Multi-Energy Flow Energy Management on Regional Energy Internet

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Abstract. In recent years, energy internet and integrated energy system has become a new research highlight and leading edge and multi-energy flow coupling is one of its key features distinguished from smart power grids. Multi-energy flow is one of the key features that energy internet and integrated energy system distinguishes from smart power grids and is an important development orientation in energy field. Compared with traditional power grid energy management, multi-energy flow energy management mainly confronts three aspects of challenge such as “multi-energy flow coupling, multi-time scale and multi-management body”. The establishment of a theoretic and method system for multi-energy flow energy management helps to promote utilization of renewable energy sources and improve comprehensive energy efficiency as well as to ensure safety in comprehensive energy supply, promote upgrading of energy industry and provide a new technological approach for energy production and consumption revolution in China.

1. Introduction
Energy is considered as a source that can provide heat thermal, optical and other forms of energy, including fossil energy, nuclear energy, wind energy, water energy and optical energy [1]. In 19th century, with the technical development and use of electric machine, internal combustion engine directly contributed to the second industrial revolution, promoted rapid development of human civilization in almost a century and also led to researches on scaled fossil energy to meet the quick consumption and added energy demands. Other forms of energy and improving energy efficiency have become the effective way to relieve the current contradiction in supply and demand of energy. In this process, processing and use of information will take the leading position and provide unprecedented opportunities and challenges on application and development of information technology. Over more than 40 years of development, internet has become an important carrier for efficient transmission and information sharing and formed into a quite effective management system. From optimization point of view, ensuring the production and transmission of energy as required in the process of traffic channel transmission is the key for effective driving and controls the operation of distributed energy production unit; Obtaining energy demand and providing information and executing rational distribution strategy can obtain energy. Effective flow and user participating in providing useful information can support realize optimum energy flow planning and personalized energy consumption. Energy internet aims to use IT and energy technology to realize energy supply and renewable energy-based application system. Therefore, energy is a highly integrated internet of “information flow, energy flow and control flow”.
Using energy can be more reliable, practical and economic and is personalized to support using other functions of smart power supply.

Openness is the core concept of energy internet. One of its services is to break the original relatively separated status among power generation, thermal energy, cooling, fuel gas and traffic and other energy flow subsystems and realize an open-type interconnection among several types of electricity. With reference to power flow concept in power grid, multi-energy flow refers to several types of energy flow, indicating the inter-coupling, conversion and transmission of energy flows, such as electricity, heat, cooling, gas and traffic. Although detailed concept of internet energy is still under discussion and development, multi-energy coupling and complementation has gradually become a consensus and is one the key features of energy internet [3]. The “Internet+” action plan of the State Council clearly put forward the concept “to create multi-energy internet based on coordination and complementation of solar energy and wind energy and other renewable energies” [3]. The guide for smart power grid as issued by the Bureau of Energy also clearly indicates the idea “to improve energy interconnection and promote multi-energy optimization and complementation” [4]. In China, the application of coupling elements such as CHP (Combined heat and power) unit, CCHP (Combined cooling, heating and power) unit and heat pump is gradually increased, objectively adds the interconnection between energies and promotes the development of multi-energy flow system.

In recent years, energy internet and integrated energy system has become a new research highlight and leading edge and multi-energy flow coupling is one of its key features distinguished from smart power grids. Traditional power grid-oriented energy management system has been relatively mature and plays core effect in ensuring safe and efficient operation of power grid. However, multi-energy flow system is obviously more complicated. It is urgently needed to develop a multi-energy flow-oriented energy management system to ensure safe and efficient operation of multi-energy flow system and realize the target of improving integrated energy efficiency and renewable energy consumption. On the basis of analyzing and summarizing existing achievements in relevant field, this paper sorts out the involved information technology and discusses the technological challenges that multi-energy flow energy management is confronting with, in three aspects.

2. Multi-energy flow system

Multi-energy coupling has many advantages. But it can also get the originally complicated energy system more complicated. Multi-energy flow system is composed of many energy flow subsystems. Those subsystems have different compositions, modes and features and so on and have mutual effect and influence. With the continuous improvement of coupling, new features of multi-energy flow system become more and more obvious, the system’s complexity is also greatly increased and traditional single energy flow analysis method becomes difficult to adapt to the new demand. In current researches on multi-energy flow, most researches place emphasis on collaborative optimization or multi-energy flow planning to realize larger collaboration benefit, but are lack of study on features of the network and safety of multi-direction flow. Safety of energy is the foundation for normal operation of multi-energy flow system. As the system is complicated, safety issue is more important.

To research the multi-energy flow system, firstly it is necessary to describe the boundary of the system on the basis of the actual condition and the research purpose. Traditional energy system also exists in conversion between different energies, while multi-energy flow system requires for tight coupling among different energy flow subsystems showing in different interaction and coupling effect. In additional to physical interconnection, multi-energy flow system also needs to be under management and control. In traditional and other power systems, energy related thermal power generator depends on coal produced energy. In North China, there are many CHP unit. But in traditional operation mode, power, heating and coal are separated from each other. Whereas, traditional energy system takes management and other aspects into less consideration, compared with other system. This case leads to serious wastes in North China and other regions. Due to heating restriction, heat unit has less output cutting restriction so as to cause over much heat output. Heating system has large thermal inertia which can be used for storage purpose. This part of capacity is often wasted in traditional operation mode. If
operation of heating system can take operation of wind energy into full consideration, the two systems can form into a multi-energy flow system. When the concern is to get certain energy injected into several subsystems of the flow system, boundary condition of sub flow (such as calculating the heat coupling system) can be taken into consideration. External coal and natural gas are regarded as boundary conditions.

From coupling point of view, composition of multi-energy flow system can be divided into mating parts and non-mating parts. Coupling element connects two energy flow subsystems to consume one or more types of energy and produce other one or more types of energy. Typical coupling forms: CHP unit consumes coal or natural gas and produces electricity and heat; heat pump consumes electricity and produces heat and electrolytic hydrogen making unit consumes electricity and produces hydrogen. Coupling element can get energy flow subsystems inter-coupled and interacted. Non-coupling elements include network inside each energy flow subsystem, equipment on the network and other non-coupling boundary conditions such as source and load and so on; Non-coupling element needs to pose influence on other system via coupling element [5].

3. Influence factor
Compared with energy management on traditional smart power grids, multi-energy flow energy management is confronting with new technological challenges which mainly embodies in three aspects such as multi-energy flow coupling, multi-time scale and multi-management body.

3.1. Multi-energy flow coupling
Integrated energy system (IES) [6] gets the production, transmission, distribution, conversion, storage and consumption of several types of energy integrated, can realize a comprehensive management and economic dispatching of electricity, heat and gas and provides an important solution for comprehensive utilization of energy. In the IES, various energy conversion equipment’s such as CHP, electric boiler and gas-fired boiler can get electricity, heat and natural gas tightly coupled, realizing interaction and conversion among several types of energy. How to effectively calculate the distribution of multi-energy flow (MEF) has important significance for guiding the investment planning and operation decision making on IES.

Fig.1 shows the diagram of multi-energy flow system which is composed of many heterogeneous energy flow systems. Its largest feature is in the inter-coupling among different energy flow systems. Electricity, heating, cooling, gas and other energy flows are converted and coupled via CHP/CCHP, electrolytic hydrogen making unit, heat pump and other equipment. Heterogeneous energy flows have different modes and obviously different features and all have different modeling, analysis and control methods. By mutual conversion and activation, heterogeneous energy flows are formed into a large system with more complicated structure. Accordingly, with the continuous increase of inter-coupling among energy flows, the system feature brought by coupling will become more and more obvious and complicated. Some algorithms and models for traditional single-energy flow system haven’t been directly applied in practice. Thereby, it is necessary to make a deep research on the modeling, analysis, optimization and control methods for multi-energy coupling and this part plays an inter-collaboration role in the entire multi-energy flow system. But it is necessary to avoid advantages caused by the coupling [7].
3.2. Multi-time scale

Different energy flow system has obvious difference and has different dynamic interaction process. Those differences are highlighted in different time scale. As shown in Fig.2, power system has the minimum inertia and fast adjustment performance; Natural gas system has high inertia and relatively slow adjustment performance; heat and other system has higher inertia and slower adjustment performance. When various types of interacted energy flow systems form into one multi-energy flow system, its feature will also show the multi-time scale feature. This makes the interaction among different types of energy flows complicated, which feature doesn’t exist in traditional single-energy flow system. So it is needed to make a deep research on the time scale relation between different energy flow interacted and further put forward the energy management method for optimum mating of time scale, improve the scientificity in evaluating the safety of energy supply and exploit the benefit potential in integrated energy management.

As different energy system has different development status and energy use ratio, energy supply is often independently planned, designed and operated, leading to the lack of collaboration among different systems and further causing the overall low use rate of energy and weak safety and self-restoration capacity of the entire energy supply system and other problems.

With the development of energy integration as well as rapid development and wide application of energy system monitoring, control and management technology, distributed power generation and energy supply technology and new energy transaction mode in recent years, the coupling among different types of energy becomes more and more tight and forms into a complementary trend. As a complete functional implementation unit of multi-energy complementation in regional energy supply system, regional integrated energy system has special meaning in actual living and production and its deep combination and tight interaction among source, network, load and storage of many types of energy put forward new requirement for the system analysis, design and operation. Regional integrated energy system generally involves integrated power supply, gas supply, heating, cooling, hydrogen supply and electrical traffic and other energy systems as well as relevant communication and information infrastructures. The relatively independent operation mode of traditional energy system cannot adapt to the multi-energy complementary energy production and utilization mode of regional integrated energy system. In various aspects such as energy production and transmission, storage and management, it is all needed to analyze the entire energy system by taking systematization, integration and fining method into consideration, to further improve the robustness and energy efficiency of the system and greatly reduce energy price [8].

![Fig.1 Illustration of multi-energy flow coupling](image-url)
To further improve energy efficiency and promote scaled use of multiple types of new energy, deep combination and tight interaction among source, network, load and storage of many types of energy will become an inevitable trend in development of energy system in the future. Therefore, the research on collaborative optimization of multi-energy flow energy management of regional energy internet in time scale has prospective and huge engineering application value.

3.3. Multi-management body
Multi-energy flow energy management system can regulate the distribution and proportion of energy flows by interaction of information to ensure the entire energy internet in safe and efficient operation. This regulation is also a key guarantee for stable operation of the system. In power system field, over 50 years of development in energy management system, development of traditional power grid energy management system has become mature. However with respect to complicated multi-energy flow energy management system, especially for the relatively complicated inter-coupling among many different types of energy, it is not available to directly use the traditional energy management system. Thereby, it is inevitable to develop a new management mode. Energy management platform is a system platform for analysis and processing and global optimized management on information of energy flow. It gets power grid, renewable energy, non-renewable energy, energy storage system, electric load, heat load, gas load and so on combined organically, realizing the supply control on different types of energy in energy supply end, appropriate conversion among different forms of energy, improvement in use rate of many types of energy, rational load distribution in energy user end as well as optimization of charging and discharging strategy for energy storage device in energy storage end [8].

Traditional power end, heating end, cooling end and gas and so on belong to different companies, abide by different industrial management rules and exist large industrial barrier among them. In the future, although it is possible to have integrated energy service company that manages several types of energy at the same time, there will still be large quantities of companies governing different levels, types and sections of energy and equipment. As shown in Fig.3, there are several management bodies. Hence, there are problems in information privacy, operation authorization and target difference and so on. This
brings considerable challenge for energy management. Thereby, it is needed to make a deeper research on multi-energy flow energy management method and, in the condition of information interaction, exchange necessary boundary information to realize collaborative control on multi-energy flow and meet the global safety and high efficiency target.

![Diagram of multi-management body](image)

Fig.3 Illustration of multi-management body

4. Outlook of multi-energy flow energy management on energy internet

With respect to the three aspects of challenge such as “multi-energy flow coupling, multi-time scale and multi-management body” on multi-energy flow energy management [8], it is needed to get the integrated energy management problems on power, natural gas and cooling and heating and other multi-energy flow system incorporated into the energy management problem of traditional power grids, as well as to create a theoretic system including in-time modeling and state estimation, safety analysis and safety control, optimization and dispatching and other multi-energy flow energy management, development multi-energy flow EMS and ensure safe and efficient operation of multi-energy flow system. At the same time, the current multi-energy flow energy management also confronts many difficulties and challenges.

Future power grid will be developed in smart, efficient, cleaning and reliable performance orientation. As an important task in creating an “Internet+” intelligent energy system, multi-energy complementation will be developed toward local power system integrated power generation, transmission, distribution, storage and use of renewable energy with high fluctuation and will be combined with large energy network to achieve joint development.

5. Conclusion

Energy internet is a complicated multi-net energy flow system taking power system as the core, internet technology and new energy power generation technology as the basis and constituted by a combination of traffic and natural gas and other systems.

Multi-energy flow is one of the key features that energy internet and integrated energy system distinguishes from smart power grids and is an important development orientation in energy field. Safe and efficient operation of multi-energy flow system depends on research and system development and application of multi-energy flow energy management. However currently, this aspect of research both at home and abroad is still in initial stage, lack of a systematic research and application of mature system and thus has large space for research. Compared with traditional power grid energy management, multi-energy flow energy management mainly confronts three aspects of challenge such as “multi-energy flow coupling, multi-time scale and multi-management body”.

Establishing a multi-energy flow energy management theoretic and method system, developing a multi-energy flow EMS and further verifying and applying it in digital simulation platform and practical multi-energy flow system can help to promote utilization of renewable energy sources and improve comprehensive energy efficiency as well as to ensure safety in comprehensive energy supply, promote
upgrading of energy industry and provide a new technological approach for energy production and consumption revolution in China.

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