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Energy Internet - A New Driving Force for Sustainable Urban Development

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Abstract

As an integration of energy technology and information communication technology, "Energy Internet" is the new driving force for global development of clean and efficient energy systems. This paper summaries the concept and characteristics of "Energy Internet" and the sustainable urban development; describes some concepts and achievements in the field, and expounds the driving forces for the development of Energy Internet. An example of multi energy system is presented to illustrate that the Energy Internet. The multi energy internet can effectively improve energy efficiency, protect the environment, promote the city's circular economy, and have good economic and social benefits for sustainable urban development.

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Keywords: Energy Internet; Sustainable Development; Circular Economy

1. Introduction

The resources of the traditional energy we have used for a long time are mainly limited to fossil fuels, such as petroleum, coal, and natural gas. The utilization of fossil of fuels has increasingly damaged the environment seriously. Besides, the forms of traditional energy, such as electricity, heat, and gas, are often independent each other and generally do not form a comprehensive integrated utilization and cannot complement each other's advantages. In recent years, the use of renewable energy such as wind and solar has been rapidly developed, and it has made effective

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contributions to the solution of environmental pollution problems. But the volatility of these renewable energy sources affects the smooth operation of energy systems and limits the efficient use of renewable energy. If wind, solar, storage, and other energy sources are used in a coordinated manner, the advantages and potential of different energy systems can be fully exploited for maximum energy capture and utilization efficiency. With the widespread application of Internet technology [1], the idea of integrating energy systems like the Internet to form an Energy Internet has come out. This paper will outline the concept and characteristics of the Energy Internet and describe the development of relevant concepts and achievements. An example is given to show the role of Energy Internet in sustainable development strategy and circular economy.

2. Energy Internet Concepts and Characteristics

2.1. Energy Internet Concept

Energy Internet is a system based on a power electronic technology and information communication technology (ICT), using the energy information management system to connect the centralized or distributed renewable energy, energy storage, consumption load together as a whole organic. With an energy internet, the close coupling and coordination sharing of energy and information, high energy security and efficiency can be achieved [2]. An example of energy internet is shown in Figure 1, where the energy controller will coordinate the energy flow between the main grid and local area network (LAN). The energy routers enable the industrial, commercial, and residential buildings to be connected together, to work as a generator as well as a consumer while energy storage devices are also connected to energy networks in either a centralized or distributed manner. In the energy internet, the information flow controls energy flow to ensure safety and reliability of the overall systems.

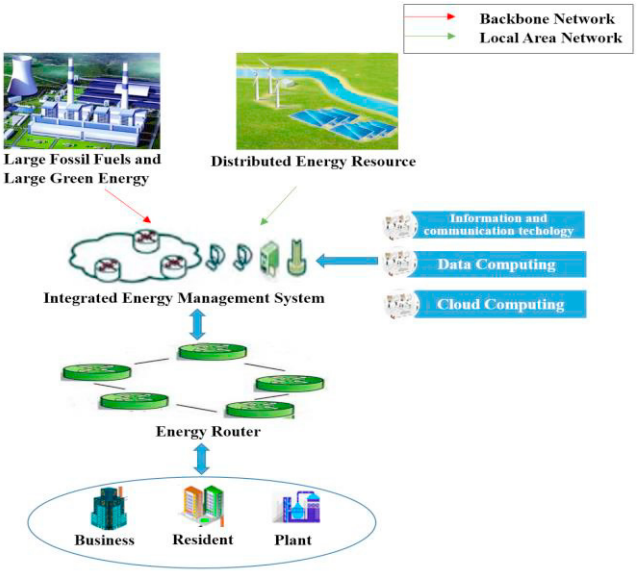

Figure 1 Sketch of Energy Internet

2.2. Energy Internet characteristics.

Energy Internet can be understood as an upgrade version of the current smart grid. While the Energy Internet has the characteristics of smart grids, such as self-healing, security, reliability, cost-effectiveness, compatibility, and friendly interaction with users, it also has the following features [3]:

- Replace non-renewable energy such as fossil energy with renewable energy such as solar energy and wind energy;
- Connect easily to large capacity energy storage devices to stabilize and smooth energy output;
- Generation, storage and consumption on the same site and same time for high efficiency operation;
- Two-way energy flow, that is, users are consumers as well as producers of energy;
- Have the advantages of the space-time complementary of distributed energy sources and the wide-area configuration of the power grid;
- Realize the interconnection of cooling/heating, electricity and gas networks for conversion between different types of energy;
- Information communication technology penetrates into all aspects of energy flow [4].

3. Development of Energy Internet

3.1. The Information centralized Energy Network in the United States.

The concept of energy routers and implemented prototypes has been introduced. A FREEDM system model centered on intelligent control has been built in United States, the system is based on power electronics technology and implemented with the concept of Energy Internet System (EIS) based on distributed system control interactions. The EIS is developed on the basis of existing energy supply system and distribution network through the use of advanced power electronic technology and information technology. Combined with new energy technology and internet technology, a large number of distributed energy generation devices and distributed energy storage devices are connected together to achieve a sharing network with two-way exchange flow of energy and information. The renewable energy generators are the main energy sources in the interconnection network, an intelligent energy management system is constructed to realize the real-time, high-speed, bi-directional power data flow and the connection of renewable energy generators [5].

3.2. EIS exploration in Europe based on practical projects and hardware

In 2008, Germany proposed the E-Energy technology innovation promotion plan and selected 6 pilot sites to carry out the EIS demonstration project [6]. The goal is to achieve communication and coordination between grid infrastructure and home appliances, for further improving the level of intelligent power grid; to achieve full coverage of information network in the power system, to enable all elements of the energy network to be coordinated through information internet by 2020. The Swiss research team has developed the concept of the Energy Hub. This concept is from the concept of the hub in computer science, also called the energy control center. Generally, an energy hub is an information center, which can optimize both the generation and consumptions based on the extra-short term load forecasting and real-time online monitoring of the power flow of distributed generation and distribution network. The energy hub may cover a household or even the whole city. The energy hub is a multi-port network node, which plays a strong practical role of replenishment, mitigation, transformation, regulation and storage for energy in distribution networks.

3.3. Development and exploration of the smart power grids in China

Smart grid are from the integration of ICT and power grid [7], which have been developing rapidly in China in recent years. At present, the attention has been shifted from a single power system to a comprehensive integrated energy system, such as electric power, heating, cooling, gas and even electrified transportation. The interconnection of various energy systems with the ICT Internet technology, the Internet thinking way and technology are transforming the existing energy industry and create a new business model to promote the public innovation and entrepreneurship. In China, the "Internet plus energy" model is adopted, through the integration of the advanced electronic technology, information technology and intelligent management technology, a large number of distributed energy production and energy storage devices, various types of load, natural gas network and other energy nodes are interconnected to realize bidirectional energy flow and peer to peer sharing and exchange networks.

4. New Driving Force for Sustainable Urban Development.

4.1. The Concept of Sustainable Urban Development

A fundamental factor of urban development is resources. In order to achieve sustainable development, cities must make reasonable use of their own resources [8], find an ecosystem friendly and high efficiency utilization process with long-term consideration. The balance between resources, their developments and utilizations is an important principle to be followed for the sustainability.

Sustainable urban development is a process in which the public should constantly strive to improve the natural and human environment of their own communities and regions, and at the same time contribute to global sustainable

development. The World Health Organization (WHO) indicated that urban sustainable development should make the urban economy more efficient, stable and innovative with a minimum use of resources. Cities should exploit their full potential and continue to pursue high-quality and high-quality social and economic and technological output, maintain their own long-term stability and consolidate their position and role in the urban system.

The urban environmental problem is a basic problem for sustainable urban development, while urban energy system is playing an important role in the sustainable urban development and has significant impact on environmental issue.

4.2. The Driving Force of Energy Internet

The characteristics of distributed renewable energy require the energy generation units to be connected to the grid for effective share. Therefore, the energy Internet is the inevitable outcome of the large-scale utilization of distributed renewable energy. However, the sustainable development still need to solve a series of problems in the development process of city energy Internet, such as

- The fluctuating renewable power productions may be difficulty to be accepted by the power grid.
- The construction of the power transmission corridors may lag behind, and renewable energy transmission is limited [9].
- The high cost of energy storage equipment limits the application of distributed energy.
- The renewable energy still has a high cost and its development is too dependent on the tariff subsidy policy.

To sum up, the driving force of the Energy Internet include:

- to adapt to the high penetration development of renewable energy, promote revolution of energy systems for a future sustainable energy system;
- to meet the provisions of the government regulation to promote energy saving and emission reduction, revolution of the energy consumption;
- to meet the industrial needs, adopting Internet technology to activate the electricity market, realizing open service;
- to adapt to the development of distributed generation and electric cars, to promote industrial upgrading of smart energy systems.

With the further research of Energy Internet, the contents of the Energy Internet is further enriched, the Energy Internet system will pursue the performance of open energy interconnection, flexible energy transmission, and open peer-to-peer access. In this way, the urban Energy Internet will face many technical challenges, including the comprehensive utilization of distributed energy; the demanded development of power electronic devices; the selection of materials for energy storage devices; the application of artificial intelligence [10]; physical security requirements such as cloud computing, big data processing, etc.; multi-energy load coordination control [11-14]. The development of the energy internet will drive many emerging energy markets [15], including new energy, electric vehicles, energy storage, micro grid, energy management services, and related industries, including equipment manufacturing, communications, finance, software, etc. [16-17].

5. Examples of Energy Internet Application

5.1. Multiple Energy System under Sustainable Development

An example of an integrated multi energy recycling system is shown in Fig. 2. The multi energy consists of a thermal power plant, heating equipment, seawater desalination equipment, brick factories, and salt fields. The system is connected to the power grid, heating network and water supply system. The power plant supplies both electricity and heat to the power grid and heating network, and to seawater desalination equipment. The seawater desalination equipment uses a part

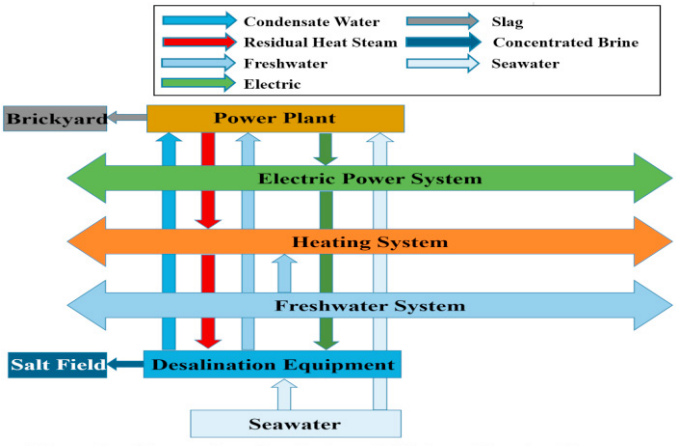

Figure 2 Comprehensive System Of Urban Circular Economy.

of the heat from the thermal power plant to separate seawater into freshwater and brine. Then the freshwater is sent to the water supply network, brine is sent to the salt farm for salt production, and the coal slag burned by the thermal power plant is delivered to the building materials factory to make high thermal insulation and high density hollow brick. Overall very little waste is generated, the system maximizes the use of resources, is an good example of circular economy and protects the environment and promotes economic benefits. However, the thermal power plant is still powered by fossil fuel and generates pollution, if the power plant adopt renewable energy source instead of fossil fuel fired, the system will further promote the sustainable urban development.

5.2. An Urban Energy Internet for Sustainable Development

Compared with the use of traditional energy systems, the application of Energy Internet in industrial development is more suitable for the sustainable development. For the practical example of "Multiple Energy System under Sustainable Development" above, taking the concept of Energy Internet discussed in the paper, the system can be optimized to achieve "green input, green output", as shown in Figure 3. The optimized system first replaces the fossil-fired thermal power plants by wind power and photovoltaic power generation, and the energy storage devices is installed at the same time to solve the volatility and intermittency of the output power of the renewable energy power sources. Also, a high-efficiency heat pump system has been added to produce the required heat for the seawater desalination equipment and the heat network. An intelligent control system is used to optimize the system operation.

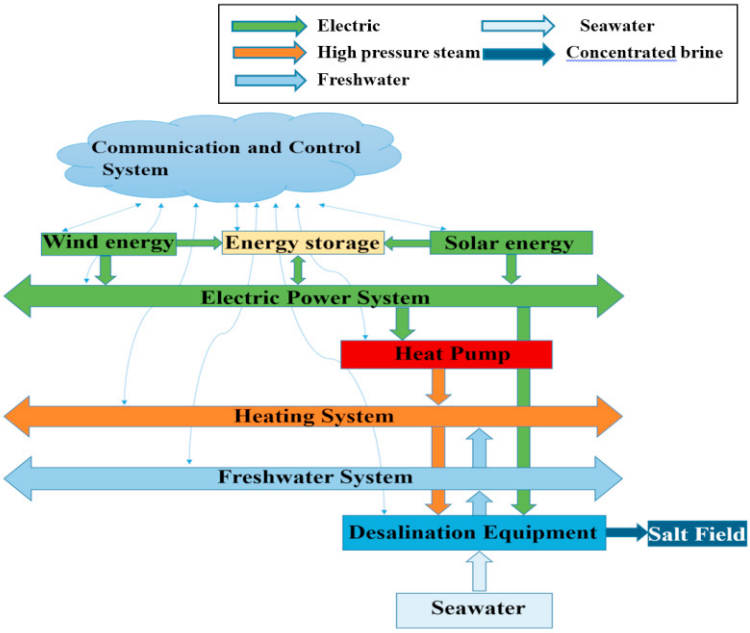

Figure 3 Urban energy Internet under circular economy

Through the replacement of the fossil fuel based power plant with the renewable power generation, the input of the Energy Internet has zero pollutants, removing the emission of sulphur dioxide, nitrogen oxides and soot. The use of clean energy in the Energy Internet system not only remove the dependence on fossil energy, reduces the emission of pollutants and their derivatives, but also improves quality of life, provides strong support to the sustainable development.

6. Conclusion:

The Energy Internet will change the way how energy is produced, transported and consumed, further impact on the people's life, Energy Internet can promote energy transformation, increase energy efficiency, and help to realize recycling economy and sustainable urban development. The paper describes the concept and characteristics of "Energy Internet" and indicate its relation to the sustainable urban development; presents some concepts and achievements in the field, and introduces the driving forces for the development of Energy Internet. A multi energy system is presented as an Energy Internet example. The multi energy internet can improve energy efficiency and realize circular economy. Replacement of fossil fuel with renewable power sources will protect the environment, further promote the city's circular economy and have significant economic and social benefits for sustainable urban development.

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