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Design of Intensive State Monitoring and Evaluation Station System for Large-scale Power Data

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Abstract. Combined with engineering application practices, we plan to collect dynamic data from various types of substation equipment, so as to implement an intensive state warning and diagnose system that faces the whole power grid in a province. In order to solve the problems of data exchange and application integration, we implement a hierarchical model in the J2EE framework. Then, based on a common information model, we construct a service-oriented and province-level state monitoring and evaluation station system. Practical applications show that the platform's operation is stable, and the number of advanced applications in the platform keeps increasing. The platform can operate under heterogeneous grids, and the data exchange compatibility among different sub-systems is good.

1. Introduction

State warning and diagnosis technology for power transmission and transformation equipment is one of the key technologies in the first defense system for preventing power grid accidents [1]. It also is a key factor to implement smart grids. Now, a standardized and uniform state monitoring and evaluation station system (platform) that can monitor the power equipment widely distributed in a province is urgently needed. The platform should satisfy the requirement of full-view state information monitoring and sharing in smart grids in the future. Moreover, the platform should be an integrated management system that can provide streamline management for power equipment in the whole province. The platform should benefit to improve safety and stability for equipment operation.

Existing research on the state warning and diagnosis technology mainly focused on single equipment. Since there are a large number of different types of single equipment, the numbers of kinds of state warning and correlated targets are very large. Therefore, some problems such as information is too dispersive, management is too complex, etc., often appear in traditional state monitoring and evaluation station systems [2-4]. Moreover, with the increase of the numbers of advanced application and upgrade of the system, some problems that correlated to the heterogeneity of the platform would happen, including: (1) Heterogeneous communication networks. Several networks that adopt different communication and networking technologies are combined in the platform. (2) Heterogeneous advanced applications. Data standards of some third-party applications are different. (3) Heterogeneous data format. In the platform, different sub-systems may use different incompatible formats to store data. Since the heterogeneous problems would hinder the data sharing and exchanging in a state monitoring and evaluation station system, high-quality analyses and decisions for equipment operations are difficult to make. Therefore, we should construct a reliable, uniform platform that can implement fluently data exchange and sharing to perform high-quality state monitoring and evaluation.

In this paper, a J2EE-based platform is constructed by using hierarchical model, common information model (CIM) and service-oriented architecture (SOA). The platform is reliable, uniform, and it can support fluent data exchange and sharing, and it can implement high-quality state monitoring and evaluation on power equipment in the whole province.

2. Construction objective

According to the requirements of production business and development tendency of state monitoring, province-level state monitoring and evaluation station system should conduct central monitoring on all the equipment. Moreover, it should provide safety monitoring and evaluation for important equipment in the grid. It can provide information support for decision makings in equipment operations.

The platform faces all kinds of power equipment, and provides multiple warning technologies and data types, so as to construct a multiple-dimension and real-time state warning system for the whole power grid. The platform also collects data from different online monitoring systems, production management information systems, so as to implement intensive diagnosis and analysis for the equipment. At the same time, users can visit the platform from Internet, and monitor their equipment's states. By this way, they can get the state warning and diagnosis information of their equipment in time, and equipment's maintain level is improved effectively.

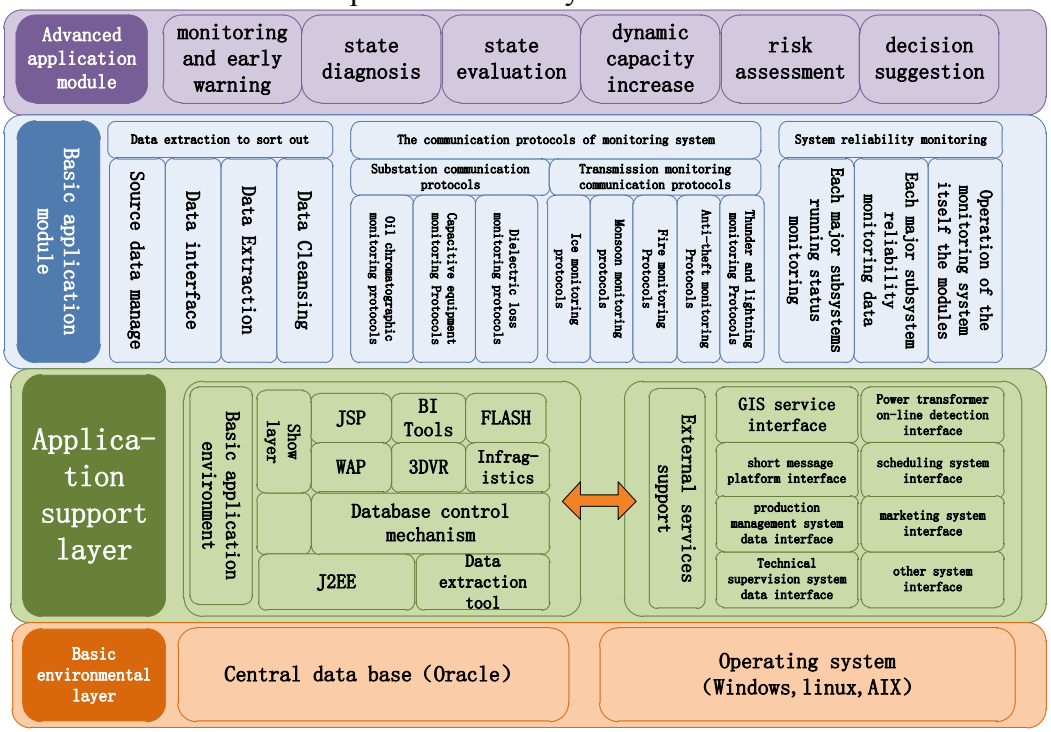

Figure 1. Hierarchical architecture of the platform

3. System architecture design

3.1 Design principle

The platform should collect all data from important transmission and transformation equipment in the whole province, and implement advanced functions such as state warning, analysis and fault diagnosis.

3.2 Overall architecture

J2EE is an architecture that is widely used in distributed enterprise applications, which is developed from the component technology and distributed computing [5-6]. In this paper, the designed platform is based on the J2EE architecture. It follows the idea of "tight coupling system integration, and loose coupling sub-system construction", and defines different components, service architectures and technology layers in the system. The idea is helpful to solve the heterogeneity problems in the platform.

We adopt a conception that the platform should be separated with the applications in the SOA architecture, in which data models are based on CIM and advanced applications are based on components. We also use extensible markup language (XML), resource description framework (RDF)

and Web Service to construct a basic data service platform to support multiple applications' plug and play function and add-on functions' development

In the layered architecture of J2EE, we add a business logic service layer between the data persistence layer and the Web application layer, so as to decrease the coupling degree of the layers as much as possible. In the Web application layer, an open-source architecture Spring that obeys the idea of model view controller (MVC) is used to construct a Browser/Server application architecture.

3.3 Application functions

Different application programs can be divided into different components according to their functions, and the components can constitute different J2EE functional application modules distributed on different hardware platforms. The functional application modules can be classified into 2 categories: basic applications and advanced applications, as shown in Figure 1.

In Figure 1, the basic applications include data extraction from business systems, communication protocols for real-time monitoring systems, monitoring of system reliability, etc. The advanced applications include monitoring and early warning, analysis and diagnosis, state evaluation, risk assessment, dynamic capacity expansion, overhauling strategies, knowledge base, etc.

3.4 Data collection

In order to satisfy the need of state early warning for the whole grid, the platform uses a front-end system protocol conversion software to collect state information of existing state monitoring systems. For the new online monitoring systems that support IEC61850 protocols, station-end state information will be sent to the server of the platform directly.

Moreover, in order to implement multi-dimension early warning and intensive diagnosis, the platform collects data from some existing business systems including production management information system (production MIS), technical supervision system, aid decision making system, and SCADA system, etc.

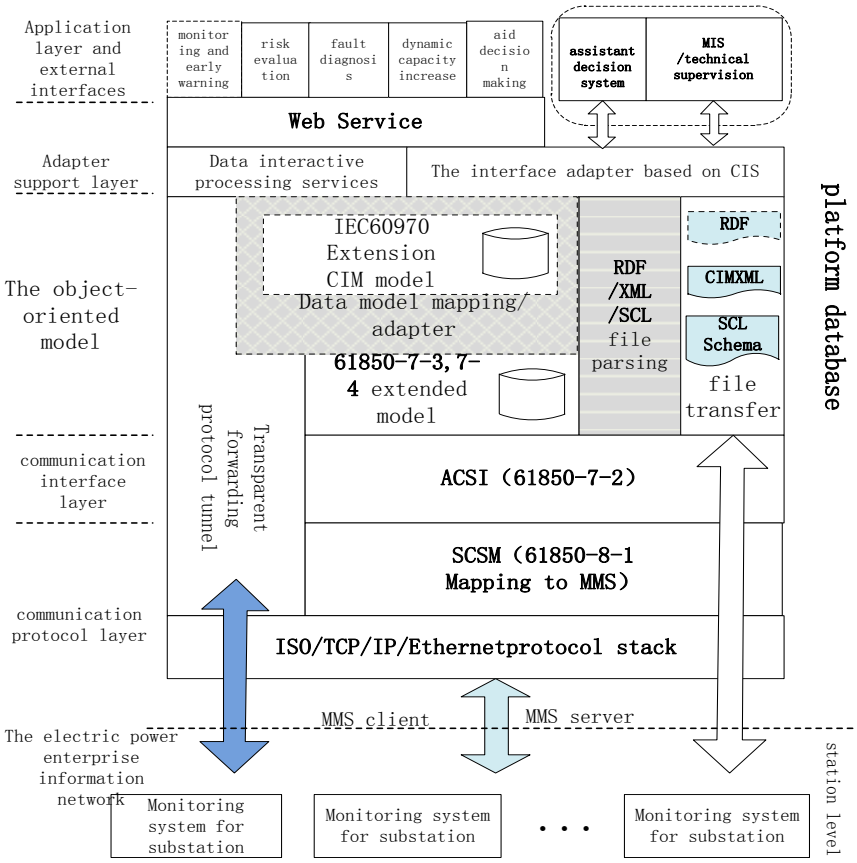

Figure 2. Data exchange interfaces among different systems

4. System integration and interfaces

Since the real-time information of power grid operation is becoming more and more standard and digital [7-9], the platform application program interfaces obeys the IEC61968 protocols, which are international standard protocols for system interface interaction. IEC61968 protocols support interaction of application systems such as data collection and monitoring, geographical information, etc. On the other hand, the platform application program interfaces also obey the IEC61850 protocols, which provide standard interfaces for application programs used in substation, i.e., they can be used for collecting data from different business systems among different substations.

4.1 Architecture of system integration

The key of the integration architecture is to satisfy the requirements of data exchange among the platform and other systems. The requirements include: (1) The integration should be based on the SOA architecture to implement publication and subscription of related models, figures and data. Moreover, information exchanging and service sharing among the platform and other systems should be achieved. (2) Information exchanging should obey the principles of unique topology model, data sources and maintenance, uniform equipment coding and descriptions. (3) The information exchange bus should satisfy the safety and defense rules of power secondary system. Moreover, it has the ability to across physical isolating devices to visit the region of production control and the region of management information from both the straight side and the reverse side. (4) The platform has MMS communication ability that satisfies IEC61850. The data exchange interfaces among different systems are shown in Figure 2.

4.2 Interface of data center for equipment

A province-level state warning platform always faces with the problem of heterogeneous data communication, which makes the sharing of equipment's state data become difficult and hinders the platform to achieve effective and intensive diagnosis and analysis. In order to solve this problem, we construct a data center with transformation components for the equipment. The data center can implement uniform code mapping and model transformation, and achieve synchronization and sharing for the data stored in the data center by using event notification mechanisms and timing mechanisms. Detailed data types include: offline experiment data, scheduling data in SCADA system, data of production MIS, data in the aid decision making system for state evaluation and risk evaluation. The communication interfaces are shown in Figure 3.

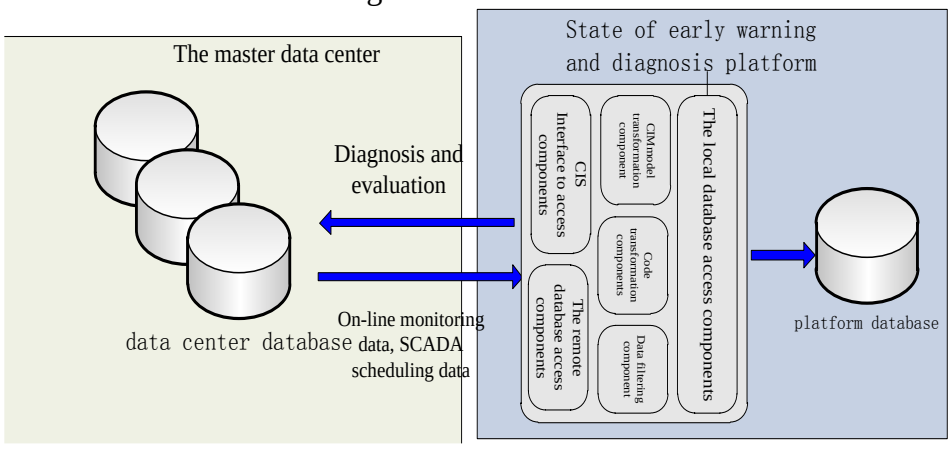

Figure 3. Communication interfaces between the data center and the platform

4.3 Interfaces of online monitoring systems

The data of online monitoring systems is the most important constituent part for basic data of the platform, which is used to realize multi-dimension real-time early warning. We designed new communication protocols of online monitoring data and data format standard of online monitoring atlas data for the platform. Therefore, the platform can collect information such as monitoring devices, monitoring types, monitoring data, alarm events information and statistics data. We list some monitoring data as example, as shown in Table 1 and Table 2.

Table 1. Transformer monitoring information

Monitoring categories	Monitoring content
Chromatographic micro water	Water content in oil of gases dissolved in transformer oil
Partial discharge	Partial discharge
Bushing insulator	Dielectric loss, the equivalent capacitance and the screen at the end of the current
Work condition information	Core earth current, the gas relay status, the main tank oil level and oil level state, OLTC tank oil level and oil level state, pressure relief devices
Cooling unit	Cooler fan and pump running state, cooler fan and pump motor drive current and voltage, cooler fan and accumulative running time of the oil pump, cooler, intelligent control, environmental temperature and humidity, load current and voltage transformer, the bottom of the top oil temperature, oil temperature, winding
On-load switch	Contact position and contact wear condition, the motor drive current and voltage, protective relay status, filter oil machine running status, OLTC online intelligent control

Table 2. Breaker monitoring information

Monitoring category	Monitoring ontent
Partial discharge	Discharge position, discharge, discharge type
SF6 gas	Temperature, pressure, density, water
Behavior of circuit breaker	Energy storage and working current of the motor start times, contact the breaking a main current, switching line current, arc time, such as circuit breaker electrical life
Lightning arrester characteristics	Leakage current and resistance current, action
GIS room SF6	SF6 concentration, $_2$ concentration
Switchgear O3 content	O_3 concentration

4.4 Interfaces of advanced applications

The platform support software takes different kinds of standard and uniform data exchange service interfaces as SOA services, and provide them to other advanced application software, according to the CIM/CIS information standards. This mode benefits the extension of advanced application functional modules in the platform, and is easy to adapt to different heterogeneous networks in third-party advanced applications. Interfaces of advanced applications are shown in Figure 4.

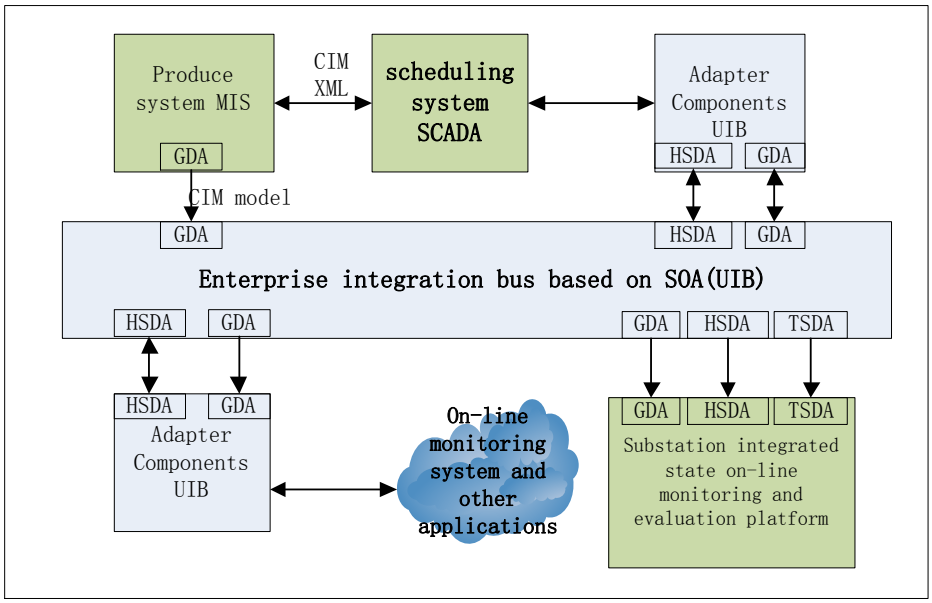

Figure 4. Interfaces of advanced applications

4.5 Interfaces of data input

The basic data that needs manual entry include structured data and unstructured data. These data should be inputted through human-machine interface.

For the structured data, we set up data analysis rules or use regular expression to analyze the data, according to the data's features. Moreover, equipment codes are connected with the equipment after verification. The verification mode and equipment codes connection include 2 patterns: automatic pattern and manual pattern.

For the unstructured data, they are connected with the equipment and are integrated into the equipment data model by manual matching, according to different data format, e.g., text, figure and video, etc. The connection relationship will be saved as structured data.

4.6 Coding system

The coding principle is to consider factors such as uniqueness, adaptability, scalability and usability. The coding method is in accordance with the coding rules of the production MIS, including parameter coding of equipment account, coding of equipment state and coding of equipment state values.

Based on this principle, we will construct an adaptive and unique coding system that contains data access layer, model driven layer and coding layer. At the same time, we will classify our coding objects into 3 types: enumerated type, hierarchical relation type and topology relation type [10], based on the CIM model and according to equipment's hierarchical relations and application requirements. The coding system can be used to perform detailed functions, such as establishing coding database and system model, defining rules, verifying codes and upgrading models, etc.

An integrated coding model can avoid the heterogeneity of data format in practical applications, and adapt to the development tendency of state early warning. It benefits the platform to connect and transplant with other business systems when the platform is put into working. Moreover, it benefits latter maintenance of the platform.

5. Data exchanging model

In order to implement the modularization and opening of the platform, we adopt the CIM model when we develop the platform. The platform contains comparative independent advanced application modules. However, the difficulty of implementing the modules is large. Moreover, we need to develop specialized interfaces in the platform to get discrete data such as power grid's parameters, topological relation, real-time parameters, which are needed by the modules. At the same time, different modules would exchange data with each other, which will improve the difficulties of secondary development

and maintenance. Therefore, we design a CIM-based support platform in the process of development, which provides convenience for the modules to implement their plug and play (modularization) functions. By this way, the problems of data disperse and platform heterogeneity can be solved.

5.1 Common information model (CIM)

Currently, since CIM can be used to standardize data of application software, it has been taken as a basic common information model in practical applications of electrical power system [11-12]. Our platform obeys the IEC61970 CIM standard, and performs extension on CIM according to the requirements of power equipment's state warning and diagnosis. We construct a uniform model for data of multiple business systems, including equipment's basic data, online monitoring data, experiment data, faults data and equipment's state data, etc. At the same time, the platform provides input/output tools for CIM, which support effective data exchange among CIM XML/RDF files of outer systems.

Uniform state monitoring data model integrates different parts of IEC 61968/61970 standard's CIM model with correlated parts of IEC 61850 model. By this way, it provides an equipment's integrated data view for different applications in the system and applications in other systems, as shown in Figure 5.

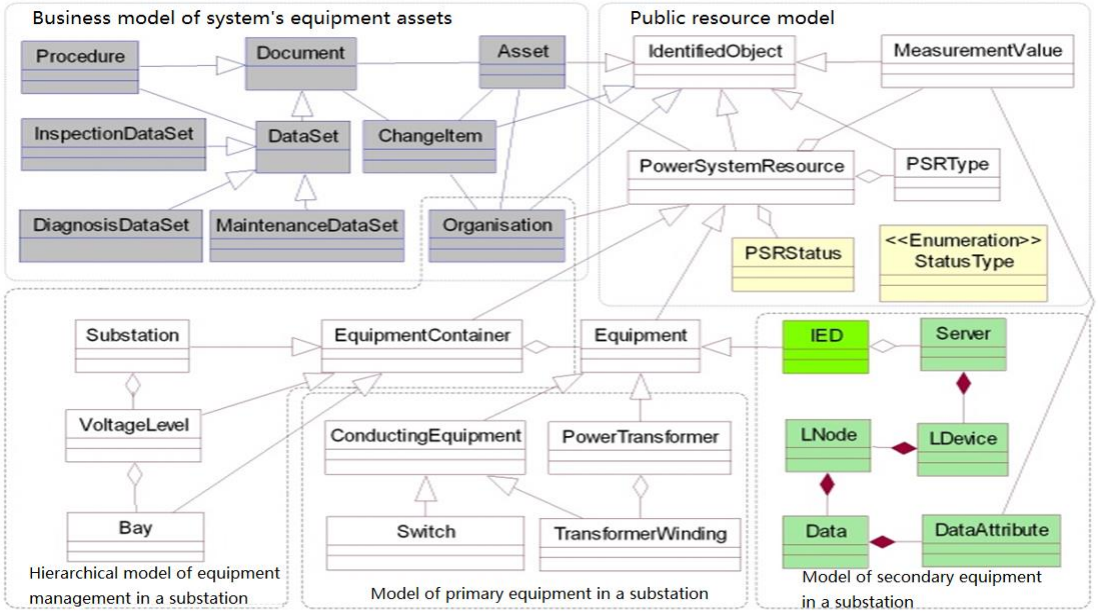

Fig.5 Equipment's integrated data view

5.2 Interaction of system's pixels

Since scalable vector graphics (SVG) are based on XML format, they have the adaptation and scalability to support cross-platform applications. SVG have been taken as the main graph standard in electrical power system [13-14]. The sizes of SVG files are smaller than that of the GIF and JPEG files. The SVG files are executed at the platform's WEB server and Client ends, which benefits to take full advantage of user's work stations' resource and reduce the server's burden. The network bottleneck problem can be solved when data demonstration, exchange and monitoring are performed for the equipment in a province-level power grid. Moreover, since SVG is an explanatory language, the platform also has the following advantages as it uses graph factors as the main data exchange form: (1) The visualization and data storage are decoupled. (2) Multiple expressions of each domain object are easier to be implemented. Graph objects will be integrated into a graph naturally. (3) The number of backgrounds in a graph would easier to be increased.

5.3 Simple object access protocol (SOAP)

The CIM data model used the platform is described by CIM XML/RDF, and it uses HTTP in SOAP to transmit XML. Since XML is an open, perfect and semantic messaging mechanism, and HTTP is widely used and has the ability to avoid a lot of firewall problems, SOAP based CIM model

has the benefit to conquer information barriers among multiple business systems. Moreover, it also benefits users to operate the platform by using WEB mode.

5.4 CIM model based database

Relational databases are the most popular database in business applications. They have features such as good openness and full functions, which benefit the system's development and stable operation. Moreover, it has an advantage of giving consideration to data portability and consistency by establishing a mapping between the object-orient CIM model and relational database when uses rational database to store CIM data. Based on the above 2 reasons, the platform uses typical relational database to store CIM data.

6. Conclusion

The platform operates stably after it is put into operation. Users of the power grid give a feedback that the platform improved the information use ratio effectively since it can integrate useful information from different business systems. Moreover, its analysis results are accurate and its application functions satisfy practical needs.

On the other hand, the platform constructs a hierarchy architecture based on J2EE and implements data exchange based on CIM model to solve the problems of platform heterogeneity, effective data access and sharing. As a result, the platform has the ability to perform multi-dimension analysis and intensive diagnosis.

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