A Study on Development and Evolution of the Intelligent Power Grid Information Communication Architecture

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Abstract. According to the development plan of smart grid and the future demand of smart grid, the construction principles and development objectives of smart grid are discussed and analyzed. Based on the existing grid resources, and on the basis of ensuring full utilization of resources, a smart grid management system with significant advantages is realized, which fully guarantees the management convenience, reusability and portability of the system. On the basis of researching and analyzing the rules of the smart grid system architecture, an intelligent grid management system named “System of Systems” (SOS) is designed and developed, which is based on the open standard hierarchical service and replaces the old business silos with an integrated system. The smart grid system combines the scientific evolution route with service-oriented as the core feature to achieve a highly integrated management system to ensure the standardization of system data interaction protocols and the adequacy of data interfaces. In order to achieve good adaptability and compatibility of the smart grid system, the system can be optimized and adjusted flexibly and conveniently according to future changes in demand to ensure the reliability and stability of the system.

1. Introduction
With the rapid development of social economy, the service pressure of power grid is constantly rising. Smart grid has become an important measure to improve the service level and management efficiency of power grid, which has been widely recognized by all countries in the world, and has actively promoted the construction and development of smart grid. At the same time, many international organizations have also explored and formulated their own technical standards and development plans for smart grid from their own fields, which provides rich evolution route guidance and standard norms for the development of smart grid and actively promotes the development of smart grid. NIST (National Institute of Standards and Technology) divides smart grid into seven different areas according to its specific development characteristics, and formulates corresponding technical standards, management norms and construction guidance. Provide effective tools for interoperability in different fields, and provide a scientific and reasonable standard process for the development of smart grid through priority action plans. The TC57 Technical Committee of the IEC (International Electrotechnical Commission) has proposed the core standard of IECTR62357, which systematically describes the general construction planning and standards of smart grids, and provides standardized recommendations for smart grid construction. This has laid a good foundation for the construction and development of smart grids around the world.

In the field of smart grid standard setting, China has also made outstanding contributions. The IEEE1888 working group put forward the green development concept of smart grid, and advocated the construction and development of energy-saving grid, energy storage grid and power grid. The IECPC118 working group proposed data interaction standards between smart grid systems and external...
devices, providing a scientific basis for smart grid construction. However, at present, China has not carried out corresponding research work in the field of smart grid architecture. It only stays at the macro level of standards and guidance, and lacks micro-level construction and development planning, which makes the overall development of China's smart grid relatively lagging behind. Based on the existing generally accepted technical standards, framework specifications and evolutionary routes, this paper analyzes and discusses the development planning of smart grid construction and related technologies and their evolutionary laws. This topic constructs a reliable smart grid construction scheme which can meet the uncertain demand in the future and guarantee the quality of grid service, and provides an effective basis for relevant practice.

2. Development Principles of Smart Grid Architecture

From the overall development point of view, the next 20 years will be the key period for the innovation and development of power grid, and the adjustment transition period for smart grid to replace traditional power grid. The development goals of smart grid construction are mainly as follows: adapting to technological innovation and development, realizing the integration and development of traditional grid and new information technology and communication technology, and ensuring the stability and reliability of power grid system operation in the process of innovation and development. In order to ensure the stable operation of increasingly complex power grid systems, control information technology and ICT technology will continue to innovate and develop. Comprehensively analyze the future development goals and current development level, and determine the scientific and rational smart grid development plan to ensure the sustained and stable development of related work. To ensure the scientific and rationality of long-term development planning, and without prejudice to the normal operation of the current power grid, the intelligent transformation work will be gradually completed to ensure that future needs are effectively met. Strengthen technological innovation, build a good data interaction channel, achieve good data interaction between smart grid and different devices and systems, and ensure the full use and sharing of data. Simple and intuitive for the development and development of smart grid systems [2].

On the basis of clarifying the overall development goals of the smart grid, the overall development plan should be scientifically formulated. Considering the development trend and future demand of the smart grid, and taking into account the investment cost and expected return, the scientific development plan is clarified. The key points need to grasp the following basic principles:

One is the principle of simplification of system structure. Simplification of smart grid system can greatly reduce the difficulty of operation management and use, thus improving work efficiency and reducing operation costs. At the same time, it constructs a measurement and evaluation mechanism, evaluates and analyses the operating efficiency and performance of the system, finds out problems and shortcomings in time, and optimizes and adjusts them to ensure the best level of revenue.

The second is to start from the service demand and create favorable conditions for the system upgrade. The system development concept and operation management concept based on business process will significantly improve the quality and efficiency of grid service, and lay a good foundation for data integration, interaction and conversion, and improve the overall operating efficiency of the system. Ensure that the system has good compatibility and expansibility, can fully meet the needs of different application environments, and can be optimized and adjusted according to the changes of requirements, so as to ensure the reliability and stability of the system operation.

Third, starting from the existing resource situation, we should try to reduce the scale of construction and improve the utilization rate of resources. As far as possible, the functions of existing power network systems and equipment should be brought into full play, the investment of new projects should be reduced, and the investment and cost of smart grid construction should be reduced as far as possible, so as to ensure the overall benefit level.

Fourth, data management should be strengthened to ensure data quality. Make and implement data quality plan, scientifically manage data sources, ensure the reliability of system data, fully meet decision-making needs and ensure the scientificity and effectiveness of the determination. Create a
trusted data source database to provide effective data support for system operation, improve data utilization and reduce costs, and avoid adverse effects on system stability due to inaccurate data.

3. Research on the evolution of smart grid development

Overall, the smart grid will show a trend of standardization, openness, and integration, requiring good data interaction between the smart grid system and external systems and devices. In the process of its evolution, the architecture of the smart grid is roughly characterized by the following phases:

Phase 1: Business Silos

It can be understood intuitively as the comprehensive management of different business silos. The overall structure is detailed in Figure 1. It can be seen from the graph that under the development mode of business silos, each business silo takes the same business unit as its service object, and achieves its established function under the management of different management systems, so as to ensure the stable operation of the power grid system. However, the level of intelligence of the architecture is low, and there are not only high cost and low efficiency problems, but also a large risk.

As business needs change, the data interaction of business silos increases, and in order to ensure good interaction, interface technology will be innovated to meet demand.

Phase 2: Bus Partial Integration

This stage belongs to standardization technology as the core, which integrates ESB, completes the common maintenance of background, application and service. As shown in the architecture relationship in Figure 2, it can be seen that when ESB support is an open standard, business silo applications can be shared across the entire infrastructure. Achieve good system interaction and flexible application. After calling, the silo architecture can change the status quo of information islands. However, ESB integration must have strict open standards, data model execution, and if not, can only play its role of sharing communication media.

Of course, we know that the ESB architecture is integrated, but it is not the ultimate target architecture and cannot fulfill the requirement of “integrating everything”. The lower system still belongs to the silo nature. In the future, the flexibility of business needs and the loose coupling of business expansion are obvious.

Fig.1. Phase 1: Business Silo Architecture
Phase 3: Heterogeneous Network Fusion

As shown in Figure 3, the focus at this stage is that heterogeneous systems can be integrated, and heterogeneous platform business application systems can be integrated, using intermediate components such as adapters. The systems, applications, and data sources of the various types of businesses inside and outside the enterprise are connected in a unified manner, and the internal application systems of the enterprise are realized to share data, information, and services.

This system can be used as the basis of heterogeneous systems. In the process of continuous evolution, adapter interface conversion can be completed. At the same time, the format conversion of heterogeneous network messages and data is completed. Through the framework of message integration, the essence of heterogeneous network messages and data is communicated in the middle of the application system. After summarizing the solution, it will realize the modularization of the business by means of network integration, and the standard of service reusability is unified, indicating that it is not the final target architecture of the smart grid, nor is it the open use of Internet technology [3].
In summary, the function of the silo structure business system obviously causes difficulties in integration and information interaction for system integration. When this kind of architecture evolves, the following three levels of management should be completed: First, strengthen the interaction between business silos, and use the bus integration application and background business silos to complete the initial integration. Secondly, based on part of integration, the construction of special network in related fields is completed, and middleware fusion is formed through data fusion to realize heterogeneous network architecture. Thirdly, through the above infrastructure, the transition to service business modularization is completed.

4. Future Smart Grid Architecture

Through the analysis of smart grid system with strong adaptability and robustness, we believe that this system must be based on flexible architecture. This service center integration method can complete the application of highly heterogeneous, distributed systems and application solutions. Therefore, this service center architecture is the future development direction of the IT architecture and can represent the development trend of the smart grid architecture.

The layered service architecture based on open standards can realize the modular integration of enterprise service bus ESB integration and adapter architecture middleware, and build services and services into the layered business model required by the grid system. This is the layered architecture pattern of the centralized/distributed shared service stack, as shown in Figure 4. This kind of architecture can realize the feature planning of "system in system". The system belongs to the integrated structure of multi-independent, distributed and independent structure. It can realize the independence of member systems in operation and management. At the same time, the member system is integrated and coordinated to realize the system function, which is a temporary sudden phenomenon.

This kind of architecture is service oriented, and all application functions can be decomposed into access services. Because the protocol and technology of the service itself are not related, each service project does not need to care about the physical location and implementation technology of other services, and its invocation can be completed by using different forms of protocol. The service project relationship is loosely coupled, which can realize interaction and inheritance. Moreover, when it comes to modification, increase or decrease, it also has no effect on other services. When services can be combined according to different ways, then different business processes can be formed, which is the origin of functional differences [4]. If a business process changes, the match can be completed through the adjustment of the service composition. The service delivery coupling, reusability, etc., can systematically adjust the underlying programming development, and the system can realize high-quality flexible development mode application.

The architecture interface foundation itself is defined by open standards, which means that the service description is enhanced and the function of the service availability guarantee system can be improved. This kind of interface cannot implement the mandatory binding of specific functions, and the technology and physical location can be reasonably shielded. Then the service interface is not guaranteed. For the service provider and user, the changes are completed independently. There is no impact on each other.

This open standard layered service architecture can support the above mentioned evolution route, and can implement the service integration mode of the system function and protect the existing infrastructure investment [5]. At the beginning of the construction of the architecture, the following issues need to be considered: first, as long as the important integration needs start, the system and application should be encapsulated and processed, and new services must be developed to support the follow-up integration services. Secondly, in the process of increasing the number of integrated services, the new integration requirements should be realized reasonably. Thirdly, the existing services can realize the continuous updating of integration requirements, so as to ensure that the system integration presents a gradual development model. Because open standards are loosely coupled and flexible, it means that system migration has been replaced by new technology platforms, which has no impact on the application of related functions, and the system has strong robustness and adaptability.
5. Conclusion

Based on the research of smart grid, the objectives and principles of the architecture are analyzed. The specific goal is to reduce the investment cost and realize the construction of complex grid architecture system. In order to maximize the investment benefits and optimize the development of the architecture, especially the integration and utilization of power grid resources, reusability of program services and easy management of the system are clearly emphasized. Intelligent grid in different stages will be transformed in the fusion stage, and the transition and replacement will be completed according to the future demand architecture. For the evolution route of smart grid in different stages, this way can realize the heterogeneous transformation from business silo to standardization stage, which is the key to the gradual upgrading of power grid architecture. Reasonable evaluation of power grid system reconstruction and equipment replacement will maximize the protection of current construction investment and reduce the transition cost. According to the analysis of the future smart grid architecture, this paper believes that this architecture model should be served in an open standard layered architecture, and the advantage is Internet technology. Therefore, the system realizes the transformation of service and business modularization, and uses open standards as a business interface to complete the change of flexible architecture. The reusability and loose coupling of the system itself are very obvious, and it is possible to achieve a high degree of adaptability and robustness by adding and replacing new services of the system.

References
[1] Sun Ying, Gaochao, Jinhua, et al. Research on the evolution trend of backbone communication network oriented to smart grid [J]. Television technology. 2017 (Z1): 58-61.
[2] Tong Heqin, Ni Ming, Li Yuexin, et al. Integrated simulation of power grid and communication
network [J]. Southern Power Grid Technology. 2016 (05): 117-122.

[3] Hu Chunchao, Hou Aijun, Ma Kai, etc. Modeling and Simulation of SCADA system communication based on OPNET [J]. Power system protection and control. 2016 (10): 54-59.

[4] Wang Fang, Wu Lihua. Evolution Strategy of Fusion Communication Architecture [J]. Telecommunications Science. 2016 (S1): 226-231.

[5] Liu Xueyan, Zhang Qiang, Li Zhanming, et al. Data aggregation and access control methods for smart grid communication systems [J]. Power system automation. 2016 (14): 135-144.