Future urban energy system shaped by digital technology

Siemens AG

Executive Summary:

Strong growth in global electricity demand and the increase of urbanization rate are putting enormous pressure on urban energy systems. How to balance the supply and demand of energy, improve energy efficiency and achieve sustainable urban development become an urgent topic. Novel technologies such as the Internet of Things, artificial intelligence and blockchain are powerful tools to help us to realize a sustainable and green energy transition.

To meet the high energy demand of cities, developed countries or regions who put big effort on energy transition, such as Germany and Nordic countries, continue to promote the construction of distributed renewable power system, invest heavily in building energy management field, and gradually materialize an open distributed power trading system. Digital technologies such as smart energy management system, can effectively supervise the power system and ensure a stable operation of grid when many power prosumers participate in the power exchange and trading.

China is the world's largest energy consumer and its electricity demand is continuously rising with the growth rate of 4.5% in 2019, of which the electricity consumption of urban and rural residents increased by 5.7%. The cities with large population are facing greater energy pressure. In order to ease such pressure, improve energy efficiency and promote sustainable development, China has introduced policies to encourage the development of distributed power generation facilities and electricity trading. In addition to promoting distributed power generation to reduce transmission losses, the efficient energy management on the user side also plays a positive role in the urban energy systems transition.

Although China has issued some policies to promote the smart energy management systems implementation, such as subsidies for intelligent retrofitting of building in Beijing, Shanghai, etc. The energy technology innovation and application still require to be accelerated and guided by

more detailed policies. According to the research of industries and policies in domestic and international market, the core policy suggestions are proposed as following:

- Accelerating the construction of distributed power generation systems in large and medium-sized cities.
- Promoting the launch of pilot distributed power trading projects. Refining the trading mechanism and regulations.
- Defining the energy consumption policies for mega buildings and incentivizing the construction or retrofitting of smart buildings.
- Encouraging the development of digital technologies, facilitating the implementation of such technologies in building or energy projects.

Introduction

With the growth of global economy and the increase of heating and cooling demands for cities because of the frequent abnormal weather, it is estimated that the global energy demand will increase by about one third in 2040[1], among which the growth of electrical power demand contributes a large portion. The report "World Energy Outlook 2019" issued by the International Energy Agency predicts the global energy demand in 2040. It indicates that with the continuous development of low-carbon technology, the growth of electrical power demand will be faster than the growth of overall energy demand[2]. Besides, 55.7% of the world's population currently lives in cities. According to the “World Urbanization Prospects 2018” released by the United Nations Department of Economic and Social Affairs, the global urbanization rate is expected to reach 68% by 2050, of which nearly 90% of the growth comes from Asia and Africa[3]. It indicates that the pressure of urban energy system in these regions will continuously rise in the future. A large part of urban energy consumption comes from buildings, which accounts for 40% of the world's energy consumption and are expected to continuously rise in the future[4]. All these bring great challenges to the sustainable development of urban energy system and environment. Therefore, how to balance the supply and demand of energy, improve energy efficiency and achieve sustainable urban development become an urgent topic.

In the information age, many developed countries have taken active measures to accelerate the digitalization process, and apply digital technology to the production, transmission, trading and consumption sections of various secondary energy in order to monitor and control the whole process. The application of digital technologies such as the Internet of Things (IoT), artificial intelligence, big data, and blockchain in the energy sector are playing an increasingly important role to lead the energy industry transition, realize innovation-driven development, and cope with

the challenges of environmental sustainability. By employing digital technology in urban energy production, utilization and regulation, such as automatic distributed power trading, building IoT and smart energy management, will greatly improve the efficiency of urban energy utilization and reduce energy consumption. What's more, using digital technology, emergent events like natural disasters and pandemics can be simulated and tested, which can help to deeply understand the resilience and adaptability of the city and make better emergency response in the future.

Distributed power trading refers to the electric power trading between the power generation parties and the power users who meet the trading conditions in the distribution grid network, which can save the high energy losses from the long-distance transmission. By using digital technologies such as blockchain, the electricity produced by small distributed power suppliers will be delivered directly to end-users via the microgrid. Distributed power trading changes the traditional power operation and trading mode, which not only converts the power user from consumer to "prosumer" who can actively participate in the power market, but also transforms the power transmission from centralized one direction to bi-direction.

Building IoT system enables an efficient energy management. The system connects various sensors such as meters, cameras in buildings or between buildings, collects and integrates a large amount of data, so as to integrate all the subsystems in smart buildings into one platform, including lighting, heating, ventilation, security, and communication, etc. It can realize data sharing and assist owners to achieve the analysis, monitor and collaborative management for the building energy utilization, equipment status, indoor environment, etc. The seamless connection among sensors, buildings and unified platform can bring new opportunities for the building owners, customers and managers to reduce costs, improve the user experience and be more environmentally friendly. If combining with the cloud computing and big data analysis, the energy management system will be smarter. The future city management platform will have functions like fault prediction, coordination and control of multiple systems, real-time data

analysis and visualization, and the digitalized urban energy system would be one of its subsystems.

In the past few years, China has made big progress on new energy technologies, yet there are still gaps between China and countries with best practices. More detailed policies are needed, to guide relevant stakeholders on how to realize an open and trusty power trading mechanism, to fasten the urban energy system digitalization, especially on building sector, so as to support a sustainable and green development of the city.

1. International trends

Global urbanization and electrification trend drives the continuous rise of electricity power demand, placing increasing pressure on the urban power system. The frequent occurrence of abnormal weather brings large heating and cooling demands, and the gradual electrification of heating system in the city further stimulates the rise of power demand. At the same time, the rapid development of the electric vehicle industry also brings pressure to the stability of the urban grid system. According to the research of McKinsey & Company, taking Germany as a sample, although electric vehicles will not lead a significant increase in electricity demand before 2030, they will increase the peak load in some certain time period. The most obvious impact is the increase of peak load at night, which will bring greater pressure to the grid. In 2050, electric vehicles will increase electricity demand by 4% compared with 2018[5]. In order to cope with the rising pressure of energy consumption and the requirement of high stability and reliability of grid, it is an imminent topic to discuss how to upgrade urban energy system through renewable energy and digital technologies.

In order to relieve the pressure of energy consumption, the developed countries keep promoting the development of distributed power and gradually marketize distributed

power trading. Distributed power generation is more efficient because it can greatly reduce the power loss in the long-distance transmission. The power system will be more diversified for sure. Besides the photovoltaic (PV) power generation from the roof solar panels, Building Integrated PV (BIPV), solar-powered parking shed, etc. can also be one kind of distributed power systems. The trend will be power generation is mainly for local use but can also be traded among neighbors. Germany has a fast development in this field among the developed countries. with more than 1.6 million PV systems currently in Germany, 60% of them are distributed small-scale PV systems with capacity less than 10kW[6]. Nowadays, some enterprises, besides generating electricity for local use, will also store excess electricity and trade in the electricity market. In 2016, a distributed power trading system combined with blockchain was piloted in Brooklyn, USA, where house owners in the community could generate electricity from solar panels and trade excess electricity with each other.

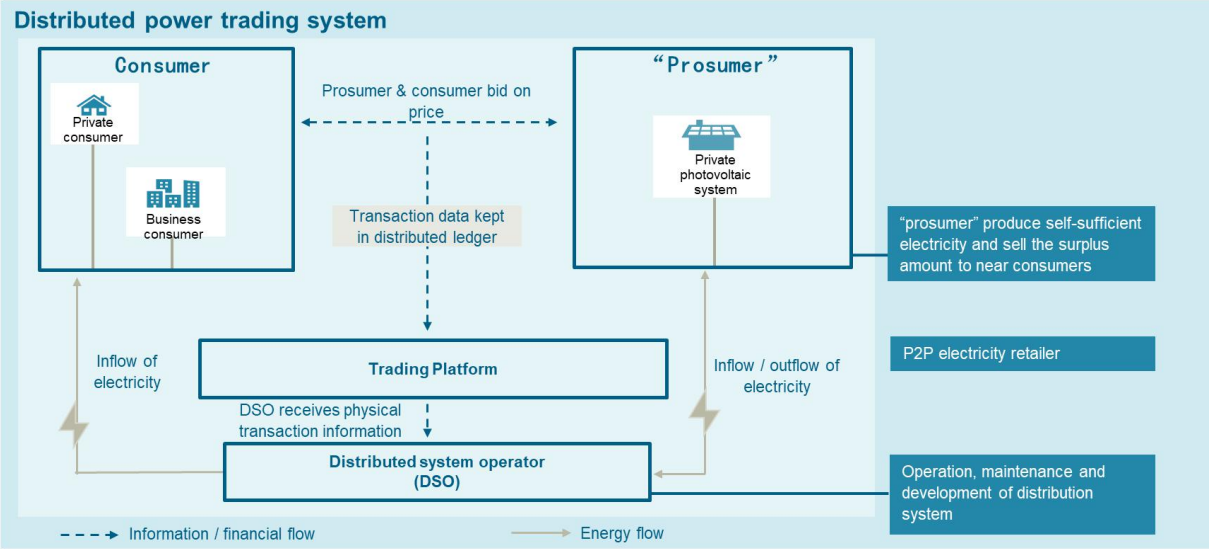

Fig.1 Distributed Energy Trading

Distributed power generation and trading bring higher requirements to the regional power system managers, while it also implies the smart energy management platform could be the future direction. By collecting and analyzing a large amount of data, as well as real-time monitoring of energy consumption, these will enable power consumption forecasting and ensure a smooth

power trading. Such solution has been successfully implemented in building management. Sello Shopping Centre is Finland's largest shopping center, with 24 million visitors a year. As the partner of the building energy management integrated solution, Siemens has installed a 600kW solar power system for Sello to make it self-sufficient in terms of power supply, while equipped with 1.68MWh of energy storage equipment to store excess electricity and transmit excess electricity to the electricity market for trading. For the indoor environment control, the building is equipped with sensors to collect temperature, humidity, lighting and other data, which will be delivered to the cloud building management platform Navigator in real time. The owner can carry out remote real-time monitoring of the energy consumption, indoor temperature, humidity, light and so on in the shopping center building through data analysis and visualization systems, so as to create a comfortable indoor shopping environment for consumers. The project saves 120,000 euros energy related expense and 281 tons carbon dioxide emissions for Sello in one year. Sello obtains 480,000 euros in revenue every year by trading surplus electricity[7].

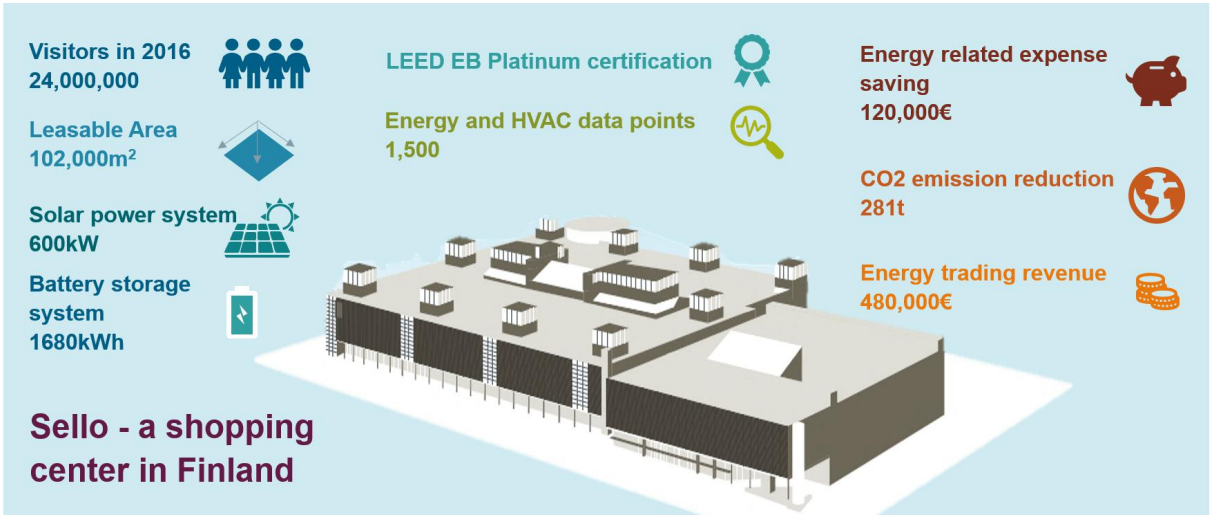

Fig.2 A Shopping Centre Energy Solution Case

Digital technologies such as artificial intelligence, big data, Internet of things and 5G are gradually integrating with power systems. Energy management will be smarter and more adaptable to meet the needs from users with the help of digital technologies and data analysis. Besides requirements such as building managers want to get energy consumption information,

sometimes people want to adjust building environment to a comfortable level. The fast-developing digital technology has enabled the interactions with buildings. For example, Siemens cloud smart building management software "Comfy" can be equipped with lighting control, heating, air quality monitoring and other systems in the building. By transmitting the data collected by Enlighted sensors to the cloud and conducting real-time analysis, users can learn the real-time using state in each area of the building in the software, and control the temperature, lighting and other environment parameters in the area, which can save energy and improve the operation efficiency of the company. Besides, during the pandemic period, sensors play an important role in population density monitoring in the specific area, social distance control and body temperature measure at the entrance or exit of building. The sensors not only protect and monitor the infrastructure of the building, but also create a "predicable, customer-friendly, interactive" environment.

Fig.3 Smart Building Management Solution

Besides the intelligent monitoring of the indoor environment and energy consumption of buildings, Siemens also takes the lead in implementing the intelligent connectivity between large-scale buildings, which gives one possible direction for future smart city development.

Taking the 2020 Dubai World Expo as an example, Siemens has provided a complete set of smart building technology solutions. It integrates the data collected from sensors and various systems in the building into the Mindsphere industrial IoT operating system, uses the software like Navigator to conduct real-time analysis and data visualization and applies artificial intelligence technology to make the forecast based on the historical weather data and other information. Consequently, the system can propose suggestions for environmental maintenance and building protection in the campus. Managers can monitor the energy consumption, environment and safety of the whole campus in real-time on smart phones, so that they can improve energy efficiency and provide tourists with a safe, reliable, comfortable and green environment. The project provides a blueprint for the construction of smart cities in the future[8], and also provides a reference for the development of smart energy systems in Chinese cities.

2. The energy system development state of Chinese cities

China is the world's largest energy consumer. According to “BP Energy Outlook” released in 2019 by British energy company BP, the annual growth rate of China's energy demand from 2017 to 2040 is 1.1%, lower than the annual growth rate of 5.9% in the past 20 years. However, by 2040, China will still be the world's largest energy consumer, accounting for 22% of global energy consumption[1]. Currently, the electricity demand increases more rapidly with a growth rate of 4.5% in 2019, among which the electricity consumption of urban and rural residents has increased by 5.7% [9]. In 2019, China's urbanization rate will reach 60.6% [10]. The energy demand of densely populated urban clusters such as the Yangtze River Delta, Beijing-Tianjin-Hebei Area, Guangdong-Hong Kong-Macao Area will continue to rise with the further urbanization. These densely populated and economically developed regions have limited space to construct large-scale power infrastructure. Therefore, China has formed the "power generation in the West and power consumption in the East" structure. Although the currently the power

demand of high energy consuming areas can be met, the spatial mismatch for production and consumption leads to large power loss in long-distance transmission. Compared with the traditional large-scale power generation equipment, the distributed power generation equipment does not have a large footprint, which is suitable for urban implementation. It can be installed near the energy consumer without long-distance power transmission, which can improve the electricity utilization efficiency and alleviate the pressure of urban energy consumption.

In order to improve the energy efficiency and promote sustainable development, China has issued policies to promote the development of distributed energy. In 2006, the State Council brought distributed power system into the research focus of advanced energy technology. In 2011, the National Development and Reform Commission (NDRC) proposed to develop regional and building distributed power system in heavy energy consumed area. The National Energy Administration then issued the "Interim Measures For Distributed Generation Management" in July 2013, which clearly defined the meaning of "distributed power" and encouraged all kinds of power users, including enterprises and individuals, to invest and operate the distributed power projects. In 2017, the pilot National Green Power Certificate was launched, which promotes enterprises to actively participate in distributed clean energy production. In 2020, "China Energy Law (Draft for comments)" clarifies the commodity attribute of energy, emphasizes the importance of energy marketization, encourages cities and rural areas to build the distributed clean energy supply system with multi-energy complementary and establishes a full-featured, independent and regulated energy market trading institutions or platforms.

Presently, great progress has been made in distributed power system. By the end of 2019, China's PV power generation has an accumulated installed capacity of 204 million kW. In 2019, the additional PV capacity increased by 30.11 million kW, among which 12.2 million kW is distributed PV power, accounting for 40.5%[11]. At the same time, the pilot project of distributed power marketization is also officially started. The "Notice On Launching Pilot Market-oriented Trading of Distributed Power System" was first launched by the National

Energy Administration in 2017, and the first batch of 26 marketization pilot projects of distributed power trading with a total of 1.65 million kW was released in April 2019, which means China's power market will gradually develop from a traditional highly integrated market to a new open market in the future. However, practically speaking, the prosumers with distributed PV power system face a great uncertainty from the unpredictable and fluctuating power curve. How to achieve accurate prediction and improve the stability of distributed PV power generation system are the main technical challenges. In addition, data security and trading trust are also considered as the problems for the distributed power market. Comparing with Germany or Nordic countries, China's marketization degree of distributed power sources is still insufficient. Hopefully with the launch of market-oriented trading pilot projects and the improvement of relevant policies, the distributed power trading market will scale-up in the following years.

In addition to encouraging the distributed power generation development, China also continuously promotes the development of building IoT and smart energy management system in recent years. In 2013, the NDRC issued the "Green Building Action Plan" to encourage the energy-saving retrofit of existing buildings. The Ministry of Industry and Information Technology pointed out in the " IT Industry Development Plan - Catalogue For IoT (2016-2020) " that it will focus on the development to " create platform for building energy monitoring and service, monitor energy consumption of mega buildings and realize the smart control and refined management of building energy consumption".

The application of the building IoT and smart energy management system is conducive for efficient energy monitoring and reducing energy consumption, while it requires high cost of retrofitting investment. The further upgrading is required for the hardware and software such as power distribution, heating and lighting systems in the building in order to be connected with the smart energy system. Some regions in China such as Beijing, Shanghai have launched subsidy policies for smart energy system projects in 2019. For example, the “Measures For The

Administration of Special Funds For Energy Saving and Emission Reduction in Haidian District" issued by Haidian District, Beijing, proposed to encourage the development of energy-saving technology retrofitting, especially for the new energy-saving technology application scenarios, the innovation and new energy-saving products promotion, the green data center and the smart energy system construction. A maximum 30% of the total investment will be covered by the subsidy, with a maximum amount of 5 million RMB after the project is completed[12]. Such local subsidies have effectively motivated the smart buildings retrofit in the areas. More national subsidy policies should be introduced to promote the application of Building IoT and smart energy management system.

3. Core Policy Suggestions

There are 3 problems elaborated in above chapters: More distributed power systems can be built in the large and medium sized cities; The distributed power trading standards should be further refined; The smart energy management system for buildings need be further promoted. Regarding to these 3 problems, the following suggestions are proposed:

The construction of distributed power generation systems in large and medium-sized cities should be accelerated. The developed areas in China are facing the pressure of high energy consumption and sustainable development. Currently, the installed capacity of clean energy is relatively low while the main power supply is still from thermal power. The thermal power installed capacity contributes about 77.1%, 74.5% of the total power generation in north and east of China, respectively[13]. High portion of distributed power system and energy marketization can effectively improve the energy utilization efficiency, alleviate environmental problems and benefit to sustainable urban development. In 2019, China's PV power generation reached 224.3 billion kWh, of which 54.5 billion kWh is distributed PV system, accounting for 24%[11], and still has opportunity to penetrate further. The government should consider the plan of urban and regional development or power development and facilitate the optimized regional distribution of

distributed power generation systems. Especially in areas with high energy consumption, such as Beijing-Tianjin-Hebei Area, Guangdong-Hong Kong-Macao Area , as well as the Yangtze River Delta, measures should be taken to accelerate the construction of distributed power in order to provide needed energy supply and reduce long-distance transmission losses. In addition, distributed power system can provide flexible and stable power supply in the special periods. Such as during the epidemic outbreak, prosumers can achieve power self-sufficiency. The power management operators can also make full use of large-scale grid combined with distributed power generation, such as microgrid, to ensure a resilient supply of electricity.

The technical specification and regulations of distributed power trading should be further refined. The trial operation of distributed power market and pilot project landing should also be accelerated. Great progress has been made for the construction and marketization of distributed PV power in China, and the government should speed up to launch pilot projects. Jiangsu Province is the first who released the "Jiangsu Distributed Power Generation Market Trading Rules (Draft for comments)" among the first batch of 26 marketization pilot projects of distributed power trading, while the other demonstration areas need to speed up. In addition, the distributed power trading in China is featured with low marketization level and is lack of regulated management tools. Presently, the rules and regulations of distributed power trading are still not ready to support real trading. Policy makers shall consider to finalize the detailed rules of market trading, promote the standardized and modularized development of the platform for the trading and guide the market to have multiple platform suppliers. The market trading rules should be further defined and refined after successfully implementing in the demonstration area, in order to guarantee the reliable electricity trading market and improve the efficiency of trading and supervision. At the same time, how to ensure the interests of the participants such as the prosumers, grid enterprises etc. shall always be considered in the process of policy making. Some commercial and individual users are less motivated to develop the distributed power system and participate in the trading due to lack of related knowledge, mature profitability

mechanism and successful development and operation references. Therefore, the national policy shall be carefully designed, in order to guide and encourage the various stakeholders to participate in the distributed power source construction and trading market.

The policies for mega building's energy consumption should be defined and the investment for smart buildings or smart retrofitting should be encouraged. The policy making is relatively lagging behind in the mega building energy consumption and its monitoring fields. Mega building owners are often hesitated to conduct the energy system upgrading hindered by the high cost of upgrading or retrofitting, even though the building energy consumption can be reduced. The absence of the financial support or incentive mechanism results in weak willingness for the building owners to do the upgrade. According to the report "Energy Efficiency Improvement and Electric Vehicles" jointly issued by the Rockies Mountain Institute, an authoritative institution of energy market in the United States, and a lighting enterprise named Signify, applying energy efficiency improvement technology as soon as possible is the most economical and effective way to meet the power demand of building. Currently, only 1% of global buildings are retrofitted every year. Once the rate increased to more than 5% every year, at least 30% of energy saving can be achieved. The energy saved from building can also cover the power demand of at least 550 million electric vehicles in 2040 without increasing the total amount of existing power generation capacity[14]. It indicates that the building renovation will effectively alleviate the problem due to the energy consumption increase. At the same time, the COVID-19 pandemic has created the 'new normal' for people to wear masks, have body temperature tested and keep social distance. People spend more time staying at home and require safer and more comfortable environment during such pandemic. Digital technology endows buildings with brains and nerves that allow them to understand their occupants, creating humancentric, safer and comfortable environment. It is suggested that the government should refine the policy related to usage and supervision of energy consumption for mega public buildings, define energy saving standard and encourage smart building retrofitting as well as

applying smart energy management system to effectively monitor buildings, which will motivate the building owners to participate in the smart building upgrade to reduce energy consumption, by applying smart energy system to monitor energy consumption, and enhance the capability of emergency event response during the special period.

Digital technology innovation and development should be encouraged to create a smart energy ecosystem. The application of digital technology in the energy field can promote the development of industry ecosystem and realize the joint development of energy systems. Although the products based on the digital technology are continuously developed and released for smart energy management, their application and the related project implementation in China relatively fall behind. According to BP's prediction, with the application of digital tools such as sensors, big data analysis and artificial intelligence based on the cloud, the primary energy demand and cost in the energy system will be reduced by 20% - 30% in 2050[15]. In addition to cost reduction, the energy big data platform is also conducive to remote and efficient monitoring as well as rapid response for energy in special periods such as pandemic time. Therefore, it is suggested that the government can introduce relevant policy to encourage collaboration among enterprises in the energy and relevant high-tech fields to support digital technology innovation and promote technology application. In the future, China should specify the subsidy rules, expand the coverage of subsidies, and promote corresponding demonstration projects, to accelerate the large-scale implementation of smart energy system in China.

4. Conclusion

The frontier application of energy digitalization in various scenarios in the world shows that digital technology and energy industry are gradually and deeply integrated with each other. The energy digitalization becomes more and more extensive and changes the way of energy production, transmission, trading, consumption and supervision. With the development of

distributed energy, the digital technology will be widely used to bridge and manage the production and consumption of different distributed energy system and facilitate the energy market trading. Following the trend of digital energy revolution, many energy enterprises are actively studying and using new technologies such as big data, cloud computing, Internet of things, artificial intelligence, blockchain, etc., and upgrade their portfolios based on these technologies. It can drive their own transition towards a sustainable development and enable the renovation of urban energy system. As the development of distributed power trading market in China is still in the early stage, government shall encourage the implementation of pilot projects and accelerate the policy making for distributed power trading. The regulatory policies of building energy consumption, and incentive policies for smart building construction or retrofitting should be put in place as soon as possible. The government shall also promote the digital solutions to drive the upgrade of urban energy system.

References

[1] BP. BP Energy Outlook 2019 Edition[R].2019

[2] IEA. World Energy Outlook 2019[R].2019

[3] United Nations. Department of Economic and Social Affairs. World Urbanization Prospects-2018 Revision[R].

[4] United Nations Environment Programme. Sustainable buildings[EB/OL].2019.

[5] McKinsey & Company. The potential impact of electric vehicles on global energy systems[R].2018.

[6] Fraunhofer Institute for Solar Energy Systems ISE. Recent Facts about Photovoltaics in Germany[R].2020.

[7] Siemens Connecting an all-electric world[C]. Ljubljana:2018.

[8] Siemens. Expo 2020 Dubai: A Sustainable Site[R]. Electrical Construction and Maintenance Magazine.2020.

[9] National Energy Administration. 2019 Data Statistics on Electricity Consumption of the Whole Society [EB/OL].2020.

[10] National Bureau of Statistics. Statistical Bulletin of the People's Republic of China on National Economic and Social Development 2019[EB/OL].2020.

[11] National Energy Administration MoM for National Energy Administration's Online Press Conference for the First Quarter of 2020[EB/OL].2020.

[12] Beijing Haidian District People's Government. The special fund management measures for energy conservation and emission reduction in Haidian District[Z].2019.

[13] China Electricity Council. China power industry annual development report 2018[M].2018.

[14] Rockies Mountain Institute. Energy efficiency improvement and electric vehicles[R].2018.

[15] BP. BP Technology Outlook 2018[R].2018.

