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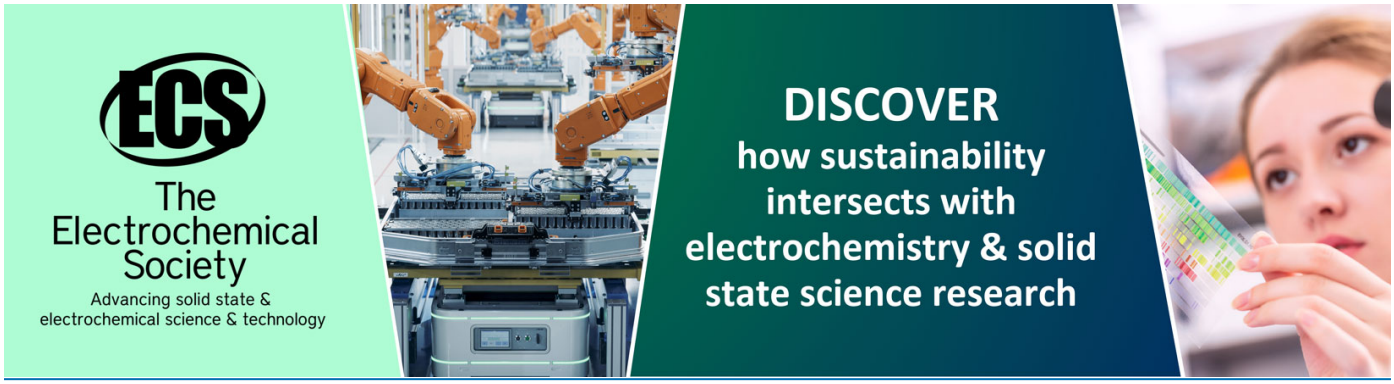

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Research on the Operation Mode of Intelligent-town Energy Internet Based on Source-Load Interaction

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Abstract. On the background of the rise of intelligence and the increasing deepening of "Internet +"application, the energy internet has become the focus of the energy research field. This paper, based on the fundamental understanding on the energy internet of the intelligent town, discusses the mode of energy supply in the source-load interactive region, and gives an in-depth study on the output characteristics of the energy supply side and the load characteristics of the demand side, so as to derive the law of energy-load interaction of the intelligent-town energy internet.

1. Introduction

Along with the economic growth and the increase of population throughout the world, the energy and environment issues become more and more outstanding, and it is difficult to maintain the conventional energy development and pattern. Various countries have proposed a new type of energy development and application solution, i.e., energy internet, by utilizing the internet and new energy technologies. Meanwhile, as the in telligentization emerges as the fourth tide, coming after the industrialization, electrification and informatization, the energy internet has become the focus in the energy research field. In 2012, Energy Research Institute of National Development and Reform Commission initially put forward the concept of "Internet +" intelligent energy (energy internet) which purports to build a multi-energy internet centering at the electric power system; namely, the conventional energy industry will be transformed by making use of the internet thinking and techniques, so as to realize a new-type energy system which can provide the horizontal multi-source complementation, longitudinal "source-grid-load-storage" coordination and high-degree integration between energy and information [1].

Scholars at home and abroad have carried out in-depth research on the concept of development, mode of application and key issues of the energy internet. The book "Intelligent Energy - Our Ten Thousand Years" points out that the intelligent energy is a kind of energy type which is provided with features of the human brain, including self-organization, self-inspection, self-balance, self-optimization and so on, and can satisfy the system, safety, cleanness and economy requirements [2]. The document [3] points out that the construction of the energy internet should refer to the Internet mode, and follow the pattern of layered structuring, separate building and sharing of income. The document [4] takes Ningbo City as an example to analyze the importance of energy internet to the urban development. The document [5] points out that the true realization and formation of the energy internet and intelligent energy require a breakthrough in the software and hardware technologies related to the energy router, and the realization of the non-decoupling operation of the energy internet

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used for the simulation study through the optimized modeling of different intelligent energy sources in the microgrid.

To sum up, the research on the energy internet mainly focuses on the establishment of policies and systems and the construction of the intelligent city; however, the discussion on the application modes of regional energy internet in the rural area, community and park zones and other smaller areas is insufficient. Towns with a smaller area are confronted by the environmental pollution, serious wasting of new energy, low efficiency of comprehensive utilization and other issues in the energy utilization network; therefore, researching the energy internet supply mode in the regions which are considering the source-load interaction constitutes a objective requirement for the application of new energies and the construction of the intelligent town, which is highly significant for the energy saving & emission reduction and the safe and economic operation of the energy industry

2. Research on characteristics of output from the energy supply side

"Source" in the mode of energy supply in the intelligent town based on the source-load interaction refers to the sum of various types of energies from the supply side. In addition to the conventional electric grids, in the small-sized energy internet of the community, park zone or rural area, the distributed energy system comprising various clean energies also plays an important role. These energies can be classified into the renewable energy and non-renewable energy by their attribute, as shown in Table 1. Characteristic of the energy output from the supply side are correlated with the characteristics of output of various energy types. The so-called energy structure refers to the proportion of the installed capacity of each type of energy supply in the total installed capacity in the area being researched. Different energy types are provided with different output characteristics.

Table 1. Classification of energies from the supply side

Technical type	Energy classification	Output type
Thermal power	Non-renewable energy	Alternating current/heating energy
Micro-turbine	Non-renewable energy	Alternating current/heating energy/ cooling energy
Geothermal energy	Renewable energy	Alternating current
Hydro energy	Renewable energy	Alternating current
Wind energy	Renewable energy	Direct current
Photovoltaic power	Renewable energy	Direct current
Ocean energy	Renewable energy	Alternating current
Fuel cell	Non-renewable energy	Alternating current
Solar power	Renewable energy	Alternating current/heating energy/ cooling energy
Biomass energy	Renewable energy	Alternating current/heating energy

2.1. Characteristic of output of wind power

The wind power refers to a technology which transforms the kinetic energy of the wind into the electric energy, and converts the wind energy into the mechanical energy via the wind turbine to drive the generator to generate the power. In the regional intelligent energy network, the wind energy is mainly applied in the mountains or sea islands endowed with abundant wind power resources. The output power of the wind turbine is primarily decided by the wind speed, and the power characteristic curve of a specific wind farm is shown in Figure 1. According to the figure, the wind turbine can only output the energy stably after the wind speed reaches its rated value but is lower than the maximum wind speed of the turbine. However, the wind power in the local area is continuously varying. That's why the wind power output is fluctuating and intermittent depending on the natural conditions.

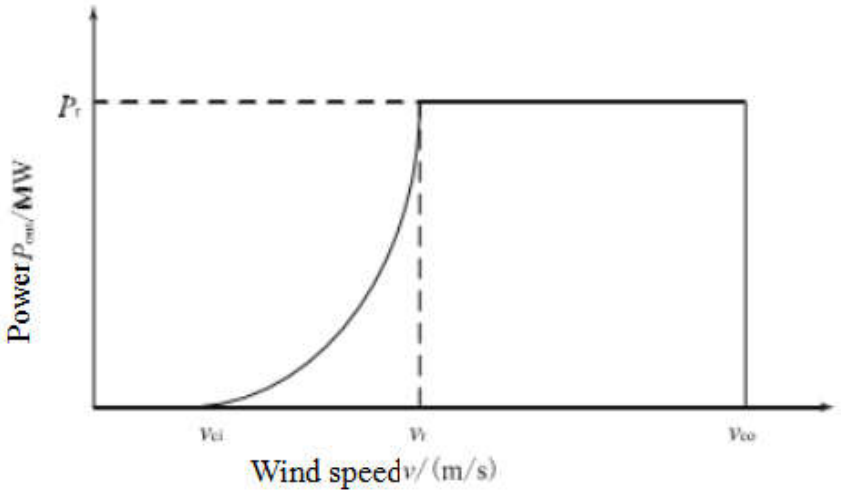

Figure 1. Output curve of the wind turbine

2.2. Characteristic of output of solar power

The solar power generation refers to a technology which converts the solar energy into the electric energy, and it includes photovoltaic power generation and solar thermal power generation. The photovoltaic power generation is a technique which utilizes the photovoltaic effect of the semiconductor interface to directly convert the optical energy into the electric energy. Its key element is the solar cell. After solar cells are serially connected and sealed, they can form a large-area solar cell pack, and with the use of the power controller and other components, a photovoltaic power generation unit is built. This system is widely applied in the distributed power grid of the community and rural area, and it can be also put into the grid-connected operation. The solar thermal power generation is to utilize the solar heat collection unit to collect the solar heat and heat the working medium to a high temperature and a high pressure, thus to drive the expander to work and generate power; meanwhile, the system can also supply the heating energy and cooling energy to users via the heat network. The output of the solar energy system is mainly affected by the solar radiation intensity and ambient temperature; therefore, it will vary largely largely with the geological location and climate conditions.

2.3. Characteristic of output of biomass energy

The biomass energy is to generate the marsh gas which can be used as a kind of energy, from the biomass materials by means of anaerobic fermentation, and the biomass fuel gas generated through mixing with the liquefied natural gas can be used for domestic energy or power generation. There are rich biomass energy resources in the rural area or the community, including domestic garbage, crop wastes, energy plants and agricultural biomass. In addition to the use as the domestic energy in the rural area, the biomass fuel gas is also used as the gas for the internal combustion engine or miniature fuel gas - steam combined cycle power generation which will adapt to the load changes by changing the quantity of generator units so as to supply the electric energy to users.

2.4. Characteristic of output of hydropower

The hydropower generation refers to the radial flow type power station which outputs the power by utilizing the natural flow and head of the river. The hydropower generator unit features quick start and stop, short response time and other advantages; therefore, it is possible to supply electric energy to the remote areas by building a small-sized hydropower station in the mountainous area which is endowed with abundant water resources. However, such a kind of power station is generally in close relation with the water yield, and the generation load is highly unstable, with poor regularity and adjustability.

2.5. Characteristic of output of conventional electric power

Conventional electric energies include the thermal generator unit and fuel gas - steam combined cycle generator unit. Now the thermal generator unit has been mature, and has been widely applied, accounting for a large proportion in the electric energy structure in China and constituting a major component of the power energy of the country. The combined cycle generator unit features quick start and stop, and is mostly used as the peak regulation and heat supply units. In the urban energy internet, the conventional electric energy features a stable output and a high adjustability. Such generator units are mainly used to bear the loads when the output of renewable energy is insufficient.

2.6. Source-source coordination and balancing of the supply side

In the regional energy internet, different types of energies are provided with different output characteristics, and it is necessary to guarantee the coordination and balancing among various types of energies. The wind energy and solar energy are highly random and intermittent, and are subject to the geological and climate conditions, liable to cause the voltage instability of the system, degraded quality and wasting of electric energy and other problems. The biomass energy output is mainly influenced by the biomass resources. The generation load of the small-sized hydropower station is determined by the water flow rate of the river. When the demand from the user side in a certain region is stable, the energy output from the supply side should be kept constant.

Both wind power generation and photovoltaic power generation require the use of the inverter to supply the electric energy to the users. Wind power and solar power resources are tactfully complementary with regard to the time; namely, the sunlight is abundant and the wind speed is low in the daytime, while the sunlight is zero and the wind speed is high in the nighttime; the sunlight is abundant and the wind speed is low in summer while the sunlight is weak and the wind speed is high in winter and spring. Therefore, the wind-solar complementary power generation can transform the intermittent wind energy and solar energy into the stable electric energy to some extent. The biomass energy, water energy and photo-thermal resources can be stored using the storing device to maintain a stable output of energy from the supply side, as shown in Table 2.

Table 2. Types of storable energies

Energy classification	Storage method	Utilization method
Biomass energy	Storage of biomass materials	Domestic energy and power generation
Solar energy	Heat storage tank	Power generation and heat supply
Hydro energy	Reservoir	Power generation

3. Research on characteristics of loads on the demand side

Load mentioned in “source-load interaction” refers to the sum of power consumptions of the energy-consuming equipment on the demand side in the energy network, mainly including electric load, heating load and cooling load. In the intelligent-town energy network, the research on the characteristics of loads on the user side constitutes a basis for discussion on the energy internet mode based on the source-load interaction. An in-depth study on the energy consumption conditions and laws of various types of users is of great significance for the establishment of the urban energy internet. The regional energy internet is mainly applied in the rural area, community and industrial park zone. In addition to the household energy and industrial and agricultural energy, loads on the demand side also include the fast-growing electric car loads and the energy storage system used for digestion of new energy and peak load shifting.

3.1. Characteristic of loads of the enterprises in the park zone

In the energy internet of the park zone, the industrial enterprises are major energy users. The energy-consuming enterprises in the industrial park zone mainly consume the electric energy, i.e., the

commercial power. The commercial power features high power factor, stable power, and high consumption, and the electric loads of the industrial enterprises vary insignificantly throughout the year, quarter and month, which makes a balanced power consumption. Meanwhile, loads of certain enterprises have a direct bearing on the lifeblood of the national economy and the safety of people's lives and property, being crucial for the stable operation of the country and the society. As any power outage or interruption may cause huge loss and influences, the stable power supply to these loads must be maintained.

3.2. Characteristic of loads of the agricultural industry

In the construction of the energy internet in the rural area, the agricultural load is the most primary energy load. The agricultural load mainly refers to the electric energy consumed in illumination, agricultural irrigation, and processing of agricultural and side-line products. An outstanding feature of the agricultural power consumption is the significant variation with the season changes, and time distribution of loads is in an imbalance. In winter, the irrigation power consumption and illumination power consumption are nearly zero, and the daily load and daily minimum load rate are 0.1 and 0.01 respectively. In summer, the power consumption for irrigation, illumination and processing of agricultural and side-line products is huge, and the daily load and daily minimum load rate are 0.9 and 0.3 respectively.

3.3. Characteristic of loads for household energy consumption

The urban household energy loads mainly include domestic electric energy, heating energy and cooling energy. In the community and rural area, the cooling in summer is primarily realized by the refrigerators, air conditioners and other electric equipment; therefore, the cooling energy is obtained via consumption of electric energy. The household energy loads are correlated with a number of factors, for example, size, population density, household income level, local weather, seasons and holidays of the community or the rural area. In the areas with a developed economy and a high living level, the load level is also very high; otherwise the load level will be low. The load level of the urban community is higher than that in the rural community. The household electric loads are highly subject to the seasons. In summer, the daily load rate is 0.5~0.6, and in winter, the daily load rate is 0.4~0.5. Meanwhile, in winter, the heating energy demand will be largely increased, so the consumption of heating energy is much larger than that in other seasons.

3.4. Load-load coordination and balancing

In the urban energy internet based on source-load interaction, the load-load coordination and balancing can be realized by responding to the demands on the load side, thus to promote the optimized configuration and utilization of the energy and guarantee the safe, reliable and economic operation of the energy internet system. Participation of loads in the grid scheduling is a basis for the effective source-load interaction. Under the background of marketization, a series of legal, administrative, economic and technical approaches can be used to guide users to change the power consumption mode and use the electric energy scientifically and reasonably under certain conditions, so as to realize the load-load coordination and balancing and the source-load interaction.

Depending on their own characteristics, loads can be classified into the transferable loads, reduce able loads and interruptible loads. Transferable loads refer to those loads of which the total energy consumption in a specific term is unchanged and the energy consumption of which in any time period can be flexibly adjusted, such as the agricultural irrigation power consumption. The reduce able loads refer to those loads which can be reduced, including most of the household electric loads, such as air conditioner, TV set and washing machine. Interruptible loads refer to those loads which can be interrupted by the user in an emergency or at the peak time of the power grid, mainly including those industrial enterprises which are less important. Transferable loads, reduce able loads and interruptible loads can be increased or reduced using the appropriate approaches under the centralized scheduling of the energy internet to achieve the load-load coordination and balancing.

4. Research on the source-load interaction mode of the regional energy internet

In the regional energy internet, the source-load interaction is the core for realization of an intelligent energy network. Based on the energy loads and energy consumption time distribution in the industrial park zone, agricultural industry and community, the law of interaction and coordination between the energy supply system, including the conventional power grid, heat network and distributed energy system, and the energy consumption system, including the enterprises in the park zone, residents in the community and the rural users, is researched to attain the target of "guaranteeing the reliable supply of regional energy and realizing the coordinated supply of regional energy".

4.1. Typical operation mode of the energy internet

The typical operation mode of the regional energy internet is shown in Figure 2. The energy supply system covers the wind-solar complementary power generation system, CCHP (combined cooling, heating and power) fuel gas-steam combined cycle system, biomass energy power generation system and conventional energy power generation system. The energy supply system will supply the electric energy and heating (cooling) energy to the enterprise, community and agricultural energy users via the power grid and heating energy (cooling energy) network. Meanwhile, the information collection system of the information control network is distributed at various nodes in the energy supply system and the energy consumption system, used to collect the information of the heating/cooling energy production, transmission and load side at any time in the region, and the control system will provide a coordinated control over the sources and loads in the region depending on the collected information so as to guarantee the efficient and reliable supply of the energy.

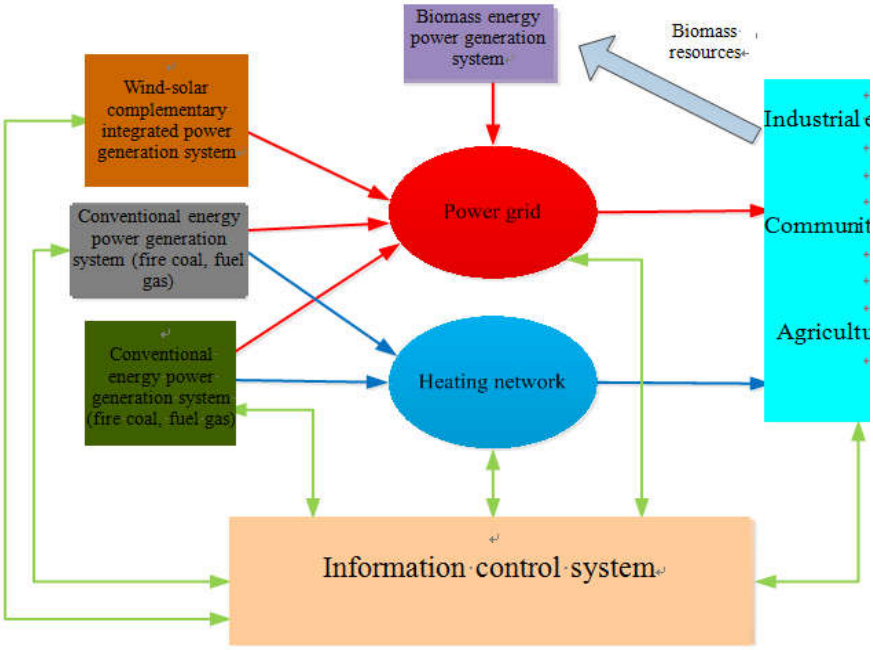

Figure 2. Schematic diagram of regional energy internet

Compared with the conventional fire coal system, the fuel gas CCHP system, namely, power generation with natural gas, heating with residual heat and cooling with residual heat, is provided with advantages of cascade energy utilization, high utilization efficiency and rapid and flexible regulation with regard to the power generation and heating. This system is clean and environment-friendly, so as to largely reduce the emission of pollutants, and furthermore, with the mutual support from the solar energy, wind energy and other clean energy systems and large-sized power grids, it can be also used for digestion of renewable energy and the peak load shifting. The biomass energy power generation system is intended to process the domestic garbage of the community, biomass resources of the rural area and industrial wastes of the industrial park zone and then use them to generate power via the

internal combustion engine or gas turbine. The biomass power generation system can store the biomass resources provided by the user side into the energy storage system, and regulate the output depending on outputs of other systems and loads of the user side. The wind-solar complementary power generation system can mutually coordinate the power generation by utilizing the consistency of wind energy and solar energy resources with regard to the power generation configuration and the subtle complementarity with regard to the time, so as to guarantee the stable output to the largest extent. The information control system acts as the core of the energy internet, being a medium for effective interaction between sources and loads. As shown in the system diagram, the information collection system will transmit the consumption and load changes of the energy consumption system to the control system which will then regulate the energy supply system.

4.2. Research on the source-load interaction mode

According to the above-mentioned typical operation mode of the energy internet, the source-source and load-load coordination and balancing and the source-load interaction are realized by the information control network; therefore, the source-load interaction is substantially the source-grid-load interaction. The information control network acts as the core of the energy internet, consisting of the information collection system and analysis control system. The source-grid-load interaction mode is shown in Figure 3. The information collection system will transmit the energy production information on the supply side and the load information on the user side in each time period to the analysis control system which will then process the collected information and send the regulation and management commands to the energy supply side and the user side respectively. Various energy systems on the supply side will increase or decrease the output as required by the regulation command, while various users on the demand side will regulate the loads as required by the command to realize the effective source-load interaction.

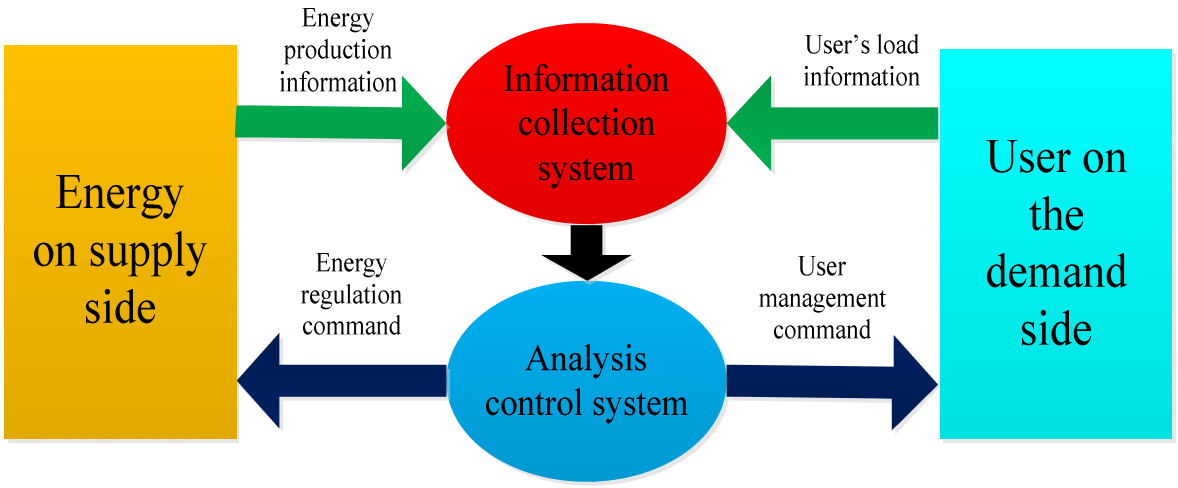

Figure 3. The source-grid-load interaction mode

The information collection system will collect the power, heating and cooling energy production and transmission and user side load information in the region via various sensors distributed in the energy network. For instance, the information collection system will collect such information as the wind speed changes in the wind farm region, the lighting intensity of the solar energy power station and the biomass resources storage information of the biomass energy power generation system and then transmit such information to the analysis control system for processing. Meanwhile, the collection sensors can be extended to various indoor temperature, power consumption and gas sensors, and certain sensors are provided with collection and control features; for example, the indoor temperature controller can measure and control the indoor temperature. The power consumption of the

electric car, the indoor temperature in summer and winter, seasonal load changes in the rural area and other such user side information can be transmitted to the analysis control system and combined with the information on the energy production side to realize the effective interaction between source information and load information.

5. Conclusion

The regional energy internet is an intelligent energy internet designed for the rural area, community and industrial park zone, constituting a key aspect of the construction of an intelligent town. Based on the intensive study on the source, load and grid of the regional energy internet, this paper draws following conclusions:

1. The energy internet is intended to realize the diversified and clean utilization of energy by introducing the wind energy, solar energy, biomass energy and other clean energies and the distributed energy system, based on the conventional energy. However, different types of energies have their own output characteristics, and by utilizing the energy storage system and the internet technology to balance the outputs of various energies, it is possible to realize the horizontal multi-source complementation.

2. The research on the characteristics of the users' loads constitutes the basis for discussion on the law of source-load interaction of the regional energy internet. Loads on the demand side mainly include the enterprise's energy loads, household energy loads, agricultural loads and electric car loads. In the energy internet, it is possible to regulate the loads on the demand side using a series of legal, economic and technical approaches, to realize the load-load coordination and balancing and promote the optimized configuration and utilization of the energies.

3. The information control system acts as the core of the energy internet, being a medium for effective interaction between sources and loads. Based on the source-source coordination and load-load coordination, the information control system will combine the sources and loads via the internet technology and regulate them to achieve the integrated source-grid-load-storage coordination.

Acknowledgments

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