

An energy internet-based distribution system morphology

W Yi^{1*}, P Wang², X W Hu¹, X N Wang¹ and F Shi¹

¹ School of Electrical Engineering, Shandong University, China

² Henan Electric Power Research Institute, China

*Email: yiwei2450@qq.com

Abstract. The future power distribution system will play an important role in the future energy system - energy Internet. With an eye to the diversification of energy and power fusion to the distribution system form, the prospect of the future integrated power distribution system for energy Internet is proposed, from the three aspects of structure, equipment form and industrial form: a multi-level AC-DC ring network as a framework, including the P2P interconnection and DC information satisfied power grid integrated network structure, is given; the concept of energy exchanger, the concept of energy server is put forward, and on this basis, the future distribution system of the equipment is prospected; the future distribution of the three types of industrial forms is analysed.

1. Introduction

In recent years, with the development of micro-grid, virtual power plant, active distribution network technology[1,2], the development of a variety of energy and electricity in traditional energy systems is generally carried out on the traditional power generation side. The main force of energy structure change - renewable energy to a large number of distributed access to the distribution network, the introduction of the exchange side of the difficult to count the interface; electric vehicle technology, small gas turbine, electric gas, hot and cold power supply, energy storage and other technologies[3-5], a variety of energy in the power system of the power distribution side of the interaction, resulting in such as random fluctuations, two-way trend and other new features[6], which makes the distribution network the most diverse area compared to traditional power grids and the distribution network will evolve into a key part of the future power system for the energy Internet. This question has led to many scholars thinking: [7] explores the structure and characteristics of future power distribution systems, pointing out that intelligent power distribution systems will be an important support for integrated energy systems; [8] suggest that future distribution networks will become power integration, multi-stream fusion of the energy Internet, and look forward to its key technical areas.

Therefore, it is of great forward-looking significance to research and look forward, combined with the concept of energy Internet, focusing on a variety of energy and power fusion complementary, to the distribution system morphology; however, such research is rare[9,10]. On the basis of the existing research results, this paper then draws lessons from the related technical characteristics of the energy system and information system, and looks forward to the future distribution system form from the three aspects of structure, equipment form and industrial form.

2. The morphology of future integrated distribution system oriented to the energy internet



The future integrated power distribution system for energy internet will be prospected from 3 aspects according to the correlation.

2.1. The structure of the future integrated distribution system

The essential difference between the future distribution system and the traditional distribution grid is the change in operation mode and equipment. The structure design of distribution grid and its macro topology are the most important research basis for the function and characteristics of the system.

In the network architecture, the future distribution grid will become a pattern with unified and standard interfaces in the high voltage and medium voltage, which is characterized by multi-layer AC / DC hybrid based on ring bus and flexible ad hoc network based on complex network theory. And the hierarchical structure is its main feature. The ring structure whose basic structural unit is regional DC and AC ring bus can be easily connected to various power, load and energy storage device, constituting the basic structural unit of one level and the device support for energy management unit as well. In normal operation, the internal bus of the unit works in a loop-close way with the ring and net structure. At the same level, different units are linked up to each other through the soft normally open points and other power electronic devices. What's more, power transfer or bidirectional power switch control can be realized by different ring buses. The level structure is set to 4 layers, called the regional distribution system, the local integrated power distribution system, the integrated micro grid and the DC information grid.

At the same time, in order to meet the needs of the energy Internet to achieve the goal of innovative development, the topology structure of the future integrated distribution system should draw lessons from the topology structure of the Internet which is typical for community, small world, fractal, and its realization method. Between the main bodies of the energy trade in the power distribution side, a more diversified connection mode should be established in order to serve for the power balance and industrial form under the energy Internet. The paper [11] designs a topology structure of energy Internet based on the simple hierarchy structure, and it introduces P2P connections within and across all levels. Besides, it is proved that the structure can enhance the robustness of the system. However, this method has some limitations from the point of the distribution grid, which only considers the structure of the simulation information system interconnection, and does not combine with the actual situation of the power system at the level of interconnection.

Combining with the characteristics of distribution grid and synthesizing and improving the existing research results, this paper designs a new topology structure of future distribution system, which takes the hierarchical AC / DC link network structure as frame and introduces the P2P connection and the DC information grid into the low voltage distribution system.

This structure has both advantages of the structure of the ring network and the P2P connection, which ensures that the high and the medium voltage distribution grid layers have a certain degree of interconnection and greatly enhances the interconnection and robustness of the low voltage distribution grid layer.

And it eventually forms the approximate full connected network in the whole distribution system level and constitutes the basic unit of a higher level of integrated power grid the energy Internet.

2.2. Equipment form for the future integrated distribution system

In this paper, the following 4 principles are followed in the prospect of the form of equipment for the future integrated distribution system.

- The equipment for the future integrated distribution system should be as far as possible with the characteristics of physical information fusion
- According to the control framework of the future distribution system which is typical for the overall coordination and the regional autonomy, the equipment should include not only the centralized controlling device

- According to the control framework of the future distribution system which is typical for the overall coordination and the regional autonomy, the equipment should include not only the centralized controlling device, but also the hierarchical autonomous control device.
- For the equipment which is similar in the function but different in levels, they are generally not given individual definition on the concept of the device but only the supplementary instructions to the level according to the way of definition in the electric power system.
- Consider both pure power distribution equipment and multi energy fusion equipment. As for the multi energy integration equipment, focus on those having interface, control and other interactive relations with power distribution system.

Therefore, a kind of equipment of future integrated distribution system which includes many new device concept is designed. For example, it perfects the concept of energy resources and puts forward the concept of energy converter. The device is composed as shown in Figure 1. In Figure 1, the rounded rectangles represent the outlook principle and the interlocking circle represents the characteristics of the device. Meanwhile, the smallest circles represent the specific device. The specific introduction is as follows.

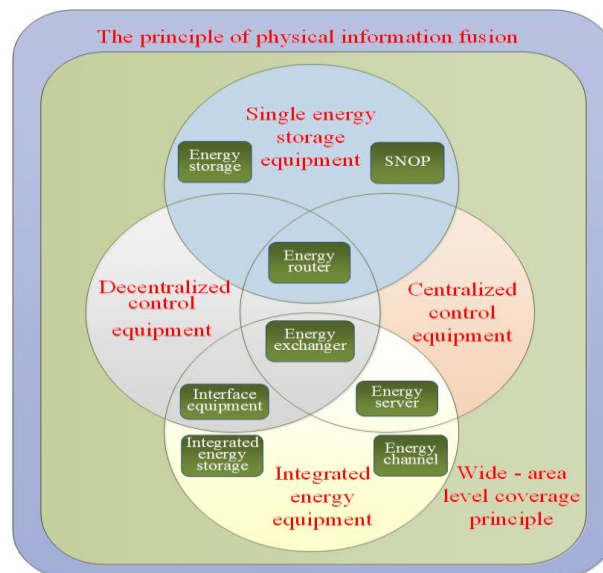


Figure 1. Equipment of future integrated distribution system.

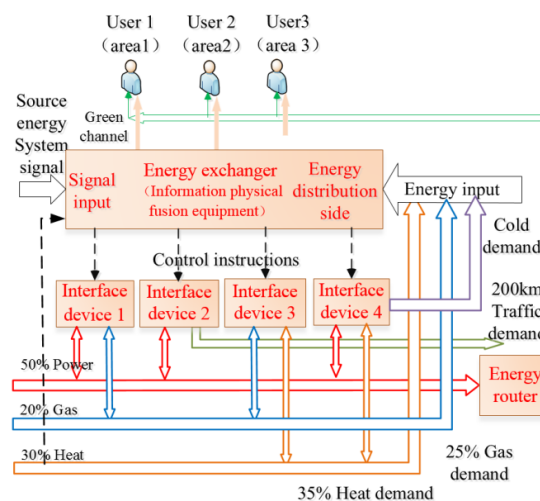


Figure 2. Conception of energy exchanger.

- **Electric energy storage and comprehensive energy storage.** In the future distribution system, the importance of energy storage device will be further strengthened. It will not only still play a buffer role in maintaining the balance of power, but also realize the sub packet transmission, integrated transmission and heterogeneous interconnection of the energy. And it can block the failure of the integrated energy system and realize the fine management of energy management unit among all levels.
- **Energy server.** The energy server in this paper is a concept of cyber-physical fusion device, whose information section is the centralized control center of the future distribution system, and the core of the system is analysis platform of big data and cloud computing. With rational use of the internet concept, its function can be designed as follows. Analyse the security posture of the system and dispose the energy allocation among the various autonomous regions through big data cloud computing in the whole distribution system level. And produce, store and distribute the energy in the high voltage distribution grid. In addition, it can deal with the response of complex demand side and complex business that is difficult to calculate in the bottom control equipment.
- **Energy exchanger.** Energy exchanger in this paper is a kind of typical cyber-physical fusion device. The information section of it is in charge of the comparison of energy demand information and energy input. At the same time, it's responsible for the control of all types of energy interface equipment to make various types of energy convert mutually to a certain proportion, ensuring the energy ratio meets the energy demand after conversion. The physical part is responsible for the distribution of non-electric energy to the energy channels of the user or the region on the next level while the electric energy is distributed by the energy router. Its conception is shown in Figure 2.
- **Energy router.** In this paper, the concept of energy router is similar to that in [12], which consists of solid-state transformers, integrated energy storage and regional coordination control system. And it is to be the core equipment of the physical layer connection and autonomy management of regional information in the future integrated distribution system.
- **The interface equipment between electric energy and multi-energy.** Interface is a device for the conversion between different energy forms. The future integrated distribution system will be mainly concerned with the interface equipment between power and other energy forms, such as inverter, electric vehicles and so on, which are the key to achieving the goal of energy integration.
- **Energy channel.** Energy channel is a kind of multi energy transmission channel. From the point of view of electric energy, electric energy will be the main energy source in the Internet. And the distribution network under the control of the energy router is responsible for distribution. Therefore, it is designed to achieve chemical energy, heat and other energy packaging long distance flexible transmission, to achieve the energy form of isolation transmission, to improve transmission efficiency and other functions.
- **SNOP.** SNOP in this paper is a new type of controllable power electronic device, which is based on full control power electronic devices to achieve accurate control of the active power, reactive power and electrical decoupling in the future.

In the future, the equipment system and the traditional distribution system of power distribution system in the future constitute a form of the future power distribution system. It is in the concept of the energy Internet, and has a clear distinction with the smart grid era.

2.3. Industrial form of integrated distribution system in the future

In the context of the energy Internet, focusing on the distribution side of the user directly, the future of the integrated power distribution system may be in the energy information infrastructure industry, the

Internet + focus on business model and the Internet + 3 aspects of decentralized business model to expand its industrial form.

2.3.1. Energy information infrastructure industry. Future integrated distribution system is integrated with other energy physical interface device and information coordination and control equipment, formed the new structure and form of equipment, in the energy and information infrastructure industry brought great opportunities for the equipment and the reform of the system. The traditional distribution system and other source system networking transformation, the popularity of the interface devices between a variety of energy demand, new physical information fusion energy equipment R & D, production, alternative, maintenance, centralized control center and regional control system technology research and development and to be built, contains a huge market potential, gave birth to their new industrial structure.

2.3.2. Internet + centralized B2B/B2C business model. Internet + power grid can significantly improve the rate and efficiency of the exchange between power supply and demand for electricity supply and demand, the contradiction between supply and demand of electricity supply and demand has some mitigation effect; simultaneously, users can choose to make it possible. In the future, the market will gradually expand. Large users across the transmission system directly with the power plant B2C (business-to-customer), power plant and the general user for B2B (business-to-business) trading, power grid companies charge transmission and distribution services, and through scheduling to balance the distribution costs as its main additional profit model, but also through the sale of reactive power, standby and other ancillary services to expand business structure. B2C function, to guide users through the demand side response to efficient use of energy, reduce the cost of purchasing power to earn the difference as the main profit model. The characteristics of a certain number of users to enhance their market power to become a proxy user to participate in market competition and interaction.

2.3.3. Internet + P2P business model. The future distribution system has the characteristics of high level of interaction and real time, so it is more innovative in the industry form. In the future distributed generation, storage and electric vehicles can be carried out. In the future, users and operators can not only carry out a simple electric two-way transaction, but also can be put into other users. Networking business P2P transactions. In addition, the demand response technology should be developed to the future distribution system stage, where the system should be highly automated instead of dependent on manual operation. The response program is automatically triggered by the integrated microgrid control system. The future integrated power distribution system can provide users with personalized automatic manual combination of demand response choice.

However, in the future integrated power distribution system, there are still a lot of technical problems to be resolved in several fields, for example, the application of internet information technology field, the planning and reliability of future integrated power distribution system field, the device technical related to future integrated power distribution, the operation control technology field related to integrated power distribution, and so on.

3. Conclusion

Energy Internet is recognized as the trend of the future energy system development, the energy distribution network in the context of the concept of how to expand, how to transform the form, and become a problem. In this paper, the future integrated distribution system form is discussed, from the structure, equipment and industry 3 aspects: a multi-level AC / DC link network is proposed, which includes the P2P interconnection and direct current information. The energy converter is presented, and the energy server is improved, and the energy and information flow characteristics are analysed.

Reference

- [1] Planas E, Andreu J, Gárate JI, Alegría IMD and Ibarra E 2015 *Renew. Sust. Energ. Rev* **43** pp 726-49
- [2] Mnatsakanyan A and Kennedy SW 2015 *IEEE. T. Smart. Grid* **6(1)** pp 230-7
- [3] Xu X, Jia H, Chiang HD, Yu DC and Wang D 2015 *IEEE.T.Power.Syst* **30(3)** pp 1212-21
- [4] Varone A and Ferrari M 2015 *Renew. Sust. Energ. Rev* **45** pp 207-18
- [5] Zakeri B and Syri S 2015 *Renew. Sust. Energ. Rev* **42(C)** pp 569-96
- [6] Lopes JAP, Hatziaargyriou N, Mutale J, Djapic P and Jenkins N 2007. *Electr.Pow.Syst.Res* **77(9)** pp 1189-203
- [7] Wang C, Wang D and Zhou Y 2015 *Automat.Electron.Power. Sys* **39(9)** pp 1-9
- [8] Zhao MA, Zhou X, Shang Y and Zhou L 2015 *Zhongguo Dianji Gongcheng Xuebao/proceedings of the Chinese Society of Electrical Engineering* **35(6)** pp 1289-98
- [9] Tianjiao PU, Liu K, Chen N, Xianjun GE, Jiancheng YU and Dan W 2015 *Zhongguo Dianji Gongcheng Xuebao/proceedings of the Chinese Society of Electrical Engineering* **35(14)** pp 3511-21
- [10] Zhang X, Li J and Fu H 2015 *Zhongguo Dianji Gongcheng Xuebao/proceedings of the Chinese Society of Electrical Engineering* **35(14)** pp 3532-40
- [11] Zhao H, Cai W, Wang J and Jia S 2015 *Diangong Jishu Xuebao/transactions of China Electrotechnical Society* **30(11)** pp 30-6
- [12] Huang AQ, Crow ML, Heydt GT and Zheng JP 2011. *P.IEEE* **99(1)(1)** pp 133-48

Acknowledgments

This work is supported by National Natural Science Foundation of China (No. 51407109).