase the input of other resources (z); The third is to increase the contribution rate of energy(γ 1) To maintain economic development while reducing the input of resources, only through the latter two ways, namely, IS upgrading, can we improve the contribution ratio of other resources and improve the efficiency of energy utilization. Through the above analysis, it explains how the change of IS affects EC from a theoretical point of view, which provides a theoretical basis for the following empirical research.

4. Analysis of the Impact of IS Changes of SG on EC

This paper decomposes the energy intensity of China in recent 10 years, and then analyzes the impact of IS changes based on SG on EC. The statistical calculation results are shown in Table 1 and figure 3.

Table 1. Breakdown data of energy intensity factors in China

Particular year	Change in energy intensity	Structural factors	Efficiency factor	Structure share	Efficiency share
Year 1	-0.063	-0.012	-0.051	0.19	0.81
Year 2	-0.035	-0.005	-0.030	0.15	0.85
Year 3	0.058	0.023	0.035	0.39	0.61
Year 4	0.071	0.004	0.067	0.05	0.96
Year 5	-0.011	0.022	-0.033	-2.17	3.17
Year 6	-0.041	0.011	-0.047	-0.29	1.29
Year 7	-0.065	-0.011	-0.057	0.17	0.83
Year 8	-0.066	0.001	-0.064	-0.02	1.02
Year 9	-0.042	-0.017	-0.027	0.38	0.62
Year 10	0.083	0.009	0.074	0.11	0.89

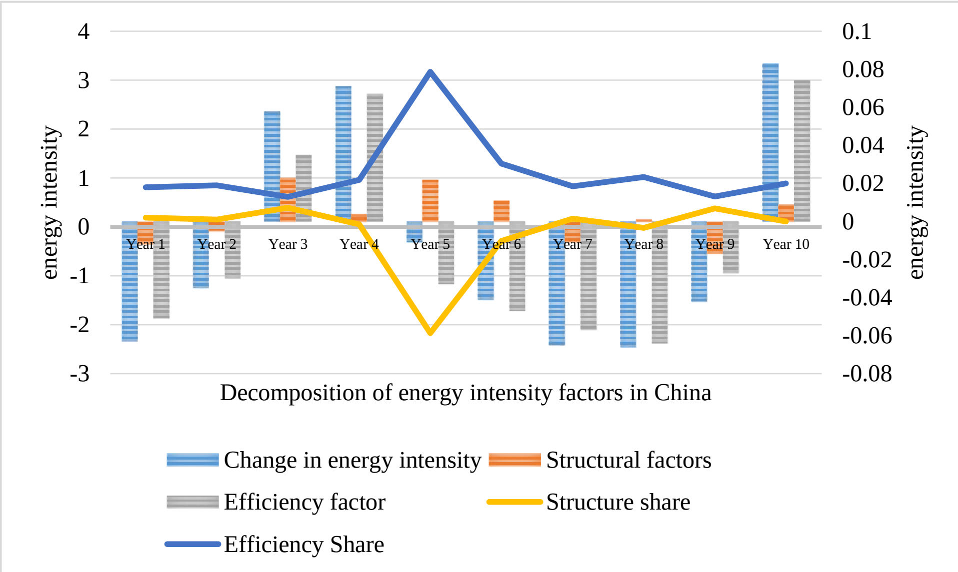

Figure 3. Decomposition of energy intensity factors in China

It can be seen from the chart data that in the three years when the energy intensity increased, both the structural share and the efficiency share were positive, indicating that the change of IS and the change of energy efficiency of various industries jointly promoted the increase of energy intensity. However, from the share proportion, it can be seen that in the fourth year, the efficiency share was as high as 0.96, which shows that the increase of energy intensity in these years is mainly due to the efficiency share. Observing the years when the energy intensity decreased, we can find that the structural share was negative in the fifth, sixth, eighth and ninth years, while the efficiency share was positive, indicating that the change of IS in these three periods hindered the reduction of energy intensity, which was jointly promoted by the change of IS and the improvement of energy efficiency of various industries.

Next, analyze the carbon emission characteristics of regional intelligent distribution network, and then analyze its impact on EC. The test results are shown in Figure 4.

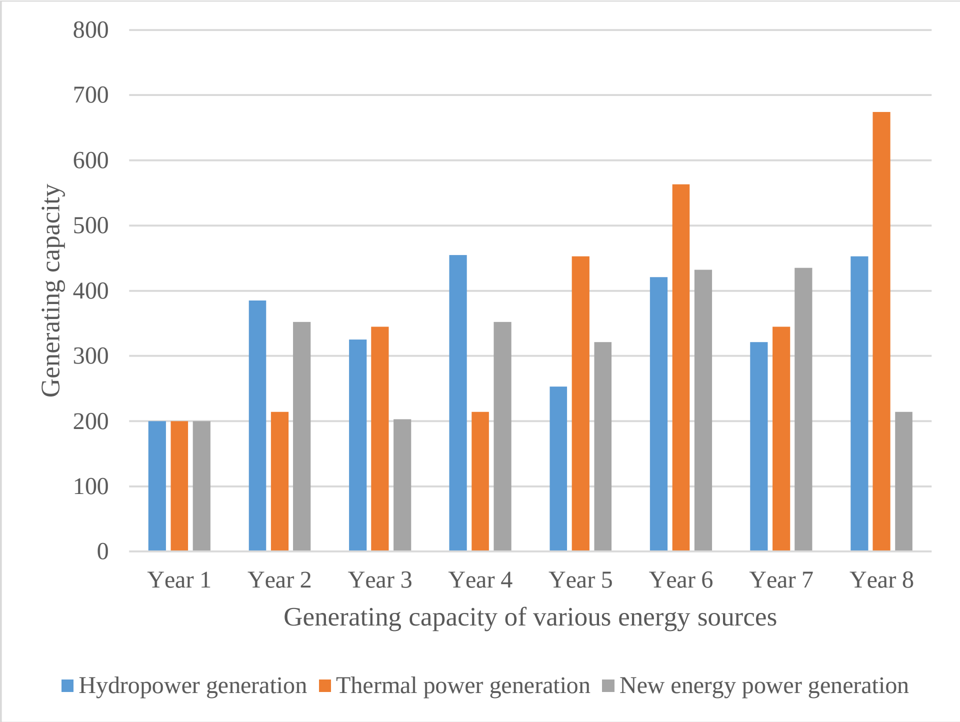

Figure 4. Generating capacity of various energy sources

According to figure 4, the growth rate of new energy has increased by about 1% in the past eight years; However, the proportion of thermal power rose sharply, from 52% to 83%, up 31 percentage points. From the analysis, we can see that the IS change of intelligent distribution network has a great impact on EC. One of the advantages of SG is to absorb and send out new energy power generation, ensure the scheduling and safe operation of traditional and new energy power generation, and promote the development of clean energy and green energy in China.

5. Conclusion

Combined with the principles of index establishment and the characteristics of SG itself, this paper discusses the impact of IS change of distribution network on EC from three aspects: generation side, grid side and user side. SG is not only the development direction of the future power grid, but also the hope of green power grid. Developing low-carbon benefits of SG is of great significance for economic and social benefits. The research on the impact of industrial changes on EC also needs to be based on the understanding of the impact of SG industrial changes on EC, based on the development characteristics of China's SG, and the impact of the entire three IS changes on EC needs to be further studied and analyzed.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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