A PRACTICABLE DESIGN OF ENERGY INTERNET COMPATIBLE WITH CURRENT POWER SUPPLY SYSTEM

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ABSTRACT

Energy Internet, a new energy system combined with advanced energy and information technology, is considered to be an effective method to solve distributed energy consumption problem. Power system is the most suitable natural carrier for the construction of Energy Internet, but the physical laws between electric power flow and information flow are different. The concept of Internet cannot be applied mechanically to Energy Internet. This article proposed a method for designing energy interconnection system which can compatible with the existing power grid structure satisfactorily and achieve the function of plug-and-play for power generation, consumption and storage equipment. Meanwhile, this article discussed the role of Micro Grid (MG) in the construction of Energy Internet and pointed out the interaction relationship between MG and Energy Internet. The ideas put forward in the article can be conducive to the construction of Energy Internet and promote the effective utilization of distributed energy.

ENERGY INTERNET

The rapid development of Internet is not only profoundly changing people's life, but also changing many traditional industries. Energy Internet is a product of integration of energy and Internet. As a new development direction and important topic in the energy industry after smart grid, Energy Internet, an effective technology to solve distributed energy consumption problem, has become a new focus in academic and industrial circles.

Energy Internet, a new energy system combined with advanced energy and information technology, was first proposed by American economist Rifkin. Research for Energy Internet has been carried out in recent years, e.g. FREEDM project in US [1] and E-Energy project in Germany [2]. In China, Energy Internet is also a hot research topic. Chinese Academy of Science and Technology for Development has regarded Energy Internet as one of the new industries of national strategy. Energy Internet Research Institutes had been established both in State Grid Cooperation of China and Tsinghua University. In April 2016, the State Council issued an innovation action road map for the Energy Internet. The development of the Energy Internet will not only affects power system operation, but also changes the role of DSOs. In recent years, China is gradually carrying out the reformation of electricity market, which means that the development of Energy Internet will be more prospective.

PROBLEMS

Currently, the definition, characteristics and implementation methods of Energy Internet are not unified. The final conclusion about the concrete morphology of Energy Internet is not yet formed but there is a certain consensus on its basic structure and function. Structurally, Energy Internet is a blend of electricity, gas, cooling, heating, transportation, and even more different forms of energy network as well as the information network; functionally, with the help of the advanced information and computing technology, Energy Internet makes the coordinated operation and complementarity of large area and multi-energy systems possible, which achieves better economic and environmental benefits.

Considering the convenience of transmission, utilization and conversion of electric energy, power grid will play a main role in future Energy Internet. And distribution network will also develop from a pure electric power distribution network to a new type of power distribution network with the function of multi-energy (e.g. electricity, gas, cooling, heating, etc.) conversion, substitution and utilization. With the clean substitution at supply side and the electric energy substitution at demand side, electricity will be the main form of energy production and consumption.

Referring to Internet devices, the concepts of "energy router", "energy switch", "energy hub", and "energy network card" are proposed in [3], which are widely recognized as basic components of Energy Internet.

However, the physical properties of power flow and Internet information flow are completely different.

Internet is a kind of computer technology for supporting information flow. It refers to a network built on a bunch of communication protocols for connecting different computers with a common language, thus it can achieve the communication between computers. For a specific process of information exchange, specific receivers can be assigned and their delivery paths can be scheduled. It can be buffered, saved or delayed for delivery.

The electric power injected by power generation units and the electric power consumed by electrical load in a

power grid must be balanced in every moment, without any buffering, saving or delaying.

If we want to achieve Internet-character functions in a power system, we need to make storage, buffering and dispatching of electric energy the same convenience as information. To achieve this goal, we need to make breakthroughs in two key technologies, the power electronic technology and the energy storage technology.

Power electronic technology is the foundation of power electronic transformer, which is considered as the key equipment in Energy Internet. It can achieve energy dispatching and flexible transformation of voltage and frequency. It has obvious technical advantages in improving power quality and system stability, realizing flexible transmission mode and real-time control of power flow. However, the current power electronics technology is mainly used in the case of low voltage and low power, and is doubtful at reliability and efficiency.

Energy storage technology is another critical technology in energy layer, which improves the quality and the economic efficiency of distributed power generation unit, and ensures the stability of system. Energy storage has become a large-scale centralized and distributed new energy generation technology but still has obvious bottleneck at present. Although all kinds of energy storage technologies are available, the related technologies and performance are immature with high cost. The developing of key materials, process of manufacture and efficiency of energy conversion are also facing with challenges.

The completely copying of the Internet mode for Energy Internet requires fundamental changes of power grid and the fully developments of power electronics and energy storage technology. But its feasibility, economy and efficiency are doubtful.

A NEW DESIGN

We proposed a design of energy interconnection system which can satisfactorily compatible with the existing power grid structure. The proposed design abandons energy routers and power electronic transformers which are depended on the existing power grid and linear elements. And the functions of frequency conversion, energy storage and energy active dispatching are not considered.

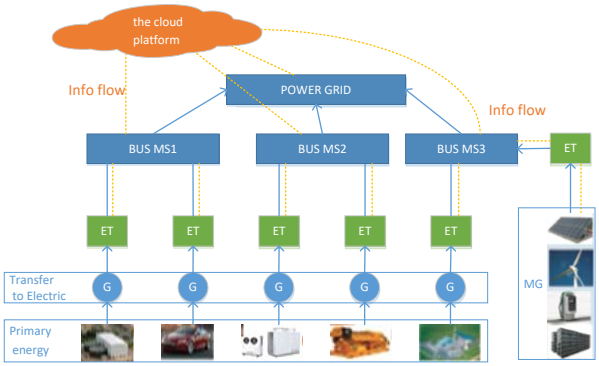

Fig1. The architecture of new design of Energy Internet

This design contains three different components: the cloud platform, the bus measurement systems (shown as BUS MS in Fig.1) and the plug-and-play energy interconnection terminal (shown as ET in Fig.1).

The plug-and-play energy interconnection terminal is the energy and information interface of power grid and energy terminal devices （such as distributed energy generator, electrical equipment and energy storage devices）. Meanwhile, energy interconnection terminal is the combination of energy flow and information flow and connected in series.

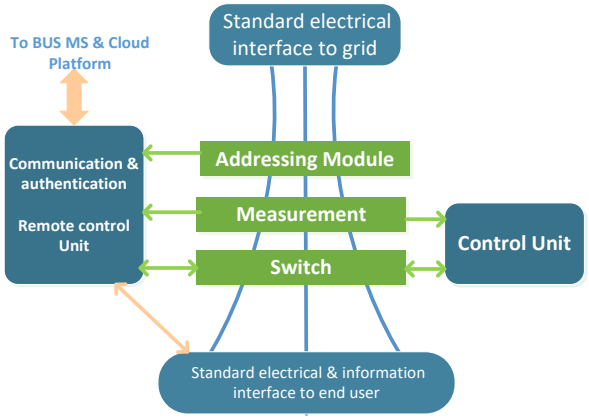

Fig2. The architecture of plug-and-play energy interconnection terminal

The terminal equipment includes:

a. Standard electrical interface: the electrical interface can achieve the universal interface for various electrical sources with standard voltage and frequency.

b. Standard communication interface: through standard interface and protocol, energy terminal devices can transmit state and instruction to the terminal.

c. Measuring module: by monitoring the voltage and current signals flowing through the standard power interface, the real-time metering of electricity and

the monitoring of power quality parameters are obtained.

d. Switch: performing a current cut-off to achieve the isolation of equipment and power grid.

e. Addressing module: getting the location of the equipment access point in the power grid by Power Line Carrier or other communication methods.

f. Control unit: achieving protection and control function through logically calculation of the information from measurement modules of terminals, bus measurement systems or cloud platform.

g. Communication and authentication module: performing the communication with the cloud platform and achieving the corresponding security authentication and identity authentication of the terminal.

Bus measurement system integrates existing power system automation measurement information, including switch state information, voltage and current information, and gets routing information of the energy interconnection terminals.

The cloud platform can communicate with bus measurement systems and plug-and-play energy interconnection terminals, obtain information, performance logical computing, and send the commands to the terminals. Its main functions are as follows:

a. Communication and addressing function: communicating with bus measurement systems and plug-and-play terminal devices, getting the information of power flow and perceiving the accessing and location of the plug-and-play terminal devices.

b. According to the power flow information of the terminal accessing location, giving the instructions of terminal accessing, terminal breaking, and storage charged or discharged, etc.

c. Energy online trading: verificating and solving energy online trading by units of generation, transmission, storage, consumption, and achieving the best trading results through flexible pricing policy.

d. Cloud control: Online accounting and release of parameters for control protection.

The design of these components can achieve the function of plug-and-play for power generation, consumption and storage equipments. With its characteristics such as less investment, economy, convenience, efficiency and practicality, the proposed design can be well compatible with current power supply system, improving the effective utilization of distributed energy and promoting the construction and development of Energy Internet.

MG IN ENERGY INTERNET

Micro Grid (MG) is an independently controllable system that can realize the balance of supply and demand of local energy. MG can only contain power terminals or present as a multi-energy MG that includes cooling, heating, electricity, gas and other terminals. MG has typical characteristics such as source and load diversity, structural diversity, operational flexibility and grid interaction, and it fits well with the features of Energy Internet. MG can be considered as the advanced stage of development in distributed energy, and also the primary stage of development for Energy Internet. If Energy Internet could be viewed as a wide area energy network, MG would be like a local area energy network.

MG can provide following supports for the construction of Energy Internet.

Firstly, MG can effectively integrate and utilize renewable energy in the local area, significantly increasing the penetration and integration efficiency of renewable energy, and strongly supporting the efficient integration of renewable energy in Energy Internet construction.

Secondly, MG can improve reliability and flexibility of the power grid and improve power quality. The power electronic interfaces introduced by MG for the integration of distributed power generation units, provide control methods for Energy Internet power quality management.

Thirdly, MG can achieve active regulation of the load. Demand side participation is one of the typical features of Energy Internet. With appropriate control technology, specific loads within the MG can actively participate in power system regulation.

Fourthly, MG is an effective carrier for the two-way flow of information. At present, the energy management system configured in MG makes MG a controllable object, and the two-way flow of information has also been initially implemented in MG. MG can serve as an end-user. On one hand, MG interacts with the plug-and-play energy interconnection terminal, on the other hand MG communicates with the local elements through the micro-grid central controller.

The development of Energy Internet has also provided the conditions for the development of micro-grid.

First of all, the Energy Internet can connect dispersed

autonomous micro-grids, organically integrate these regions, and achieve overall coordinated optimization of energy within a wide area.

Secondly, Energy Internet can improve the overall efficiency of energy use. An energy source often requires the conversion and coordination of other multiple energy sources to achieve high efficiency. The multi-source MGs can maximize the efficiency of primary energy use.

Thirdly, Energy Internet can provide virtual energy storage for MG, innovate the distributed energy storage business model, effectively use a large amount of distributed energy storage, and manage fragmented energy storage resources.

Finally, Energy Internet can better support distributed energy friendly access. Through the Energy Internet, accessing to renewable energy can be achieved in a wider range. From the perspective of Energy Internet operational control and energy management architecture, a distributed and collaborative architecture should be developed with the properties of quickly and accurately achieve convergence control for Energy Internet overall control objectives through internal collaboration of MGs.

CONCLUSION

Energy Internet is a wide-area system integrating variety of new energy technologies, information technologies, and new energy trading models. Its development is not accomplished overnight.
Judging from the objective law of the development of things, first of all, we should carry out researches on various innovation-enabled technologies within the framework of existing power system. And then, we should integrate relevant technologies to conduct comprehensive demonstration applications within a smaller region, and gradually expand them to a larger scope.
MG has almost all the essential elements of the Energy Internet, such as multi-energy complementary, two-way energy and information flow, operation optimization technology and energy management technology. Therefore, the construction of MG is a preferred and prior proposal for the construction of Energy Internet.

REFERENCES

[1] Huang A Q, Crow M L, Heydt G T, Zheng J P, Dale S J. The Future Renewable Electric Energy Delivery and Management (FREEDM) System: The Energy Internet. *Proceedings of the IEEE*, 2011, 99(1):133 - 148.
[2] Vermesan O, Blystad L C, Zafalon R, Moscatelli A, Kriegel K, Mock R, et al. Internet of energy-connecting energy anywhere anytime. *Springer Berlin Heidelberg*, 2011: 33-48.
[3] Geidl M, Klokl B, Koeppel G, Andersson G, Frohlich K. Energy hubs for the futures. *IEEE Power & Energy Magazine*, 2007, 5(1): 24-30.