Promote the Energy Revolution by Energy Technology Innovation Revealed by Energy-Brain Model

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Abstract. At present, the energy development and utilization has to be adjusted comprehensively in the world. It is crucial to unlock the energy code and seek ways to optimize the development of energy. The energy-brain model has been established in this paper to explore the general key factor for connecting and changing the energy system life cycle, which is electric energy, one of the secondary energy resources. The reason why the secondary energy can optimize the primary energy has been mainly elaborated in this paper. The fact that the energy system life cycle can be extended by optimizing electric energy has been revealed in this paper, which has indicated the direction of energy optimization and technology innovation for promoting the energy revolution.

1. Status and trends of energy development

1.1. Trends of the world energy development
In the next five years, the international energy structure will adjust significantly. The international competition around the energy market and energy innovation will be fierce. Energy development and utilization will face comprehensive challenges. Specifically, the world energy development will present five trends: First, the energy supply capacity will be sufficient, and the energy demand will maintain a low rate of growth. Second, the focus of energy consumption will transfer to the Asian-Pacific region, and the energy supply will be gradually diversified. Thirdly, the energy structure will evolve to clean energy and lower-carbon content. [1] Fourthly, the intellectualization of energy systems will develop and popularize quickly. Fifthly, the game between big energy nations will be more complicated. [2]

1.2. Status of the unbalanced and insufficient energy development of China and the solutions
The energy development of China has achieved remarkable results in recent years, but the problem of unbalanced and insufficient energy development still exists. The concrete manifestations of the problem include at least the following: the overcapacity problem in energy industry such as coal, coal-fired power generation, and primary processing of crude oil is conspicuous; the development of renewable energy faces multiple bottlenecks such as the abandoning of wind, solar and hydro energy; the task of clean energy substitution is arduous; the energy utilization efficiency is lower than the world advanced level; the mismatch between energy supply regions and consumption regions is still obvious. [3]

In order to solve the problem of unbalanced and insufficient energy development, there are four solutions should be taken. First, China's energy development direction should shift from ensuring
supply to improving the quality. Second, the energy structure should be adjusted by reducing the proportion of coal consumption, developing natural gas actively and promoting non-fossil energy replacing fossil energy. Thirdly, system optimization should be propelled by improving power system peak load regulating capacity, strengthening demand side management and speeding up the smart energy construction. Fourthly, the modern energy market system should be found with the feature of unified, open, competitive and well-organized. In a word, the most important solution is optimizing energy structure, promoting non-fossil energy replacing fossil energy, and building a clean, low-carbon, safe, and efficient energy system.

2. Energy-brain model

2.1. Introduction of the energy-brain model

In order to unlock the energy code and seek ways to optimize energy development, the energy-brain model has been researched and established. The energy-brain model is a model that presents the relationship between various primary energy sources and the relationship between primary energy and secondary energy in a pictographic manner. Its shape and structure are similar to the human brain. It reveals the mystery that the energy industry can be a closed-loop system. It also finds out the key factors that determine the balance and stable operation of the entire energy system, and provides solutions for improving the efficiency and effectiveness of the energy industry.

The primary energy group in the energy-brain model includes almost all common primary energy sources, including coal, oil, natural gas, nuclear energy, geothermal energy, solar energy, wind energy, hydro energy, biomass energy, and mechanical energy (including potential energy, water flow energy, etc.). Among all the primary energy sources, coal, petroleum, natural gas, and nuclear fuel have limited reserves and cannot be recycled; while geothermal energy, solar energy, wind energy, hydro energy, and biomass energy can be recycled. Every kind of primary energy source seems to exist independently, but can actually be linked by a common chain to form a closed-loop energy system. The key factor on the chain is the electric energy which is one of the secondary energy sources. Coal, nuclear energy, solar energy, wind energy, hydro energy, biomass energy, and mechanical energy can be converted to electric energy directly. Oil, geothermal energy, and natural gas can be converted into other secondary energy sources such as gasoline, steam, hot water, hydrogen, and gas first, and then converted into electric energy.
In the energy-brain model, the primary energy group seems like human’s cerebrum, which is the high-level nerve center and controls a variety of advanced functions. The proportion of every kind of primary energy resource is determined by the proportion of the installed capacity of its corresponding power generation type. Whether the ratio distribution of primary energy resources is reasonable or not determines the operational efficiency and effectiveness of the energy-brain. The secondary energy group is similar to the human's cerebellum. It is not only controlled by the cerebrum and executing the instructions of the cerebrum, but also plays the role of secondary regulating and balance promoting. The approximate proportion of every kind of secondary energy resource is determined by the proportion of its corresponding primary energy resource, and can be redistributed within a certain range to help achieve the balance of the entire energy system. In the process of coordination and optimization of various energy sources, informatization, perception systems, and big data analysis will contribute to the neural network interaction.

2.2. Electric energy is the best choice to optimize primary energy through secondary energy

Energy source such as coal has its life cycle, which refers to the process from first exploiting to exhausting. For now, coal is used by human beings for the first period and is in its first life cycle. After several hundred million years, coal will be formed again and be used up again in another life cycle. The energy system also has its life cycle, which refers to the process from discovering and using certain type of energy resource to the disintegrating of the entire energy system because of the exhaustion of some types of energy resources.

At present, China is comprehensively promoting the revolution for energy production and consumption, and is striving to build a clean, low-carbon, safe and efficient energy system. The process of replacing fossil energy by non-fossil energy will be accelerated and the energy system life cycle will be extended. Meanwhile, in order to guarantee the national energy strategic security, China also needs to extend the energy system life cycle to prevent local collapse of the energy system caused by the exhaustion of certain types of energy resources. In order to extend the energy system life cycle, energy system need to be optimized. The most convenient and most effective way is to optimize primary energy sources through secondary energy sources.

The energy-brain model reveals the key and common factor in the energy system, which is electric energy. Electric energy is the best choice to optimize primary energy through secondary energy. By adjusting the electric energy, the energy system architecture can be adjusted to operate efficiently and stably. By reasonably configuring the ratio of electric energy from various sources, the energy system can be more balanced; its life cycle can be extended; and its flexibility and coordination can be upgraded.

To realize the eternal life of electric energy, energy storage technology is needed as support. The eternal characteristics of non-renewable energy power generation and renewable energy power generation need to be studied respectively. The energy resource such as coal, oil, natural gas, and nuclear energy has strong power, but the formation time is too long and the reserves is irreversible due to the influence of the environment and conditions inside and outside the earth. In order to prolong their life cycle, it is necessary to reserve the resources and their energy. The energy resources such as wind, solar and hydro energy can be recycled, and the continuity of power generation from them can be realized with the energy storage devices. Furthermore, hydropower, wind power, and solar power generation can realize complementary operation. Energy storage devices can be classified into mechanical energy storage, thermal energy storage, hydrogen energy storage, and battery energy storage by the energy storage manner. Battery energy storage is the most primary manner for energy storage while high-density battery is the most important development direction. The development of high-density battery will promote the technological progress in the superconductor and metal materials industries.
Figure 2. Solution for eternal characteristic problem

Although every kind of electric energy needs to achieve eternal life through energy reserving, the solutions for electric energy from different sources are different. Taking the zero-start wind turbine as an example, the alternating current generated by the wind turbine is converted into direct current by the conversion module. Part of the direct current is stored in the energy storage devices, and the other part is converted into stable alternating current to access to the power grid after processing. As wind energy is an intermittent resource, when the quality of the generated electric energy is poor because of the unstable wind speed or the wind speed is too low to make wind turbine work, the energy storage devices will release the stored energy to superpose with the energy from wind turbine, and the continuous, stable, and high-quality electric energy will be provided for the power grid. In addition, when the wind turbine is restarted from the stopped state, the energy storage devices can be used as an external power supply for the control system to start the wind turbine.

Figure 3. Energy storage pattern for zero-start wind turbine

For the entire power system, to get the continuous and stable electric energy supply, an integrated solution is required, including the top-level design, elastic design, distributed management, and technology innovation of sensing and identifying systems.

2.3. Regional differences of electric energy optimization in China

China has a land area of 9.6 million km², a latitude span of nearly 50° across north and south, a distance of 5,500 km from north to south, a longitude span of nearly 60° across east and west, and a distance of 5,200 km from east to west with spanning 5 time zones. The climate in the south and north of China is quite different. Especially in winter, the maximum temperature difference between the north and the south China is close to 50°C. The time when the maximum electrical load occurs in north and south China is different, so does the electricity demand, and that is why the regional differences in electric energy optimization are generated.
Figure 4. Regional differences of electric energy optimization in China

The maximum electrical load in the north China and the central, west and east regions usually appears in winter. The priority of electric energy optimization in these areas is to meet the heating demand. Energy pipeline transmission or energy storage can be used as backup and supplement to prevent power shortages and blackouts in winter. In the south China, the maximum electrical load usually appears in summer, and the focus of electric energy optimization is to meet the demand for heat protection. The energy storage can be used as backup and supplement to prevent power shortages and blackouts in summer.

3. Promote the energy revolution by energy technology innovation

3.1. Energy technology innovation is the fundamental approach to promote the energy revolution
At present, the Chinese government is vigorously promoting the revolution in energy production and consumption and building a clean, low-carbon, safe, and efficient energy system. The extension of the energy system life cycle is also greeting a rare policy environment and strategic opportunity.

In order to promote the energy production revolution, it is necessary to establish a multi-dimensional energy supply system with the development of both non-coal energy resource and coal clean and efficient utilization. Energy technology innovation is an important support for the development of the energy supply system by promoting the exploitation and application of multiple energy sources, especially new energy resources.

In order to promote the energy consumption revolution, the unreasonable energy consumption should be suppressed, and the energy utilization efficiency should be increased. The R&D and application of new technologies is an important means for improving energy utilization efficiency and promoting the transformation of energy consumption. Therefore, energy technology innovation is also an important way to form a new energy-saving energy consumption pattern.

In summary, energy technology innovation plays a decisive role in the energy revolution and is the fundamental way to promote the energy revolution and extend the life cycle of energy system.

3.2. Analysis of technical requirements in the energy industry
Technology innovation is always driven by technical requirements. Since electric energy is the best choice to optimize primary energy through secondary energy, solving the problems in the electric power industry properly will make the entire energy industry develop in a more healthy direction. At
present, there are four key problems need to be solved in the electric power industry in China. The first problem is about the security-based electric power system development and control. China has become the largest electric power producer in the world. The electric power system is characterized by complexity, vulnerability, and strong rigidity. With the AC-DC hybrid power grid, a complete technology and management system must be established to ensure the safe and stable operation of the electric power system. The second problem is about the negative effects and atmospheric pollution caused by the unbalancing between carbon sources and carbon sinks. It needs to cooperate with the electric power system to promote a new balance between carbon sources and carbon sinks through energy-saving and emission-reduction transformation, as well as electricity substitution of coal and oil. The third problem is about the coordination of power source and power grid with the rapid development of new energy resource. Faced with the contradiction of the continuous increase in the installed capacity of new energy power generation and the limited local grid support capacity, it is necessary to improve the balance and stability of the power system. The possible ways include developing new energy generation, smart distribution grid and distributed power supply technologies, and optimizing the adjustment method. The fourth problem is about the development and application of energy information networks, awareness systems, and big data analysis technologies. The intelligent and coordinated development of the energy industry is inseparable from accurate data identifying and big data analysis. With the support of the information system, the energy structure can be adjusted effectively, optimized continuously and reconstructed reasonably to meet the energy demands in different periods, and eventually reach to the balanced development.

3.3. Prospects for new technologies in the energy industry

Based on the technical requirements in energy industry and the demands to promote the energy revolution, the energy optimizing development and energy technology innovation of China in the next five years will mainly include three directions, which are primary energy to electric energy conversion, electric energy transmission, and energy storage and interconnection.

In the development direction of primary energy to electric energy conversion, there are three kinds of new technologies need to be focused on. The first one is clean coal-fired power generation technology, including the design and manufacture of advanced ultra-supercritical units, large IGCC units, and energy-saving CFB units; research and development of low-energy large-scale CO₂ capture technology and equipment; and research on deep peak-regulating technology of thermal power unit. The second one is efficient application technology of renewable energy technologies, including the establishment of intelligent control system and operation management system for large-scale wind farms; development of new types of solar cell technology; improvement on efficient heat collection and system integration technologies for large-scale solar-thermal power stations. The third one is safe and advanced nuclear power technology, including continuous improvement and innovation of advanced nuclear reactor types; and research on detection, monitoring, and life extension technologies for in-service nuclear power units.

In the development direction of electric energy transmission, there are four kinds of new technologies need to be focused on. The first one is grid-connected and transmission technology with high proportion of renewable energy, including the optimization of grid connecting and dispatching technologies for large-scale renewable energy bases and a large number of distributed renewable energy; breakthrough on the key technologies of large-capacity UHV DC transmission and flexible AC transmission; and improvement on information integration technology between power grid and internet. The second one is superconducting power transmission technology, including basic research on high-temperature superconductor materials and breakthroughs in superconducting power transmission, energy storage and power equipment. The third one is advanced power electronic devices technology used for smart grid. The fourth one is active distribution network technology, including application of distributed energy and multi-energy complementary power generation technology in micro-grid; and reconstruction of user-side management system and construction of the intelligent city.
In the development direction of energy storage and interconnection, there are three kinds of new technologies need to be focused on. The first one is energy storage technology, including development of various energy storage technologies and breakthroughs in large-capacity energy storage. The second one is hydrogen energy and fuel cell technology, including research on hydrogen energy utilization and fuel cell power generation technology; development of efficient catalytic technology; and research on efficient low-cost hydrogen storage and transportation technology for promoting the industrialization of high-performance low-cost fuel cell power generation. The third one is energy interconnection technology, including construction of energy interconnection and research on the operation and transaction technology of energy interconnection systems. [4]

4. Conclusion
This paper analyzed and studied the status and trends of the word energy development, especially focusing on the current problem of unbalanced and insufficient energy development in China and finding out the solutions. The energy-brain model has been established to reveal the mystery that the energy industry can be a closed-loop system and explore the general key factor for connecting and changing the energy system life cycle, which is electric energy, one of the secondary energy resources. The reason why the secondary energy can optimize the primary energy and why the electric energy is the best choice to optimize primary energy has been mainly elaborated. Then, the paper analyzed and demonstrated that energy technology innovation is the fundamental way to promote the energy revolution and extend the energy system life cycle. By studying the technical requirements of China's energy industry, especially the power industry, and looking forward the new technologies for energy optimization, this paper has not only pointed out the direction of energy optimization development and energy technology innovation in China, but also contributed to promote the energy revolution in China.

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