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我国智能电网发展相关问题探讨

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Discussions on Related Issues of Smart Grid Development in China

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ABSTRACT: Since entering the 21st century, demand for electricity in China has been very high due to the rapid development of economy. Meanwhile, the problems related to climate change, environmental protection and sustainable development have become increasingly noticeable. Also, requirements from electricity consumers for higher supply reliability, excellent power quality and satisfactory services have emerged. In this scenario, two main characteristics of Chinese power grids are deduced. The first one is that the grids will remain the trend of rapid development for a long period of time. The second one is that Chinese power grid must take the road of constructing strong grids. These strong grids have UHV grids as their backbones and are supported by coordinated development of grids at different voltage levels. Based on the analysis of the necessities and the basic conditions of smart grid development in China, the paper provides an in-depth understanding of the four following aspects that should be correctly dealt with: constructing strong and smart grid with Chinese characteristics, scientifically planning the temporal orders of intellectualizing transmission and distribution systems, designing the integration of information project and smart grids in advance, and ensuring the coordinated development of smart grid, power sources and users. Finally, the paper presents some suggestions on construction of Chinese smart grid.

KEY WORDS: information engineering； smart grid； sustainable development；temporal order

摘要：进入 21 世纪以来，我国经济持续快速发展，电力需求增长快速。同时，气候变化、环境保护和可持续发展问题日益突出，消费者对于供电可靠性、电能质量和电力服务的要求越来越高。在此背景下，我国的电网具有 2 个主要特色：在未来很长时间内，电网仍将处于快速发展过程中；必须走以特高压电网为骨干网架、各级电网协调发展的坚强电网之路。基于对我国智能电网建设的必要性和基础的分析，重点探讨了我国发展智能电网应关注的 4 个方面，即建设具有中国特色的坚强的智能电网、科学规划输配电系统智能化时序、超前谋划智能电网与信息化建设的融合，以及牢固树立智能电网与电源和用户和谐发展的思想。提出了开展我国智能电网建设的相关建议。

关键词：信息工程；智能电网；可持续发展；时序

0 Introduction

Since entering the 21st century, China's demand for electricity has been very high due to the rapid development of its economy. At the same time, the problems related to climate change, environmental protection and sustainable development have been increasingly noticeable. As the basic industry that combines production materials with living essentials, electricity industry is inevitably drawing much attention from society, government and the public. Meanwhile, as the largest user of primary energy resources, electricity industry cannot shirk its responsibility on lowering the emissions of greenhouse gases and attenuating its negative impacts on climate, which is particularly true for China. In 2008, China ranked the second place in the world in terms of the total emissions of greenhouse gases with its 16 cities joining the world's top 20 most-polluted ones. Besides, the direct losses brought about by acid rains are over 100 billion yuan. So, it is an urgent mission to save energy and abate emissions and turn the society into a resource-saving and environmentally friendly one[1]. With the development of digital economy and information era, the requirements of consumers for power supply reliability, power quality and services become increasingly high. Therefore, it turns to be a social problem to accelerate the mode transition of power

production, transmission, and consumption and that of electricity industry development. In this scenario, China and some European and American countries have made some efforts in solving the related problems according to their own conditions. The achievements made include application of UHV, distributed generation, and power electronics technology, development of electricity market, and rapid development of renewable energy sources. Impressively, from these efforts germinates and grows the concept of smart grid.

By comparing the smart grids in China with those in the US and Europe and considering the conditions of energy resources and the interior driving forces of grids in China, this paper presents the main characteristics of China's grids, analyzes the four aspects that need much attention while constructing China's smart grids, and reveals that only strong and smart grid can meet the requirements for building a resource-saving and environmentally friendly society in China.

1 Comparisons of smart grids in China and those in US and Europe

Comparisons of smart grids in China and those in US[2-3] and Europe[4] are made as follows in terms of backgrounds, goals and main characteristics.

1.1 Smart grids in US

1.1.1 Backgrounds

1）Major problems of grids include aging electricity infrastructure, transmission congestion, low market efficiency, poor reliability and gap between the secondary systems and digital and information technologies.

2）There are numerous electricity utilities, and various management modes. Most balances between power generation and power consumption are realized locally. Long-distance transmission is rarely performed.

3）Permissions to construct power lines are hard to get because public concerns over environmental protection are enormous and raising money is difficult on electricity market.

4）Though there is national interconnection, some problems exist in management and security due to lack of nationwide backbone networks and uniform dispatch control.

1.1.2 Goals

1）Digitally upgrading transmission and distribution (T&D) systems, optimizing operation of T&D systems, opening market for alternative energies and offering diverse options for electricity consumers.

2）Increasing reliability, security and efficiency of power transmission and consumption with advanced technologies of information, communication and control.

3）Turning future networks into the smart grids of resilience, reliability, interactivity and self-balance.

1.1.3 Main characteristics

1）Participation of consumers begins with distribution systems. Installing advanced metering systems for consumers is in the first phase.

2）Much importance is attached to demand responses and development of demand-side resources and high efficient resources. Consumers can be provided with real-time information and options.

3）Be able to realize integration of intelligent electrical apparatus and user's equipment into grids, and application of advanced energy storage systems and peak-load shaving technologies.

4）The grids are adaptable to distributed generation and renewable energy generation.

1.2 Smart grids in Europe

1.2.1 Backgrounds

1）Grids in European countries are interconnected, and the interoperation among them is increasingly strong.

2）The energy policies address the importance of environmental protection and development of renewable energy sources.

3）Due to the saturating electricity demands and limited development space, the final goal of energy development is distributed generation, not the expansion of the scales of grids.

4）The user-centered philosophy becomes popular and the freedom of electricity market is enlarged.

1.2.2 Goals

1）Adaptable to changes and challenges faced by future grids and accommodating various demands of consumers.

2）Guaranteeing all users to be accessible to grids and to easily obtain renewable, efficient and clean energy.

3）Making power supply reliable and secure in accordance with the requirements of digital society and information era.

4）Improving the efficiency of electricity market by innovating technologies, efficiently managing

energy resources and introducing orderly competition into market.

1.2.3 Main characteristics

1）The terminal users play more active roles in power supply. Demand Side Management (DSM) becomes an indirect generation means, which highlights the users being rewarded for their participation.

2）The new systems will cover the whole European continent and make sure that the terminal users can access to as much resources as possible and realize high efficient power exchanges.

3）Problems concerning environmental protection can be solved with the full use of renewable energy.

1.3 Smart grids in China

1.3.1 Backgrounds

1）The grids develop rapidly with large capacity for growth in electricity demand thanks to the rapid increase in social economy.

2）Breakthroughs have been made on UHV transmission technologies, which lay the foundation for improving the grids' capability of wide-area optimal allocation of resources.

3）Electricity occupies a small part in terminal energy consumption. Efficiency in energy application is low, participation of users is not enough, and marketization of electricity industry should be accelerated.

4）Problems concerning grids' accommodating capability, receiving end markets, and dispatch and operation have become prominent due to the impressively rapid development of renewable energy.

1.3.2 Goals

1）Serving the development of social economy, helping build a resource-saving and environmentally friendly society, and making power supply secure, reliable, clean, and efficient.

2）Serving both power sources and users, contributing to the coordinated and sustainable development of electricity generation, transmission, distribution and consumption.

3）Enabling the optimal operation of power systems and improving the grids' capability of optimal allocation of resources to realize efficient application of social resources and maximize the benefits.

4）Implementing the "plug-and-play" integration of renewable energy generation and distributed generation with strong network structures and flexible operation modes.

1.3.3 Main characteristics

1）Based on digital substations and smart grids, the self-healing capability can be obtained via smart management and smart dispatching.

2）The interactivity will be emphasized in information exchanges and data transfer among power sources, T&D systems and users and among the dispatching centers at various levels.

3）Importance will be attached to the harmonized development between smart grid planning and planning of the backbone networks of bulk systems, and the mergence of the planning for various electricity sources.

4）Smart grid's fusion with information construction and its leading function will be highlighted.

5）Mutual connection, unification and harmonization are stressed in managerial sectors such as planning, designing, construction and operation, and in production sectors such as electricity generation, T&D and consumptions as well.

6）Emphasis will be laid on life-cycle asset management, the coordinated planning of electricity sources and grids, and the standardization and normalization for the construction of electricity sources and grids as well.

2 Necessities and basic conditions of China's smart grids

2.1 The option of smart grids is determined by China's basic conditions and the interior driving forces

Due to the fact that China's energy resources are located far from load centers, the energy has to be transferred across long distances, in large capacity and with lower losses. Hopefully, the emergence of UHV transmission[5] will provide opportunities to optimally allocate resources in a wide range and enable electricity delivery from large energy bases. But, the upgrading of voltage level is only the exterior appearance for grid development. Its interior driving forces include the flexibility of control, the high efficiency of management and the interactivity with consumers, which contribute to the formation of smart grids.

Firstly, in the process of building smart grids the employment of advanced technologies and equipment will contribute to forming a substantial platform for the stable and secure operation of grids and enhancing the strength of grids' primary systems.

Secondly, in the process of building smart grids, the optimal operation of the system, the optimization of resources and life-cycle asset management can be materialized via utilization of advanced philosophy, enhancing professional qualities of the staff, integrating the internal resources of the enterprises and excavating the internal potentials of the enterprises.

Thirdly, the interactive actions between utilities and consumers and the effective DSM approaches can contribute positively to shifting peak loads to filling valley loads, lowering system reserves and reducing operation costs, lifting the loadability of the grids and improving the utilization of grid investment.

2.2 Bases of constructing China's smart grids

Some work in the fields of smart grids has been conducted in China. More specifically, the work can be categorized into three groups, namely, power generation, T&D and consumptions. The power generation group includes distributed generation, renewable energy generation, and energy-saving oriented dispatch technology and auto-generation control. The T&D group consists of UHV AC and UHV DC transmission, FACTS, digital substation technology, PMU-based WAMS, DMS, state-oriented maintenance and life-cycle asset management and so on. The power consumptions group contains custom power, auto-metering and auto-transcription and so on. Besides, most electricity companies are making themselves more digital and information-wise, which establishes a foundation for smart grid construction.

Objectively, the base of China's smart grid is being formed, which can be proved by the following:

1）The strong grids with UHV grids as their backbones and the coordinated development of the grids at different levels are still under construction. The wide-area allocating capability of the grids needs further improvement.

2）The nation-wide unified electricity market is in its primary stage and the transaction mechanism and pricing policies are far from mature. Therefore, the basic conditions for clean energy sources, and distributed generation to participate market competition haven't been made. The efficiency and benefits of electricity market haven't been fully revealed.

3）Electricity users haven't enjoyed the benefits arising from the interaction with the grids as yet. What they can receive is the one-way passive services. The meters can only be read automatically. A lot of work needs to be done to guide electricity users' consuming habits and their consuming demands.

4）The relevant policies or laws related to smart grids haven't been made or issued by the government. The government is supposed to be a leading role in constructing smart grids with great support because the work is a systematic project covering all walks of life and needs an overall arrangement in planning and development. Especially, policies encouraging users to join the effort of saving energy and mitigating greenhouse gases emission should be promulgated.

3 Constructing the smart grids with Chinese characteristics

3.1 The significance of constructing the smart grids with Chinese characteristics

As is shown in the former chapter, China's smart grids are different with those in the US and Europe in terms of backgrounds, goals and main characteristics. It is the chosen road for China to construct the smart grids with Chinese characteristics that are suitable for the developing level of China's electricity industry, technology and economy. The Chinese characteristics are displayed in two aspects:

Aspect One: China's grids are still rapidly developing.

In order to make the country more wealthy, its economy will expand rapidly for a long period of time in the future and so will its electricity demands. According to predictions, by the year 2010, the total installed capacity of electricity generation and the electricity consumption are expected to reach 900 GW and 4000 TWh. By the year 2020, these figures will be 1600 GW and 7700 TWh, which are twofold of those of the year 2008.

Aspect Two: China's grids must take the road of constructing strong grids with UHV grids as their backbones and the coordinated development of the grids at different levels.

The reverse distribution of energy resources and electricity demands exits in China. 76% of coal resources of the country are buried in Shanxi, Inner Mongolia and northern Shaanxi. 80% of hydro resources spread in southwestern areas. The on-land wind resources are concentrated in North China, Northeast China and Northwest China. However, over 2/3 of the energy are consumed by East China and Central China where primary energy resources are

scarce. So, UHV transmission can be relied on to transfer energy in large capacity and long distance with little losses.

Currently and in a certain period of time, the smart grids with Chinese characteristics are the means and modes to realize the life-cycle asset management of grids, enlarge grids' capability to serve both electricity producers and electricity users, make rational development planning strategies and optimize system operation under the conditions of continuously lowering costs, improving efficiency and benefits and enhancing the reliability and availability of the whole systems, with UHV grids as their backbones and the coordinated development of the grids at different levels and in combination of advanced information, communication and control technologies and the advanced managerial philosophy.

3.2 Four problems that should be stressed for China to construct smart grids

3.2.1 The smart grid with Chinese characteristics is both strong and smart

China's grids, as an important part in the national energy strategy and a vital link in energy sector and the important component of the national comprehensive transportation system[6-8], are in the phase of rapid development. The country has to stick to the road of constructing large grids and UHV transmission systems because of the basic conditions of the country on energy resources. However, the requirement on the level to which the grids are smart is very high, which can be ascribed to the diversification of energy sources and electricity demands and people's concerns about environmental protection and sustainable development.

On one hand, a strong property of grid is the base of safe and reliable operation of the grid and immune to natural disasters and even attacks from outside. And on the other hand, the introduction of advanced technology and equipment, scientific managerial philosophy enables flexible operation and controllable flows of power.

Therefore, the grid, both strong and smart, is the direction for China's future grids. The construction and planning of China's smart grids should be fully considered with the construction and planning of its UHV grids.

3.2.2 Scientifically planning the temporal orders of making T&D systems smart

As the US and Europe have evolved into a relatively mature phase which has limited room left for electricity demands to grow, their smart grids start with distribution systems and emphasize the importance of electricity users. Power balance is usually maintained in local regions. But in China, at the beginning of constructing smart grids, more importance should be attached to making large-capacity trans-area power delivery more efficient, more reliable and more cost-effective.

In middle stage, with the maturity of electricity market, the function of DSM will become more prominent. More enthusiasm will be displayed by users to participate the market. Meanwhile, the smart transmission systems will accelerate the installing of advanced metering systems that will enable the two-way flow of data. Therefore, the whole system can be made smart under the condition of electricity market. By that time, electricity users will have enjoyed more options and decision-making power and electricity will have taken up more part of terminal energy consumptions, which display the flexibility, interactivity and environmentally friendly quality of smart grids.

In a mature smart grid, as the introduction of "plug-and-play" types of energy, such as distributed generation and new energy sources, and more frequent interactions from users and the emergence of micro-grids and island operation, the modes of the system operation will be more flexible and the topologies of the grids changeable. So, the flexibility and openness of smart grid planning and the temporal orders of making T&D systems smart should be stressed. A network with rational structure, flexible operation and high adaptability will guarantee the security, flexibility and efficiency of the grids.

3.2.3 The integration of smart grid and information project should be considered in advance

With introducing advanced managerial philosophies into system management, smart grids need an ocean of data from all sections of the system (power generation, power T&D, power consumptions) and should process them in smart ways. From the viewpoint of information, constructing smart grids is equal to building a communication platform, a framework, and a decision-making system, a hierarchical system of agreements, which will make an efficient managerial platform to realize automation of production, modernization of management and

scientification of decision making process.

For instance, currently the State Grid Corporation of China (SGCC) is devoted to realizing the whole-process information project that covers its staff, money and materials and business. Therefore, when SGCC constructs its smart grids, advance consideration should be made on the consistence of their information structures, decision-making process, communication frameworks and the system of agreement to settle the mutual integration of the to-be-used and obtained information and data, without producing contradictory data, congestion or mutually rejected data. Only this way can smart grids promote further development of the information projects and integrate all kinds of databases scientifically, rationally, and efficiently. Then, the system operation can be optimized and the asset utilization can be maximized to realize life-cycle asset management and perfect the strategic plans of the enterprises and financial plans and maximize the users' satisfaction.

3.2.4 Stick to the idea of harmonized development among smart grids, power producers and users

The relationship between grids and power producers is win-win and mutually beneficial, which is based on helping construct a resource-saving environmentally friendly society. With the introduction of renewable energy sources into grids, uncertainty, intermittence and poor dispatchability of these types of energy sources will bring negative impacts on power delivery systems and interconnections. One function of smart grid is to increase its capability of accommodating renewable energy sources with advanced technology and scientific management. On the other hand, the improvement of power generation in its controllability, predictability, robustness, immunity to interruptions and load following capability will produce positive impacts on the operation of smart grids.

The relationship between smart grids and users is two-way interactive. With the help of advanced technologies and scientific managerial philosophy, smart grids enable diversification of the electricity demands and high quality of services. Smart grids can properly guide the consuming habits of electricity users and reduce electricity consumption in peak load periods and thus the users' expenditure on electricity. Smart grids can also increase the utilization ratio of electricity and enable the users to enjoy clean energy sources. At the same time, the change in users' consuming habits will function as shifting peak load to fill up the valley and then the system reserves will be reduced and so will the installed capacity of the system, which will beautify the capacity factors of power generation sets. Furthermore, as a resource, smart grids can provide users with better added value services. For instance, electricity-driven cars that hold a very promising future in China will benefit from the large-scale construction of charging stations in smart grids. Therefore, smart grids will provide these users with more human-based services.

Finally, smart grids will be adaptable to the change of society and become an open, fair and public platform of transaction for all participants (electricity producers and users and so on) of electricity market.

3.3 Suggestions on China's smart grid construction

1）Much importance should be attached to the study of developing strategy for smart grids in combination of China's specific national conditions to elevate the overall efficiency of large grids. The strategic planning of smart grids is supposed to make clear the positions, developing frameworks and measures. Currently, the emphasis should be laid on issues such as the coordinated development of smart grids of the whole voltage ratings, the relationship between the development of smart grids and that of the UHV grids and the development issues of smart grids in the scenario of electricity market.

2）The study of devising the standardization system for smart grids should be conducted as soon as possible. Standardization will contribute to making the interconnections of different smart grids cost-effective. The standards and norms of planning and designing should be consummated and a planning system of unification, efficiency and clear structures, definite functions and mutual linkage will be indispensable. Therefore, an overall standardization planning for smart grids will be produced.

3）The problems regarding the structures and mechanism for smart grid development, especially in the scenario of electricity market, should be studied. The problems include the relationship between smart grids and the marketization of China's electricity industry, the determining mechanism of electricity tariffs and the roadmap and goals of China's smart

grids adaptable to the marketization.

4）The study of DSM-based smart dispatching work needs emphasizing. Currently, the dispatch centers have lots of data from electricity producers but lack the data from users. Therefore, the smart management of user data should be strengthened. In case of emergency, dispatchers can shed the load of large users, which should be clarified in contracts.

5）While constructing smart grids, the impacts of renewable energy sources and distributed generation on the grids should be analyzed, especially those caused by the wind power delivery in large capacity and long distance. The seamless connection of short- and middle-term of wind power forecasts with the dispatch centers should be realized to make generation schemes and adjustment for smart generation.

4 Conclusion

Construction of smart grids with the Chinese characteristics is indispensable to the healthy, rapid, and sustainable development of China, and is essential for the building of a resource-saving and environmentally friendly society. Also, it contributes to fulfilling the commitments to saving energy and reducing greenhouse gas emissions. At the same time, construction of smart grids with the Chinese characteristics can promote the development of industries such as information, communication, electronics and machine manufacturing. It enhances economic growth and promotes the innovation in science and technology. Power grids in China have the feature of rapid development, and they must take the road of constructing strong grids with UHV grids as their backbones. Due to the characteristics of energy resource distribution and the internal driving forces of the development, power grids in China should be both strong and smart. Only in this way can power grids support development of economy in China and promote the building of a resource-saving and environmentally friendly society.

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