

# *Renewable Energy Consumption Technology Under Energy Internet Environment*

Jizhong Zhu, Pingping Xie, Peizheng Xuan, Jin Zou

Electric Power Research Institute  
China Southern Power Grid  
Guangzhou, Guangdong, 510663, China  
Jizhong.zhu@ieee.org

Pengfei Yu

School of Electrical Engineering  
Chongqing University  
Chongqing, China

**Abstract**—The accommodation of renewable energy has become a worldwide problem restricting the development of power grid. The development of energy internet will provide a new way to solve this problem. This paper analyzed the key factors influencing the accommodation of renewable energy in our country, as well as the basic connotation of energy internet. Some accommodating technologies of renewable energy orienting to energy internet are also discussed, such as optimal dispatch, integrated energy system, market consumption and so on, to provide reference for the optimization of future power grid operation and accommodation of renewable energy.

**Keywords**—Energy Internet; renewable energy; optimal dispatch; electric market; integrated energy system

## I. INTRODUCTION

With the development of the economy and society, we are facing the issues on energy security and environment issue. We need to find a way to better use the all kinds of energy resources to avoid the threat of a climate disaster or environment issue. Therefore, renewable energy sources have been developed very fast in the world [1-4], which include the increasingly decentralized supply structure and central supply form. Due to the randomness and volatility of renewable energy resources such as wind power and solar energy, renewable energy consumption becomes a big challenge in many countries. This is particularly prominent in China since most of the renewable energy sources are distributed only in several provinces and our electricity market is not mature [5-7]. It is need to have some new technologies to combine and integrate the available systems to optimize energy systems.

Energy Internet, which is the transition from the current energy system to an Internet of Energy, provides some new application scenarios for renewable energy consumption. Energy Internet can better solve the energy crisis and environmental pressure through the combination of information technology and energy technology. It is committed to increase the consumption of renewable energy, and resolve the contradiction between the current energy supply and demand through intelligent coordination from generation to consumption. There are some new technologies applied to Energy Internet, but most of the necessary technologies for the intelligent and efficient of the energy system are already available today. Furthermore, power system or energy system

will still play a major role in Energy Internet. Reference [8] discussed the definition and basic frame of Energy Internet from the view of power system, and listed the major challenges in the research of Energy Internet. Reference [9] provided a joint complementation idea between global Energy Internet and city Energy Internet based on the layered pattern of power grid. Reference [10] prospected the possible change of power system under the frame of Energy Internet. Reference [11] designed an energy router, which is a key device of Energy Internet. The research on Energy Internet has been paid great attention in the world [11-14].

This paper analyzes the key factors that impact China renewable energy consumption, and proposes the accommodating technologies of renewable energy orienting to Energy Internet through considering the features of Energy Internet. They include dispatch operation, comprehensive energy optimization, renewable energy consumption based on markets, etc. It will have important guiding meaning to push the development of China's renewable energy.

## II. SITUATION OF CHINA'S RENEWABLE ENERGY CONSUMPTION

China's renewable energy has developed rapidly in recent years. The increasing speed is number one in the world. However, there exists the consumption issue for the great deal of renewable energy sources. As of 2016, the abandoned renewable energy power reached over billion kWh, where the abandoned amounts for several major provinces are listed in Table 1. It can be observed that the serious areas that have abandoned renewable energy power are north parts of China as well as Yunnan and Sichuan provinces. The discarded power in the north parts of China mainly include wind power and solar energy sources, while the curtailed power in Yunnan and Sichuan provinces mainly include hydropower.

The key factors that impact China renewable energy consumption are:

### A. Load Demand

The load demand in the above-mentioned areas is relatively small compared the huge capacities of renewable energy sources. The north parts of China have only 36% of whole country's load, but have 75% of renewable energy capacity in

the country. It is impossible to consume all power produced in these areas.

#### B. Limitation of Transmission Interface

Due to the limitation of transmission interface, some renewable energy power cannot be transferred to outside of the area. The transmission channel needs to be improved. For example, there are lots of hydropower plants in the west area of Yunnan province. It needs to transmit hydropower to the outside of the area during flood season. However, it is impossible to send out all the hydropower in the flood season due to the limitation of transmission interface. Consequently, there are a great amount of hydropower curtailment.

#### C. Shortcoming of Flexible Adjustment Capacity

There are not enough power sources that can be flexible adjustment. The flexible adjustment generations such as pumped storage and gas only take up 6% of total generations in China. The capacity of thermal power generation is over 1TW, but the ability of peak load regulation only has 50% or so.

TABLE I. TOTAL GENERATION CURTAILMENT OF CHINA IN 2016

| Province       | Curtailments/(TWH) |
|----------------|--------------------|
| Yunnan         | 320.2              |
| Xinjiang       | 168.08             |
| Sichuan        | 142                |
| Inner Mongolia | 131.06             |
| Gansu          | 129.78             |
| Jilin          | 29                 |
| Ningxia        | 23.03              |
| Hebei          | 22                 |
| Heilongjiang   | 20                 |
| Liaoning       | 19                 |
| Shanxi         | 14                 |
| Qinghai        | 8.13               |
| Shaanxi        | 3.4                |

### III. BASIC CONNOTATION OF ENERGY INTERNET

Energy Internet is complex multiple network flow system, where power system is its core and renewable energy is major power supply type that is closely coupled with gas network and transportation network, etc.

#### A. Power System as Core

With the development of economy, electric power becomes more and more important in the energy supplies. China's electric energy is about 16 percent of end-user energy consumptions in 2000. This proportion was raised to about twenty percent, and will reach to thirty percent above. Therefore, Energy Internet is nothing without power energy. All power energies need to be transferred to end users through power system. Most of clean energy resources also need to be

converted to electricity in order to make full use of them. Thus, building Energy Internet means to construct the new energy system that is focusing on electricity.

#### B. High Proportion of Distributed Energy

Conventional power stations, such as coal-fired, gas and nuclear powered plants, as well as hydroelectric dams are centralized and often require electricity to be transmitted over long distances. By contrast, distributed energy resources (DERs) are decentralized, modular and more flexible technologies, which are located close to the end users they serve. DERs typically refer to renewable energy sources, including wind power, solar power, biomass, biogas, geothermal power, and small hydro, and increasingly play an important role for the electric power distribution system. DERs are the basis of Energy Internet, which change the traditional vertical structure of electricity supply.

#### C. Deep Fusion of Multiple Energy Sources

Modern power system is a mixed system with multiple energy sources. It combines all kinds of primary energies such as coal, gas, hydro resource, wind power, nuclear power and solar energy. The deep fusion of multiple energy sources of Energy Internet mainly reflect in the field of terminal energy, which implements the cascade utilization of energies and guarantees the operation of comprehensive energy system with economy, flexible and high efficiency.

To implement the Energy Internet, new technologies are needed. Information and communication technologies are the basis of Energy Internet. They play a key role in the implementation of a future Energy Internet. Due to the intelligent electronic networking, the network components, generator plants, usage devices, and energy system users will be able to exchange information among each other and optimize their processes on their own. Thus, Energy Internet is a cyber-physical system (CPS) with the features of open interconnection and exchange sharing.

From the view of markets, Energy Internet will provide a platform for flexible trading green energies. This will form a market environment with open, freedom, and full competition, which is able to excite the enthusiasm of the commercial subjects in the markets. Its characteristics include:

- Flat division of market transactions. Since distributed energy suppliers are widely existed in many countries, it will form lots of micro energy system that can be autonomous balanced. This provides the condition for energy transaction between local energy balance trading and micro energy system. In addition, with the fusion of internet and energy industry, the energy supply and consumption in Energy Internet can obtain sufficient information with fast and low cost manner through the internet. Decentralized micro balance will replace overall balance in Energy Internet that becomes a most important trading mode.
- All commercial subjects participate widely. The market mode under the internet thinking is widely connected. It gathers the distributed mass entities in the information

system through information as a link. A great amount of commercial subjects will be emerged in Energy Internet such as all kinds of energy production enterprises, and distributed consumers include industry parks, smart buildings, and individual families. They all can participate in energy market transactions.

- Changeable supply and demand mode. The supply-demand relationship is fixed in the traditional mode. However, in the trading markets of Energy Internet, the roles of commercial subjects (energy suppliers and consumers) can be converted. They can freely participate in trading or exit trading. This can promote the efficiency of resource coordination and optimal allocation.

#### IV. ACCOMMODATING TECHNOLOGY OF RENEWABLE ENERGY ORIENTING TO ENERGY INTERNET

The outputs of renewable energy sources such as wind power, solar energy and small hydropower are easily impacted by the weather, topography and temperature, etc. They have randomness and volatility. At present, under the condition of safe operation of power grid, renewable energies are fully accessed to the grid, and the fluctuations caused by renewable energy are stabilized by thermal and big hydropower. However, the adjustment ability of the conventional power sources is limited. When there is a big bias between renewable energy outputs and expectations, the power system real power balance will be broken, and some transmission flows may be over the limits. In this case, the measures of discarding wind, solar or hydro have to be taken.

The development of Energy Internet brings new chance for renewable energy consumption. This paper discusses the technologies of dispatch operation, comprehensive energy optimization, and renewable energy consumption through markets.

##### A. Technology of Dispatch Operation

Renewable energy sources are similar to the load demands, which are uncontrollable power. It needs to forecast the output curve of renewable energy sources, and make the generation schedule of conventional power sources through dispatch calculation to ensure the power balance of power system. Currently, the prediction accuracy of renewable energy sources cannot totally meet the need of engineering. For example, the error of short-time wind power prediction has about twenty percent. This produces big difficult for the traditional economic dispatch based on accurate power prediction.

Under Energy Internet environment, there exists deep fusion of multiple energy sources that include coal, gas, hydro resource, wind power, nuclear power and solar energy. This can tap the dispatch-able ability of power system. The consumption level of renewable energy will be enhanced by making full use of the complementary operation features of multiple energy sources.

In addition, Energy Internet has an information system with the features of open, equivalence and sharing. It is good for setting up multi dimension spatiotemporal dispatch control

system. The impact of uncertainty of renewable energy on power grid can be gradually reduced through spatiotemporal complementary dispatch method. Therefore, a framework of multi dimension spatiotemporal coordinated optimal dispatch is proposed under the background of Energy Internet, which is shown in Fig. 1. The generation schedule is divided into different time scales such as year, month, week, day ahead and daily. Each period has its own continued dynamic optimization. The generation schedule under the background of Energy Internet should implement multiple level coordination and optimal decision.

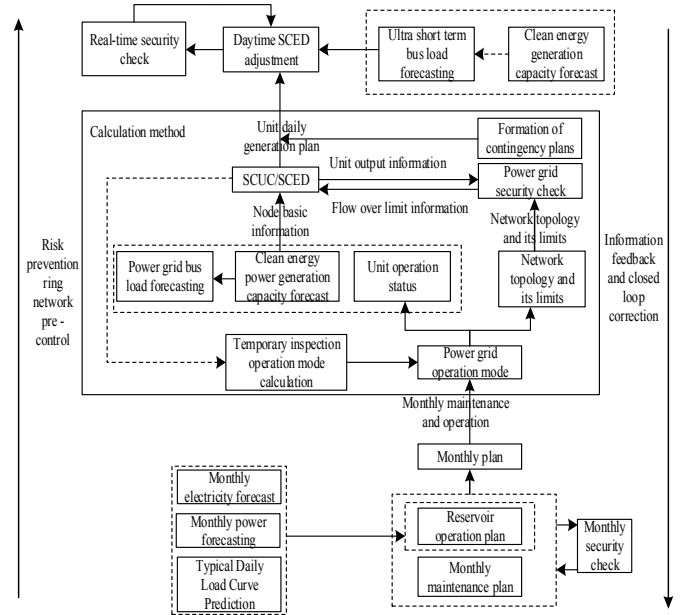


Fig. 1. Framework of multi dimension spatiotemporal coordinated optimal dispatch

##### B. Optimization of Comprehensive Energy Sources

Comprehensive energy system is one of the important features in Energy Internet. Its purpose is push the utilization and sharing of distributed renewable energy. It promotes the integration of electric power, transportation, and gas network. Comprehensive energy system consists of the following four meanings.

- The physical entity consists of power system, transportation system, and gas network.
- There exists the reciprocal transformation among multiple energies such as electric energy, chemical energy and thermal energy.
- Local consumption of renewable energy will be changed to wide area coordination.
- Open information network will play more important role.

The large scale electric vehicles connecting to power grid is one important feature on reciprocal transformation between electric power and transportation. When the electric vehicles are randomly connected to the grid, they will increase the pressure of the grid on adjusting peak loads, which is unfavorable to power system economic operation. However, if we actively dispatch and control the electric vehicles, and use their feature of rapid response, the electric vehicles can be used as load peak shaving and valley filling, which will enhance the performance of the frequency control in power system.

By computing a practical power grid, we obtained a net load comparison of electric vehicles for coordinated charging and uncoordinated charging, which is shown in Fig. 2. The corresponding comparison of frequency deviations is shown in Fig.3.

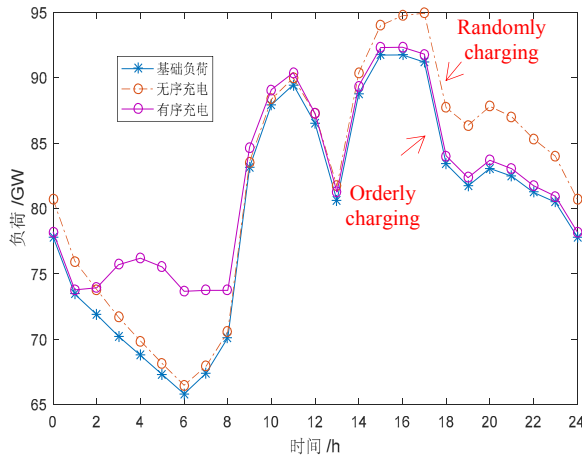


Fig. 2. Net load comparison of electric vehicles for coordinated charging and uncoordinated charging

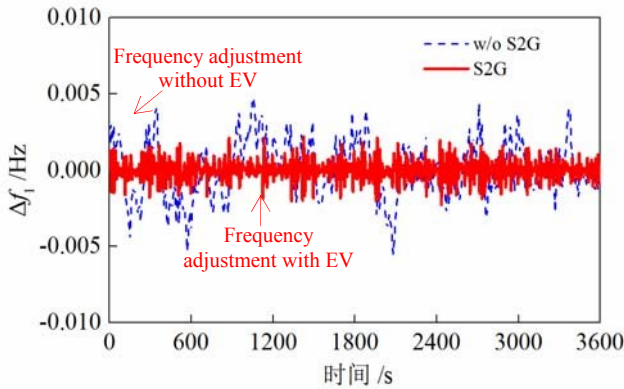


Fig. 3. Comparison of frequency deviations

### C. Renewable Energy Consumption Through Markets

China's renewable energy industry has been rapidly developed due to the policy support from government. But there exists some issues on renewable energy consumption in our country without marketization. Thus, there are many

discarded wind power and solar energy in China at present. It will be a new challenge to consume the renewable energy through scientific, systematic, rigorous design of power market. This is also the focus of attention in the international academia and Industry.

Energy Internet provided an open platform where the information and energy flow can be free flowing. It is able to allocate more all kinds of resources. Thus, the multiple types of coordination can be implemented in wide area. Energy Internet adopts advanced power electronic technology, automatic control technology, as well as energy management system. It makes user data analysis more facilitation. Under the background of Energy Internet, market subject will be more diversification. The process of power transaction will be more transparency and fairness. These will brings new opportunity to renewable energy consumption through market.

### V. CONCLUSION

China's renewable energy has developed rapidly in recent years. This paper first analyzed the key factors influencing the renewable energy consumption in China, and then discussed the basic connotation of energy internet. A new chance for renewable energy consumption under the background of Energy Internet is presented. Furthermore, the paper discussed the technologies of dispatch operation, comprehensive energy optimization, and renewable energy consumption through markets. These will provide a reference for the optimization of future power grid operation and accommodation of renewable energy.

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### REFERENCES

- [1] Liu Zhenya, Zhang Qiping. Study on the development mode of national power grid of China. Proceedings of the CSEE, 2013, 33(7): 1-10.
- [2] Shu Yinbiao, Zhang Zhigang, Guo Jianbo, et al. Study on Key Factors and Solution of Renewable Energy Accommodation. Proceedings of the CSEE, 2017, 37(1): 1-8.
- [3] Peng Bo, Chen Xu, Xu Qianqiao, et al. Preliminary Research on Power Grid Planning Method Aiming at Accommodating New Energy. Power System Technology, 2013, 37(12):3386-3391.
- [4] J.Z. Zhu, *Renewable Energy Applications in Power Systems*, Nova Science Publishers (USA), 2012.
- [5] Pei Zheyi, Wang Caixia, He Qing, et al. Analysis and Suggestions on Renewable Energy Integration Problems in China. Electric Power, 2016, 49(11): 1-7.
- [6] Cao Yang, Li Peng, Yuan Yue, et al. Analysis on Accommodating Capability of Renewable Energy and Assessment on Low-carbon Benefits Based on Time Sequence Simulation. Automation of Electric Power Systems, 2014, 38(17): 60-66.
- [7] ZHU Jizhong. Development and Implementation Method of Electricity Market in the USA. Southern Power System Technology, 2016, 10(5):22-28.

- [8] Dong Zhaoyang, Zhao Junhua, Wen Fushuan, et al. From smart grid to energy internet basic concept and research framework. Automation of Electric Power Systems, 2014, 38(15): 1-11.
- [9] Huang Renle, Pu Tianjiao, Liu Kewen, et al. Design of hierarchy and functions of regional energy internet and its demonstration application. Automation of Electric Power Systems, 2015, 39(9): 26-33.
- [10] Zhao Hai, Cai Wei, Wang Jinfan, et al. An architecture design and topological model of intergrid. Transactions of China Electrotechnical Society, 2015, 30(11): 30-36.
- [11] Huang A Q, Crow M L, Heydt G T, et al. The future renewable electric energy delivery and management (FREEDM) system: the energy internet. Proceedings of the IEEE, 2011, 99(1): 133-148.
- [12] European Commission. Recorded conference “mission growth: Europe at the lead of the new industrial revolution”[EB/OL]. <http://ec.europa.eu/avservices/video/player.cfm?ref=85716>, 2013-10-13
- [13] Federal Ministry of Economics and Energy of Germany [EB/OL] . [2013-06-26] . E-Energy project official website: <http://www.e-energy.de/en/index.php>.
- [14] [http://www.gov.cn/zhengce/content/2015-07/04/content\\_10002.htm](http://www.gov.cn/zhengce/content/2015-07/04/content_10002.htm).