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To Enhance Power Distribution Network Management of Local Power Service Enterprise by using Cloud Platform

Gang Xiong, Timo R. Nyberg, Pekka Hämäläinen, Xisong Dong, Yuan Liu, and Jiachen Hou

***Abstract*—The availability of new technologies in the areas of digital electronics, communications, internet, and computer technologies opens a door to build a smart grid, which can increase significantly the capacity, services and intelligence of power systems. This paper proposes a power distribution network management cloud platform based on Tekla Xpower. Proposed system can support the implementation of current power grid and/or the coming smart grid. Utilizing the existing computing and storage installations, cloud platform can integrate the existing resources to improve the computation and storage capacities, the data security of the entire system, and can increase application intelligence, service quality and decision-making capability as well. The four layer architecture of cloud platform is designed, and a pilot case study for DMS is provided.**

I. INTRODUCTION

THE availability of new technologies in the areas of digital electronics, communications, and computer technologies opens the door from power grid to smart grid. Smart grid enhances the whole power grid's ability for information collection, system integration, information analysis, data mining, and service providing. Smart grid strengthens the whole power grid's information content, classification management, and intelligence. Smart grid is the natural development trend of current power grid.

In China strong smart grid has some special difficulties and features of its own. China has massive amount of diverse users distributed on her vast territory, plenty of different equipment are being operated, and masses of data are being generated and gathered by different methods. Therefore, high capacity of storage and strong computing power are needed to support those IT systems for the extensive business and manufacturing processes, such as ERP (Enterprise Resource Planning), SCADA (Supervisory Control and Data Acquisition), and GIS (Geographic Information System), and CRM (Customer Relation Management). Smart grid's features demand the high efficacy, stability, security and reliability of those IT systems [1].

In the meantime, reliable two-way communication and computer technologies, large scale data warehousing and database management provide the necessary capabilities. To realize the concept a cloud platform can be introduced into the power system. By establishing the power system management cloud platform with the existing power equipments, and integrating the system's internal computing and storage capacity, it is possible to get rid of the traditional data storage and computing problems. This may boost the data processing capacity and increase the efficiency through increasing the utilization rate. I can improve the security and reliability, too.

This paper introduces a comprehensive concept of smart grid and cloud computing and integrated aspects to solve the problems of the existing power grid and the coming smart grid with the advantages of cloud computing. The power distribution network management requirements for local power service enterprise, the responsible cloud platform tool to accomplish the task, and its operational issues leading to the intended results, are discussed. How the cloud platform architecture should be designed with TEKLA Xpower [2] system to support smart grid cloud platform are discussed as well. In addition, the cloud platform architecture may be applied into particular smart grid domains, such as DMS (Distribution Management System), EMS (Energy Management System), etc. that can be integrated with the data collection or perform control actions in the power system.

The rest of the paper is organized as follows: Section II presents the background of smart grid and cloud platform. Section III introduces the cloud platform architecture based on Xpower system for power grid and smart grid. Section IV pilots a case study concerning DMS cloud. Conclusions are drawn out in Section V.

II. BACKGROUND

A. Why Smart Grid

Smart grid is basically overlaying the physical power system with an information system which links a variety of equipments and assets together with sensors and actuators to form a service platform. It allows the utility and consumers to constantly monitor and adjust their electricity usage. Based

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on the dynamic analysis of the electricity needs both from the provider and user side the operation management will be more intelligent, which can increase the capital investment efficiency. Tighter design limits and more optimal usage of power grid assets will be possible. In comparison with traditional power grid, smart grid consists of the integrated communication systems, advanced sensing and measurement infrastructure, decision support and human interfaces etc. [3]

The drivers for smart grid can be mainly in markets, environment, safety and power quality. There challenges are in; improving the efficiency of power investments, operation security, and reliability of power grid, to ensure power quality; improving the maintenance of power system; enhancing the service quality for users; and improving the power grid management level in China. For these issues, smart grid can become an ideal solution. [4]

According to research [5], there are several reasons why China need and want smart grid, such as higher quality/reliability of power grid for the fewer blackouts, and renewable power needs smart grid.

B. Why Cloud Platform

In this case the cloud platform is a whole dynamic computing system. It provides a mandatory application program environment, can deploy, allocate or reallocate computing resources dynamically, and monitor the usage of resources at all times. Generally cloud platform has a distributed foundation establishment to achieve efficient use of the IT system. Cloud platform collects the computing resources and manages them automatically. In the process of data analysis, it can integrate the history data and real time data to assure the collected information accuracy and provide more intelligent services for the users. The cloud platform not only collects the computer resource, but also provides a management mechanism and services for big numbers of users simultaneously. Cloud platform provides dependable and secure data storage center, provides increased possibility for internet application, provides inexpensive and flexible space for storing and managing data, provides powerful computing capacity for users to complete many kinds of computing application.

Based on the features and advantages of smart grid and cloud platform, cloud platform can be introduced into power system and smart grid to establish the power grid and smart grid cloud platform [6].

III. CLOUD PLATFORM SOLUTION BASED ON XPOWER FOR SMART GRID

A. General Description

From the advanced experience of development and application, Tekla corporation's Xpower systems give us a better enlightenment on smart grid.

Tekla Xpower is a Network Information System (NIS) designed for operational asset management of energy utilities (both electricity distribution, and district heating and cooling). The Tekla Xpower system consists of a data model, database and configurable set of applications and functionalities. Tekla Xpower has following benefits for the operational asset management of energy utilities: [7]

- Tekla Xpower is a all-in-one solution that offers the functionalities needed to manage the energy networks. It provides fast, easy and low-risk implementation without extensive development needs.
- Tekla Xpower is designed to serve the needs of energy utilities in all processes during the entire lifecycle of the network. Utilities can improve their processes and plan, maintain, and operate networks and provide 24-hour services to customers.
- The database is based on a product model. All the network objects are stored in the database as individual objects. Any updates need only be applied to one object. Graphics, maps and other output information is automatically generated from the updated object data and is always up-to-date. [8]

Tekla actively develops functionalities which can be used to control smart electricity networks, and allow the utilization of information obtained from these.

B. Cloud Platform Architecture for Smart Grid

Combined with Xpower system experience, this paper

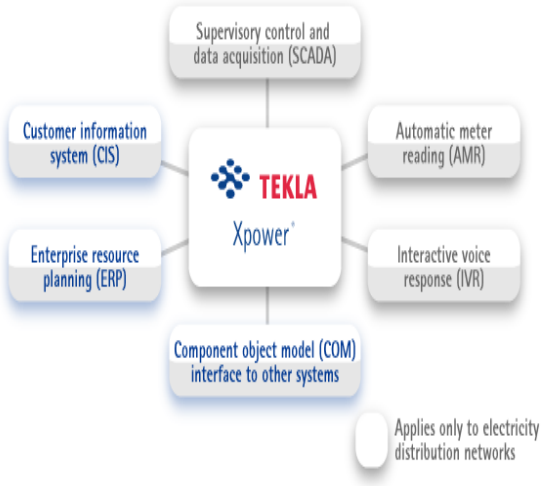

Figure 1 Tekla Xpower architecture

designs a cloud platform architecture for smart grid, i.e. smart grid cloud.

Smart grid cloud could automatically splits big calculations into small computing blocks through the power system's internal network, then submits those data to complex system composed with different servers to process computational analysis, afterwards sends the returned computing results to the users. By virtue of smart grid cloud, massive data can be processed in short time, to achieve good service quality and speed provided typically only by supercomputers. Smart grid cloud switches solo smart node computing to a smart node network computing, letting the cloud to process the computing request. Computing capacity for a particular node or computer can be obtained from smart grid cloud, and the whole system's computing capacities would be greatly

improved. Currently, different power grid levels have processor and storage resources of their own, smart grid clouds' advantage is that the power system's information networks could be optimally utilized, and the existing computers assigned to computing and storage resources for current tasks.

In China existing power grids distribute in different regions with different features and have different networks topology. The grid's electric features cut the whole grid into different subnets. Different subnets have their own centers to take responsibility of the distribution, processing, monitoring, protection and marketing of power grid, and have all circumstantial data concerning the centers. Each center has established its detailed power system model within the jurisdiction, but often different from its adjacent subnet models. Optimizing the operations will be a challenge, but process simulations based on these diverse models can give a picture how the different systems may work together. The cloud platform may help to avoid some problems concerning data collection, and reduce the system simulation complexity. By the smart grid cloud the problem could be solved perfectly. China could establish the smart grid cloud by utilizing mostly the existing physical equipments. [9]

Utilizing Xpower's various application modules, the architecture integrates different power system analysis and management functions including SCADA, DMS, GIS, CRM, PSA (Probabilistic Risk Assessment) etc., covering the power grid's full life cycle.

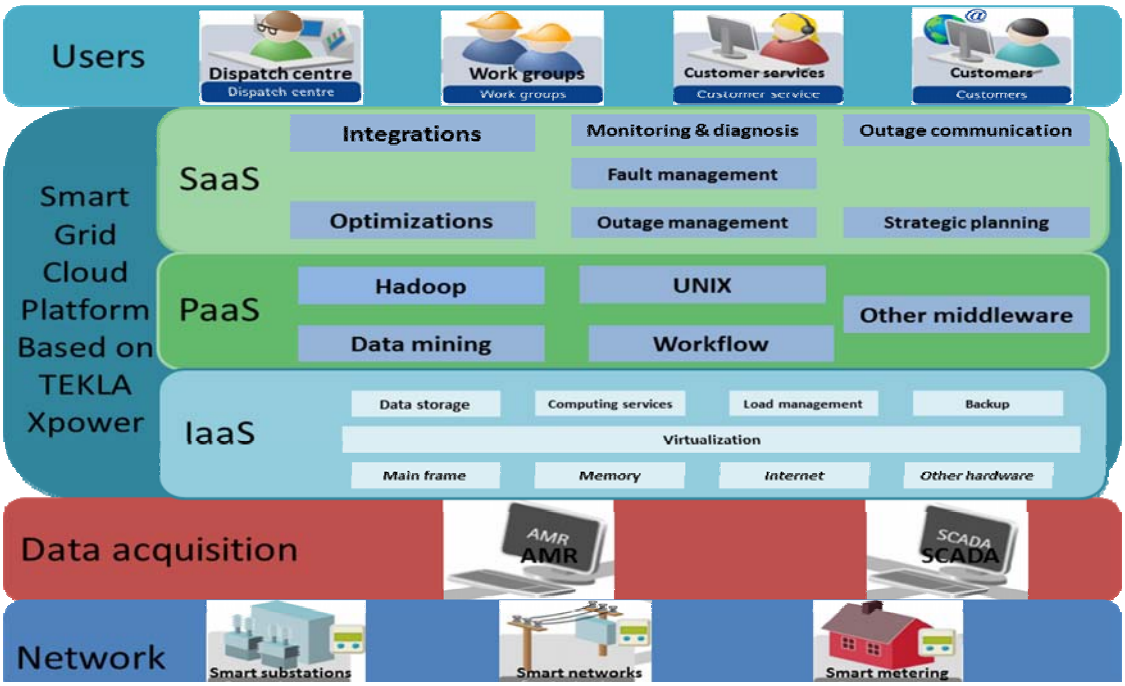

Figure 2 The Smart Grid Cloud Architecture

The cloud platform architecture of smart grid can be described as following:

- Network level: the network level is smart grid's physical level which includes some equipment, such as substations, networks and metering.
- Data acquisition level: this level has the functions to collect the power grid data in real time. It has modules like AMR (Automatic Meter Reading) and SCADA (Supervisory Control and Data Acquisition).
- Cloud level: this level is the core of the whole system, where cloud computing is combined with Xpower system.

This smart grid cloud provides integrated services of several layers, not a single level service. On the layer of IaaS (Infrastructure as a Service), the service of hardware (server, storage and network) and its associated software (operating systems virtualization technology, file system) are delivered. It is an evolution of traditional hosting that does not require long term commitment, and allows users to use the infrastructure resources on demand. By using the virtualization technology, infrastructure resources are provisioned, and the machine images packaged with software configurations are deployed across the infrastructure. In the illustrated scenario, the system would still have to deploy the entire traditional platform components like the operating system, database engine etc. which are required by the applications. The applications can be designed to interface with these components directly.

On the layer of PaaS (Platform as a Service), an application development and deployment platform can be delivered as a service. This platform consists of infrastructure software, which typically includes a database, middleware and development tools. Normally, a virtualized and clustered grid computing architecture is the basis for this infrastructure software. The independence of specific vendor's cloud ware is the driving force to establish the standards for cloud computing.

The application would be built to function on the platform's

"compute" infrastructure and interface with the platform's relational storage service or other APIs. One of the key technical tools is Apache Hadoop, which is a open-source software framework that supports the data-intensive and distributed applications. It enables applications to work with thousands of nodes and petabytes of data.

On the layer of SaaS (Software as a Service), business applications can be provided as service, e.g. custom software and simulation models are installed there. SaaS provides complete applications, or customizable application within limits, to solve the specific business needs, which focus on end-user requirements. The management of the underlying architecture is the core responsibility of the service providers. In this sense, SaaS is not an architectural design concept, but a business model. In the illustrated scenario the application can use the functionality provided by the smart grid cloud without regarding its underlying architecture. This part has some features: [10]

- Utilize the metering and status information obtained from the network, to analyze the network state, optimize the network usage, and improve the quality of electricity distribution.
- Real-time integration with smart network components and other subsystems.
- Support the distributed production by controlling and utilizing its related network components for the network planning.

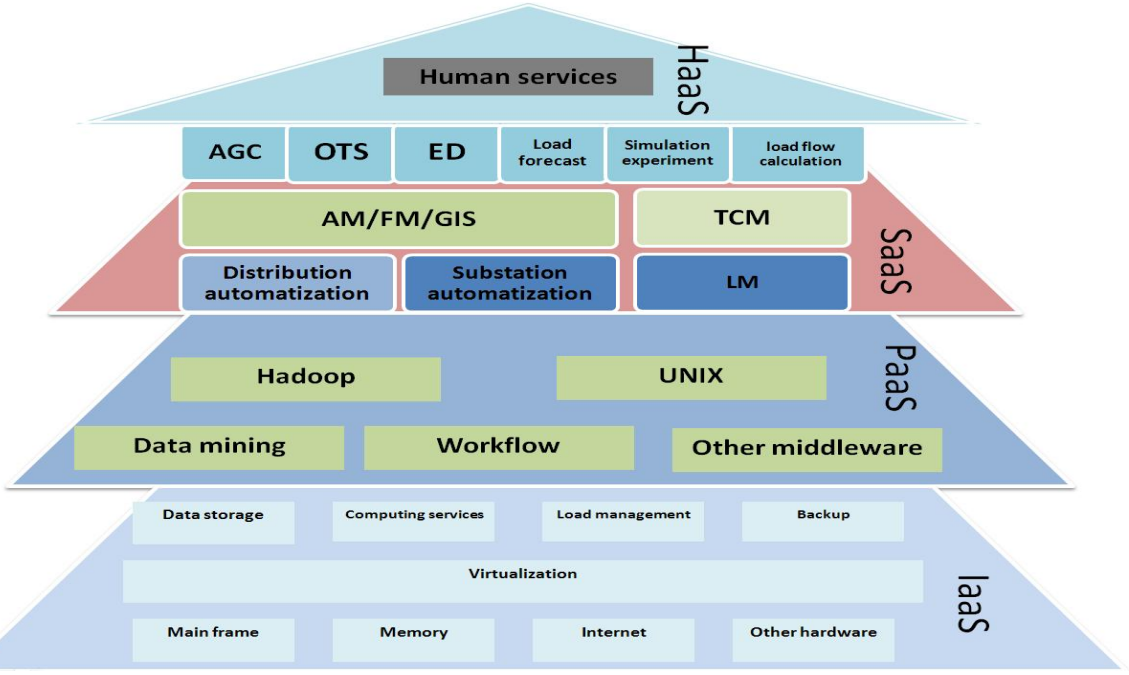

Figure 3 DMS Cloud Architecture has four levels

- Improve the information quality and up-to-date information services for control room staff, work groups, customer service and customers.
- Support the network assets control for planning, documentation, operation, maintenance, and reporting.
- The switching state of the network can be shown and controlled on several voltage levels.

C. *Virtue Analysis of the Cloud Platform Architecture*

1) *Expansibility, scalability and economy.* No matter how small the node or computer terminal is, it should distribute the monitors, hard disk, CPU, memory, etc. Its performance must satisfy the computing and storage demands. Using this architecture, merely little physical equipments need to be connected with the power system wide network. Various computing and storage functions can be processed according to the users' permission. The equipment replacement problem will be less critical. The power system can have satisfactory expansibility, scalability, and economy on information protocol level.

2) *Powerful computing and storage capacity.* This architecture distributes all nodes, computing, and data in large grid computers. Massive amount of computers provides large computing capacities for the cloud platform. Especially for Chinese huge power grid scale and system data, the cloud platform can provide the more powerful computing and storage capacity.

3) *System data security*. In this architecture, data storage can be centrally managed, so it is convenient for security monitoring. Especially, high security level data like power system internal management can execute the unified management, resources distribution, load balancing, software deployment, control security and security monitor in real-time. This helps to optimize data security and data usage.

4) *Computing and storage virtualization.* The virtualization is the technical basement of the cloud platform architecture. It can establish a large power system resource pools through virtualization all physical hardware including CPU, memory and hard disk in the whole

system.

5) *Power system intelligence*. Due to the cloud platform, massive amount of data could be mined to gain the core knowledge. Many operations could be optimized as well.

6) *System integration*. All the power grid functions and equipments can be integrated into one platform, which is convenient for system and operation optimization.

IV. Pilot Case Study of DMS

The cloud platform architecture can be piloted in DMS (Distribution Management System) [11]. The DMS is a comprehensive application system targeted for the realization of universal system functions, including distribution network dispatching, manufacturing and management services. The distribution management functions consist of SCADA, DA (Distribution Automation System), GIS, video monitoring, and distribution power application software, and so on. Due to DMS's features, the cloud platform can be combined with DMS to form a DMS cloud, which can support DMS's massive data computing and storage requirement. The DMS cloud architecture has four levels：

The first level is IaaS, and the second level is PaaS. These two levels have the same construction and theory. No detailed description is given here.

The third level is SaaS, including DMS's various functions, such as Automated Mapping, Facilities Management, and Geographic Information Management, etc. The computing and storage of these functions are connected to the DMS cloud through various protocols. [13]

The fourth level is HaaS, which means Human resources as a Service because the staff work is a service too.

By the object modeling, software reuse, high-speed internet, and operation system technique etc., and by embodying software bus concepts it is possible to achieve plug and play software domains. It is possible to satisfy DMS cloud's real-time, reliability, and high performance request; solve heterogeneous systems communication; and satisfy data processing needs. Realizing the seamless connection among equipment and data is convenient for maintenance and it will increase work efficiency. [12]

The cloud platform architecture can be extended and applied into other functions such as EMS (Energy Management System), CIS (Customer Information System) etc. in the distributed power grid. It could be popularized to other domain of smart grid like transmission grid, generation grid, and so on. [13]

V. Conclusion

In the smart grid information and decision making superiority is the basement and precondition for stable and reliable operation. This superiority depends much on the process speed and accuracy of massive data collection, data processing and data mining. The smart grid cloud described in the paper will fundamentally change the whole power grid's communication, computing and storage. By dint of the smart grid cloud, the computing and storage capacities can be optimally used, and the overall performance will be increased by using the existing equipments. Information and decision-making superiority can be achieved. To sum up, this proposed solution can provide a powerful technique to support the smart grid's realization and exploitation.

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