Design and Development of Two-level Deployed and Multi-level Applied Electric Energy Substitution Effect Improvement and Business Expansion Support Software

Bo Miao 1,*, Chang Liu 1, Hao Li 1 and Jingyi Lin 1
1China Electric Power Research Institute, Beijing,100192,China

*Corresponding author e-mail: miaobo@epri.sgcc.com.cn

Abstract. With the in-depth promotion of electric energy substitution and the rapid development of grid informationization, the building of systematic and integrated electric energy substitution effect improvement and business expansion support software becomes an important means to further optimize the electric energy consumption management level and realize the overall improvement of electric energy utilization efficiency. This paper introduces the design idea of this software, shows the layer structure of the platform, describes the relationships among all layers, analyzes the key technologies of the system, and researches and designs the general architecture and function modules. This platform provides the strong technical support for the state to promote the lean management of electric energy substitution and for the State Grid to develop the building of electric energy substitution service system.

Keywords: Electric Energy Substitution, Effect Improvement, Online Energy Consumption Monitoring, Smart Grid

1. Introduction
In recent years, the global fossil energy supply is in short supply and the ecological environment is deteriorating day by day, which promotes the gradual international consensus of energy saving and emission reduction. With the issuance and implementation of power demand side management, energy saving and emission reduction and other relevant policies, the building of a unified electric energy substitution effect improvement and business expansion support software to effectively manage and analyze the huge energy data has become an important part for power enterprises to further optimize their power structure and improve their energy utilization rate [1-2].

In foreign countries, the electric energy management information system has been widely used, and has played a certain role in improving the energy efficiency. However, there are still many deficiencies. For example, American Opower has developed a relatively complete household energy management system to provide the household energy management SaaS solution for customers and to monitor the household power consumption and provide the energy saving and demand response service. However, limited by data scale and architecture system, its customers are only the residents instead of large industrial users.
Most energy data information management in China is at the traditional manual writing and reporting level. The data query is not only tedious, but also inaccurate. Most information platforms are in the initial stage, are lack of systematic theoretical methods and standards [3], don't apply the advanced energy efficiency monitoring management technology based on system comprehensive energy efficiency evaluation, are lack of technology means combining the power load management and the efficient operation of energy consumption equipment and energy consumption system, are lack of macroeconomic analysis and energy consumption analysis in different industries and different regions, and are failed to reach the stage of improving overall comprehensive energy efficiency utilization rate [4-5].

The modular and intelligent electric energy substitution effect improvement and business expansion support software mentioned in this paper has many functions, such as energy efficiency management, macroeconomic analysis and demand response. It serves energy consumption enterprises to provide the energy saving monitoring means for them and serves the governments and grid companies to assist them in realizing the energy saving and emission reduction and in improving their demand side management level. This paper researches the layer structure of electric energy substitution effect improvement and business expansion support software, describes the relationships among all layers, analyzes the key technologies of this platform, designs the architecture and function modules, and proposes a two-level deployed and multi-level applied physical architecture and multi-system integrated physical architecture to provide the comprehensive energy monitoring management and analysis service for five type of users, i.e. governments, grid enterprises, energy saving service operators, energy consumption enterprises and the public..

2. Platform Architecture Design

2.1 Physical Architecture of Platform

The software is aimed at building a two-level deployed and multi-level applied physical architecture, multi-system integrated application architecture and intranet and extranet mixed application mode, creating a perfect security protection system and realizing the unified application of intranet and extranet of the platform.

Two-level deployment: the platform is deployed at two levels, i.e. headquarters and provincial platform of State Grid. From the physical perspective, it can be divided into headquarters platform and provincial platform, both of which include the application system and the external portal website of electric energy substitution effect improvement and business expansion support software, such as servers, storage devices, network devices and security devices. All devices are connected by Ethernet and public network of operators (APN/VPN).

Multi-level application: the platform is applied for users at four levels, i.e. headquarters, province, city and county level. The users at province, city and county level realize the data acquisition and upload and the response to the command of the headquarters. The users at headquarters level realizes the data collection and analysis and the formulation of decision scheme through the headquarters platform. The users at four levels operate the different commands based on their own permission and business demand so as to guarantee the ordered deployment from upper level to lower level of the platform.

Intranet and extranet mixed application: from the perspective of security, it can be divided into intranet and extranet of power information. Both the intranet and the extranet of power information adopt the modular structure. They are connected by the strong isolation device. The headquarters platform and the provincial platform realize the information interaction and information sharing through the Ethernet and switch of intranet of power information. The main website of an enterprise is connected with the provincial platform through public network of wireless operator APN/VPN, security access platform and Ethernet. This connection mode can improve the security factor, anti-interference ability, stability, reliability and confidentiality in system operation so as to ensure the safe and stable operation of power information intranet.
2.2 Application Architecture of Platform

Relevant functions of platform need to obtain data through external system. Therefore, it is necessary to realize the connection with 9 systems, such as marketing business application system and power consumption information acquisition system. The platform has the multi-system integrated application architecture and realizes the data sharing and interaction through interface.

As an internal business management system of State Grid, both the headquarters platform and the provincial platform can connect with marketing business system, marketing analysis and assistant decision system, power consumption information acquisition system, load management system and dispatching automation system. The platform is integrated with all internal business systems through the mode of Webservice, Java Message Service (JMS) and data replication. Based on relevant data exchange standards of State Grid, the platform obtains data of relevant business systems through Enterprise Service Bus (ESB) and Data Exchange Platform (DXP).

As for external system, the provincial platform can connect with internal energy consumption management system of enterprises or energy saving service operators so as to obtain the low-voltage side power data and other energy consumption data of the enterprise. The provincial platform is integrated with external system through Webservice, JMS, intermediate database, etc. The electric energy substitution effect improvement and business expansion support software is formulated with unified interface standard. The external system can transmit the data to the software based on the standard.

2.3 Technical Architecture of Platform

From bottom to top, its technical architecture includes hardware support layer, software support layer, database layer, public service layer, application service layer and interface display layer.

2.3.1 Hardware Support Layer

The hardware support layer is the bottom support equipment which supports the realization of functions of all upper layers.

2.3.2 Software Support Layer

The software support layer adopts browser/server architecture mode, uses service description language, and uses simple object access protocol to call based on Hypertext Transfer Protocol and JMS so as to support the data exchange and sharing with other systems.

2.3.3 Database Layer

The database layer realizes the data access, upload, collection, sorting, analysis and storage, and responds to the data call request of the public service layer.

2.3.4 Public Service Layer

Based on the user request, it can call and process the data from database layer. Meanwhile, this layer has the functions of permission control, log management, data access, etc.

2.3.5 Application Service Layer

The application service layer is used for forwarding of request, processing of session state, analyzing of business data in display layer and calling the business rule in public service layer and realizes the core service and routine service.

2.3.6 Interface Display Layer

The interface display layer includes headquarters and provincial intranet portal and external portal and accepts user input, data verification and data display.

2.4 Data Architecture of Platform
Based on the structure, the platform data can be divided into structured data and unstructured data. The structured data includes customer data, statistical analysis data, service data, basic support data, market data, measurement data, acquisition data, etc.; the unstructured data includes contracts, paper documents, files, materials, faxes, pictures, etc.

The platform data can be divided into power data, energy consumption data and other data based on content. The power data is imported from internal data of State Grid system. The platform can realize data interaction with the headquarters basic marketing data platform, provincial basic marketing data platform, national power demand side management platform and provincial power demand side management platform so as to collect and analyze the power data. The energy consumption data is obtained from access of the data of the energy-saving service operator's platform in the provincial region, and from real-time acquisition of the terminal data of the energy consumption enterprises and users. Other data includes meteorological data, economic data and other data resources obtained from external statistics.

3. Key Technologies of System Design
The key technologies of platform system design mainly include information integration technology, online energy consumption monitoring technology, security protection technology, etc [6].

3.1 Information Integration Technology
Based on the data requirements of electric energy substitution effect improvement and business expansion support software, to avoid the repeated building, it is necessary to connect with the existing marketing business application system, dispatching automation system, SMS platform, marketing analysis and assistant decision system, and power consumption information acquisition system of State Grid. The information interaction bus based on IEC61968 standard realizes the data exchange to ensure that each system can obtain the relevant data required and meet the business management demand, business execution demand, technical service demand and information query demand of platform users.

3.2 Online Electric Energy Consumption Monitoring Technology
Based on the metadata object of energy consumption unit, the platform builds a user energy consumption monitoring and analysis system, which classifies the equipment, production lines and buildings containing similar energy consumption information together and realizes storage, statistics and analysis of energy consumption data.

3.3 Security Protection Technology
Based on the security strategy of State Grid “region division, safe access, dynamic sensing and overall protection”, the security protection grade of platform system is defined as grade III. By deploying the strong information isolation device, firewall and intrusion detection equipment, and by adopting the equipment safety management, equipment link redundancy, communication link load balancing and other technologies, the platform is carried out with overall security protection, including physical security, boundary security, application security, data security, host security, network security and terminal security[7].

4. Platform Function Design

4.1 Platform Function Orientation
The electric energy substitution effect improvement and business expansion support software is based on the existing integrated platform and business application system of State Grid and integrates relevant functions. It forms a comprehensive energy monitoring and management system to support the development of electric energy service management business. It can provide the
overall energy saving services, analysis and management for governments, grid enterprises, energy consumption enterprises, third party evaluation organizations and energy saving service operators.

4.2 Platform Function Modules
The platform consists of eight functional modules as follows.

1) DSM target responsibility assessment: DSM target responsibility assessment manages the completion of index plan and index of power saving of grid enterprises in implementing DSM target responsibility assessment task and provides the information support to relevant government authorities to know the DSM index implementation situation and the implementation of DSM target responsibility assessment of grid enterprises. It provides many functions for headquarters and power companies in various provinces (autonomous regions and municipalities directly under the Central Government), such as management of completion of index plan and index of power saving of grid enterprises in implementing power demand side management target responsibility assessment task.

2) Energy saving service business management: the energy saving service business management refers to the whole-process management of the energy-saving business of the energy-saving service organizations by the grid enterprises. It provides data and information support for the energy-saving business. It provides many functions for the headquarters and grid companies in provinces (autonomous regions and municipalities directly under the Central Government), such as the whole-process management function of the energy-saving business of the energy-saving service organizations (energy-saving service companies, evaluation organizations and energy efficiency network groups).

3) Ordered power consumption management: the ordered power consumption management refers to legal control of partial power consumption demand and maintenance of safe and stable power supply and consumption order in case of predictably less power supply by administrative measures, economic means and technical methods. It can realize the ordered power consumption information release, scheme formulation, execution monitoring and result statistics in various provinces (autonomous regions and municipalities directly under the Central Government) and can realize the analysis and display of execution effect of all levels.

4) Demand response: the demand response refers to the market participation behavior of users in power market responding to the incentive mechanism and changing the conventional electricity consumption mode. The functions include demand response policy and regulation release, response resource management, scheme formulation, scheme release, scheme start, scheme execution monitoring, and execution effect statistical analysis of power companies in various provinces (autonomous regions and municipalities directly under the Central Government).

5) Macroeconomic analysis: the macroeconomic analysis refers to the analysis of power consumption data of regions, industries and typical enterprises to reflect the economic trend and to provide the data support for governments to make the macroeconomic policies. It provides many functions for power companies in various provinces (autonomous regions and municipalities directly under the Central Government), such as periodic analysis of power consumption data of regions, industries and typical enterprises.

6) User energy consumption service: the user energy consumption service refers to energy consumption monitoring, analysis, benchmarking and consultation services provided for users. The service helps the enterprises to know their own energy consumption and to promote the enterprises to optimize the energy consumption structure. It has the user energy consumption monitoring, analysis, benchmarking and consultation service functions, including online energy consumption monitoring, energy efficiency model management, energy consumption analysis, energy efficiency benchmarking and evaluation analysis, and energy-saving business consultation.

7) Energy consumption acquisition management: the energy consumption acquisition management refers to the establishment of basic file, information acquisition file and data acquisition business for online monitoring users and the information maintenance of acquisition devices of users so as ensure the energy consumption information acquisition. It provides many
functions for the grid companies in provinces (autonomous regions and municipalities directly under the Central Government), such as online monitoring of basic files, information acquisition files and data acquisition of energy consumption users, information maintenance of user’s acquisition equipment and support of access function of information acquisition of energy-saving service operators.

8) Knowledge base management: the knowledge base management refers to the management of relevant policies and regulations, index systems, standards and specifications, skill service institutions, technical products, energy-saving cases, benchmarking database, energy efficiency experts, training materials, tools and software, etc. involved in power service and energy-saving business. It realizes the maintenance and application of relevant policies and regulations, index systems, standards and specifications, typical cases, expert information and other information related to energy-saving services by platform users.

5. Platform Application Effect
The electric energy substitution effect improvement and business expansion support software researched in this paper has been used by the headquarters and 26 provincial companies of State Grid and has been stably operated for more than 2 years. At present, the software realizes the input of more than 110,000 energy-saving and electric energy substitution projects, the installation of more than 13,000 energy efficiency acquisition terminals and the access of data of 1,300 energy consumption enterprises. The platform helps the governments to realize the scientific regulation and supervision of power operation, assists the State Grid in realizing the reasonable analysis and scientific dispatching of power supply and consumption parts, assists the energy-saving service operators in expanding the market and developing the energy-saving analysis in depth, guides the energy consumption enterprises to control the total energy consumption and reduce the power consumption costs based on relevant strategies and provides an approach for the public to learn the energy-saving knowledge and improve the energy-saving awareness[8].

6. Conclusion
The two-level deployed, multi-level applied and intranet and extranet mixed electric energy substitution effect improvement and business expansion support software mentioned in this paper plays an important supporting role for China to promote the energy-saving and emission reduction and for State Grid to build an energy-saving service system. With the continuous attention of China to power demand side management, the platform will further utilize its information resource and technology advantages in the field of energy, combine many technical means, such as cloud computing, big data, Internet of things, mobile Internet, efficiently tap the potential of data resources, and carry out the energy efficiency benchmarking, electric energy substitution, power industry prosperity analysis and other functional in-depth application.

Acknowledgments
This work was supported by State grid Corporation of China headquarters science and technology project "research on key technologies and system research and application of electric energy replacement effect improvement based on electric energy service management platform" (YDB17201800128).

References
[1] SU Sheng-xin. Fulfill grid social responsibilities to promote energy conservation and emission reduction[J]. Power DSM, 2012,14(3):1-4.
[2] XU A-yuan. State Grid Corporation promotes DSM long - term mechanism construction[J]. Power DSM, 2011,13(1):5-6.
[3] YANG Xiao-qin, LI Hua, CAO Xue-hua. Introduction of Electric Management System Reconstruction Scheme[J]. Building Electricity, 2010(2):46-48.
[4] FANG Li-li. Research and Implementation of Universal Service and Management Platform[D]. Beijing University of Posts and Telecommunications, 2013.

[5] ZHENG Hao, LI Jian. Design and Implementation of Integrated Data Platform for Whole-Process Management of Electric Energy[J]. Electric Power Information Technology, 2011, 9(10):80-83.

[6] ZENG Wen-qiu. Design and Implementation of the High Performance of Key Technologies of Service and Management Platform[D]. Zhejiang University, 2011.

[7] ZHOU Heng. Application of Siemens Energy Management System in Industry[J]. Electrical Technology of Intelligent Buildings, 2009(3):92-96.

[8] Serra H, Correia J, Gano A J. Domestic power consumption measurement and automatic home appliance detection[C]//IEEE International Workshop on Intelligent Signal Processing. Faro: Institute of Electrical and Electronics Computer Society, 2005:128-132.