Research on System Development and Application of Electrical Equipment Intelligent IoT Platform

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Abstract. With the increasingly development of the new information and communication technologies, China has proposed the integration of new information technology, electrical equipment, and intelligent Internet of Thing (IoT) system to accelerate the innovative development of the manufacturing industry. However, the information isolation and data scattering cause the poor services of electrical equipment. Aiming at the question, the preliminary construction of electrical equipment intelligent IoT Platform (EIP) is carried out in this article through system analysis and system design, which helps enterprises to improve the quality of manufacturing, realizing the transformation and upgrading and healthy development of the enterprise. At the same time, through the accumulation of heavy and complicated IoT big data, the quality evaluation and total life cycle management of electrical equipment are strongly supported to enhance the level of supply chain operations management, which lays a more solid foundation for the electrical equipment manufacturing industry to enhance the core competitiveness and for China to accelerate the realization of high-quality development by the intelligent manufacturing.

Keywords: Electrical equipment, intelligent IoT platform, smart manufacturing, system analysis, system design.

1. Introduction
In recent years, the next-generation of information and communication technologies represented by cloud computing, big data, Internet of Things (IoTs), mobile Internet, and artificial intelligence have come increasingly wide use in the construction of Energy Internet. As the implementation of Energy Internet, the synchronous development of strong smart grid and Ubiquitous Power Internet of Thing (UPIoT) is the new type of business with the deep integration of these new technologies and the energy industry, which is an important cornerstone for promoting the transformation and upgrading of the smart electricity and the real economy [1]. In order to accelerate the innovative development of the manufacturing industry and realize the transformation from a major manufacturer to a strong one, China has proposed the integrated development of next-generation information technology, electrical equipment, and intelligent IoT system [2], which requires the application of advanced technologies to build the intelligent supply chain.

At present, most of China's electric enterprises have realized the whole digital process of material business, and have relevant intelligent application functions. In addition, most of the electrical equipment suppliers have also greatly improved their digital and intelligent manufacturing standard. However, there still exist some defects during the process of equipment supply. On the one hand, due to the lack of effective data exchange channels, the electrical equipment enterprises fail to accurately
acquire the process information such as supply capacity, production schedule, manufacturing quality, etc. from the suppliers, so it is necessary to send a large number of experts and staff to track process regularly, resulting in unnecessary cost problems [3]. On the other hand, the suppliers cannot timely obtain the feedback on demand changes, as well as the information of the delivery time, production and operation, fault handling, etc., which means that the suppliers are unable to provide satisfactory services [4]. Therefore, it is of great significance and urgently needed to rely on an information platform to open up the information sharing channel between the supply side and the demand side for improving the energy efficiency of the production of electrical equipment, which is the key to promote the digital development in electric power industry.

By building the electrical equipment intelligence IoT platform (EIP), electrical equipment company and equipment organic connection, the testing data, equipment operation defect data timely feedback to the bidding procurement and production manufacturing, improving the quality of equipment procurement and production, from the source service provider equipment product quality promotion, power electrical equipment capacity upgrade, efficient development.

2. Literature Review

In terms of the architecture research and prototype research and demonstration application of EIP, the United States, Japan, Europe, South Korea and a few other countries started earlier and have a strong overall strength [5]. In 2008, IBM of the United States put forward the "Smart Earth" strategy, and in 2009, the EU put forward the ‘Internet of Things Action Plan’ [6]. The purpose is to use a variety of information technology means to break through the various restrictions of the Internet, to achieve the UPIoTs. The United States emphasizes the use of sensors and other sensing technologies to build an intelligent infrastructure, while the European Union mainly carries out the wide use of RFID and pays attention to information security [7]. With the increasingly widespread application of RFID technology, its distributed characteristics are combined with the large flow of processing, and the design of the technical architecture of the intelligent Internet of Things platform for electrical equipment, as well as the specification of the architectural requirements, function Settings, integration methods, system deployment and other requirements of each construction component have become the top priority of the research. Li and Wang [8] proposed a new smart city service management and application development platform, based on which different people can collaborate and make contributions, such as demand acquisition and service development. Amine et al. [9] carried out a careful study on the overall framework of the environmental protection Internet of Things and the key technologies of intelligent environmental protection applications, and finally designed a new gateway software architecture of the environmental protection Internet of Things.

For the system development, there are relevant researches. Alvarez et al. [10] theoretically analyzed the building non-central information system, and makes a comprehensive and in-depth analysis and discussion on the feasibility of the system, the design of basic elements, the design of system architecture, the stability of system operation and the effectiveness of control decisions. Wu et al. [11] introduced the research status of electric power information system control from the present situation of electric power dispatching information and work requirement. Hao et al. [12] combined with the ability of SOA architecture of business process reengineering, puts forward a new kind of three-layer model as the core support fast, smooth, reusable application system development framework. Lin et al. [13] discussed the architecture and related technologies of the power dispatching integrated data platform, and proposes that the power dispatching integrated data platform is an information product, which can use modern information technology to calculate and analyze the power data, so as to get the final power consumption ratio.

In spite of the above researches, the majority of them mainly focuses on the design of the platform technology architecture, while there is a lack of research on the architectural requirements, function Settings, integration methods, system deployment and other aspects of the specification of each construction component. Therefore, it is urgent to conduct the in-depth research on the development of EIP to realize the intelligent management for the electrical equipment.
3. System Analysis

3.1. Target and Demand of the Platform

3.1.1. Overall target

The overall target of EIP is to achieve the efficient supervision and management on the 7 major categories and 20+ kinds of materials in the electric power industry by integrating all kinds of big data such as production data, test data, logistics data, etc., and conducting the module construction of IoT gateway, IoT management, and category center, so as to create the ‘transparent factory’ in the electrical equipment manufacturing industry. Therefore, based on the analysis of the demand positioning of EIP and the necessity and feasibility of its development, this article designs the system architecture and module composition of EIP, sorts out its business process and data process, and integrates multi-source heterogeneous data which is cross-systems through the thinking of "Internet +", so as to expand new business patterns driven by data.

3.1.2. Functional demands

Functional demand refers to the basic requirements that the system must provide users with specific operation in order to accomplish the target contents, which requires the system to possess the corresponding capabilities. According to the overall target, the functional demands of EIP should follow the following points.

1. Data control of electrical equipment in whole process. Efficient data control is an effective solution to manage equipment in an orderly way, which includes data acquisition, data synchronization, data processing, and data fidelity. This is the fundamental demand directly determining whether EIP can be used to its maximum effect.

2. Online business. Since the business of electrical equipment enterprises involves equipment manufacturing, logistics and transportation, product operation and maintenance, etc., the online business of EIP should cover the entire process which can be divided into three phases of production monitoring, logistics tracking, and after-sale services.

3. Combination between industry and finance. Equipment suppliers should be able to choose financing institutions independently and fill in the required information for the financing application by EIP to realize the close combination between industry and finance, which is conducive to the collaborative development of the material supply chain. It needs to be noted that EIP only acts as a role providing the links of financial institutions such as banks, trust institutions, and insurance institutions for suppliers to apply for financing rather than serving as a qualification guarantee institution.

3.1.3. Non-functional demands

Different from the functional demands, the non-functional demands are usually put forward to measure the performance and feature of a system, ensuring the stable and secure running. The concrete non-functional demands of EIP involve the system performance, system reliability, and system manageability, which are listed respectively in Tables 1 to 3.

According to Table 1 which gives the evaluation criteria and corresponding explanations on the system performance of non-functional demands, the multi-point flexible deployment is carried out for the databases by the way of library division and the application services are constructed by the distributed micro-service architecture, to speed up the running efficiency of EIP.

Table 2 shows the criteria and corresponding explanations on the system reliability of non-functional demands. In order to satisfy the above requirements, the distributed architecture ought to be applied to reduce the single point of failure, and the load balancing of services should be provided through the multi-node deployment of application servers. Furthermore, designing the local backup schemes and log monitoring reports will contribute more to the stability of EIP. And EIP must be able to run on all versions of operating systems and browsers which are popular currently.

The criteria and corresponding explanations on the system manageability of non-functional demands are listed in Table 3, which ensures the orderly organization of system data. EIP is designed around the
above target and demands.

**Table 1.** Non-functional demand of EIP on system performance.

| Criteria                          | Demand explanation                        | Target                                                                 |
|----------------------------------|-------------------------------------------|------------------------------------------------------------------------|
| **System capacity**              |                                           |                                                                        |
| Number of registered users       | 500 people during the early implement     |                                                                        |
| Maximum number of online users   | 100 people during the early implement     |                                                                        |
| Size of structured data          | 500 GB during the early implement         |                                                                        |
| Size of unstructured data        | 1 TB during the early implement           |                                                                        |
| Business throughput              | 50/minute during normal hours and 200/minute during rush hours |                                                                        |
| Growth forecast of business throughput (after three years) | 100/minute during normal hours and 500/minute during rush hours |                                                                        |
| **Average response time**        |                                           |                                                                        |
| Home page browse                 | ≤3s                                       |                                                                        |
| System login                     | ≤5s                                       |                                                                        |
| Comprehensive business execution | ≤8s                                       |                                                                        |
| Basic statistical statement query| ≤8s                                       |                                                                        |
| Monthly statistical statement query | ≤20s                                      |                                                                        |
| Yearly statistical statement query | ≤30s                                      |                                                                        |
| Tabular statement processing     | ≤20s                                      |                                                                        |
| Graphic statement processing     | ≤30s                                      |                                                                        |
| **Transaction failure rate**     |                                           |                                                                        |
| 2 hours of running time with the maximum online users | ≤0.1%                                     |                                                                        |
| 8 hours of running time with 40% of the maximum online users | ≤0.1%                                     |                                                                        |
| **Database and server performance** |                                        |                                                                        |
| Average CPU utility              | ≤80%                                      |                                                                        |
| Average memory utility           | ≤80%                                      |                                                                        |
| Network throughput per unit      | 5Mbps during normal hours and 20 Mbps during rush hours |                                                                        |

**Table 2.** Non-functional demand of EIP on system reliability.

| Criteria | Demand explanation |
|----------|--------------------|
| **Fault tolerance** | First, the code logic should be rigorous with all kinds of system exception processing to ensure that every method and process has exception handling statements. Second, the system transaction failure, communication failure, and other cases should be automatically identified and resolved to ensure the availability. Third, when EIP is abnormal, the data being manipulated by servers should be automatically stored into a temporary data table to realize the data protection and recovery. |
| **Robustness** | EIP should establish the protection mechanism under the condition of large concurrent or overloaded business to ensure the stable operation. For example, in the case of large concurrency, a single service node should be able to undertake 1/(N-2) of the maximum concurrency designed by the system with a service cluster of N nodes that the system can bear. |
| **Self-monitoring** | The system should be capable of self-monitoring, which can record, monitor, and alert the important processes and services such as running status, key operations, fault repair, etc., by providing the monitoring interfaces of related components. |
| **Compatibility** | A good compatibility of EIP with other systems should be available to support the respective business of different enterprises. For the C/S (Client/Server) architecture, the clients need to be compatible with the current mainstream Windows (Win 7, Win 8, and Win 10). For the B/S (Browser/Server) architecture, the browsers need to be compatible with the current mainstream IE, Chrome, Firefox covering the latest version and the previous versions. For the APP applications, the mobile devices need to be compatible with IOS and Android. |

**Table 3.** Non-functional demand of EIP on system manageability.

| Criteria | Demand explanation |
|----------|--------------------|
| **Log management** | EIP needs to be able to collect and query logs, including user behavior, system exception, and error information. |
| **Monitoring** | EIP should have the ability to manage the monitoring data, providing indicator data according to the |
management requirements of relevant interface standards to give the real-time feedback on system operation.

Audit management

EIP should standardize the business files and system files related to audit projects, including at least: business serial number, IP address, user information, operation time, specific operation content, operation result, etc.

Authority management

On the one hand, EIP should realize the authority management of internal employees through corresponding interfaces.

3.2. Development Necessity of the Platform

EIP is the core of supply chain management system with digital, networked, intelligent, and standardized characteristics, working on the basis of three business chains of intelligent procurement, digital logistics, and panoramic quality control, which is highly consistent with the decision and deployment to build the Energy Internet. As a significant part and the concrete embodiment in material department of the UPIoTs, on the one hand, the construction of EIP gives full play to the hub advantage of material resources coordination to promote the integration and interaction of resources, technology as well as information, and creates an open, equal, collaborative, and sharing supply chain management platform, realizing the improvement of quality and efficiency of material management and the reinforce of supply chain service capacity. On the other hand, EIP is constructed on the center of boosting the quality of purchase equipment with the implementation of smart business scenarios as the starting point, which promotes the construction of strong smart grid and UPIoTs to a certain degree, and consequently achieves the integration of internal business and the cooperation of external industries. In particular, the necessity to develop EIP can be described from the following aspects.

(1) In terms of the construction concept, EIP promotes the internal integration as well as the quality and efficiency of enterprises, drives the process of collaboration and in-depth cooperation for upstream and downstream industries, and realizes the collaboration and sharing of technologies, logistics and data resources, which is consistent with the strategic goal and development direction of the company.

(2) In terms of the construction method, intelligent operations such as intelligent procurement, digital logistics, and panoramic quality control are closely combined with novel information technologies and fresh practical applications to comprehensively improve the quality, efficiency, and benefits of traditional material management from the whole chain aspect, which is in line with the strategic path of the company.

(3) In terms of the construction effect, EIP enables the purchase equipment all interconnected, the supply chain data entirely connected, the business operations carried out online, and the enterprise resources whole shared. Accordingly, the quality of purchase equipment, the efficiency of procurement and supply, the service effect of users, the standard management level, and the value creation ability will all get comprehensively improved, which will strongly support the construction of UPIoTs.

(4) In terms of the existing platform construction, there are a fair number of systems to manage all kinds of information, however, only several of them are suitable for energy material supply with some defects. On the one hand, these systems cover the narrow categories of power materials and are applied to some kind of material as well as the corresponding supplier. On the other hand, the IoT management capability is not perfect enough to support the access of massive data, which consequently fails to realize the remote maintenance and intelligent management of the gateway. Therefore, it is necessary to develop a new platform to make up for the deficiencies of existing platforms by adding corresponding functions to raise the effectiveness and efficiency.

3.3. Development Feasibility of the Platform

3.3.1. Technical support

The information processing technology of intelligent IoT for electrical equipment and the key technology of coordination between edge agent and category center for electrical equipment can provide
technical support for the research on the architecture design and prototype development of EIP. The specific applied technologies can be listed as follows.

1. **Big data analysis technologies.** Big data as the popular conception in IT industry, is followed by data warehouse, data fusion, data mining, data security, and so on.

2. **Industrial big data management technologies.** This kind of technologies is used for the collection of diverse data, management of multimodal data, and writing of high-throughput data.

3. **Data security technologies.** By adopting the edge computing, applications are launched at the source of data to generate faster network service response and to converse some sensitive data through desensitization rules, which meets the basic needs of material industry for real-time business, application intelligence, as well as security and privacy protection.

### 3.3.2. Methodology basis

The methodology basis will provide more theoretical support for the construction of related models by EIP, laying a solid foundation for the power enterprises to accelerate the high-quality development. The specific methodologies can be listed as follows.

1. **Comprehensive evaluation theory.** Aiming at the objective evaluation of electrical equipment suppliers, it is necessary to use multi-attribute comprehensive evaluation theory to filtrate the core evaluation indicators, construct the evaluation system, and establish the data model, so as to provide the decision-making basis for electrical equipment enterprises.

2. **Typical scenario method.** In the design of system business process, the method can be adopted to start from a certain process, determine the business process by describing the path of business information, and finally traversal all information flow and business flow to complete the design of the entire system process.

3. **Statistical process control.** The method, through statistical analysis to find abnormal fluctuations caused by system factors and accidental factors in the production process for quality control, is a mathematical statistical method used in process control.

### 3.3.3. Application benefits

The research aims at accelerating the construction of intelligent IoT for electrical equipment and promoting the win-win development of energy industry chain through the development of EIP with which the market prospects are broad and the application benefits are considerable.

1. **Management benefits.** EIP integrates the information of the whole lifecycle in which the equipment is from manufacturing to operation then to scrap, scientifically evaluating the high-quality suppliers with strong quality assurance ability, high technological level, and timely service and accurately identifying the high-quality products with advanced technology, exquisite materials, and good environmental adaptability in the bidding evaluation, so as to improve the procurement management level.

2. **Economic benefits.** Aiming at the crucial business in the whole process of material procurement, EIP makes full use of advanced information technologies such as big data, artificial intelligence, edge computing, and so on to carry out the innovation and optimization of core business to achieve the more timeliness, better economy, and higher compliance during procurement.

3. **Social benefits.** By giving full play to the hub advantage and sharing value, EIP continuously expands the information sharing range of upstream and downstream enterprises in the material supply chain and improves the quality and efficiency of business operation driven by data, accelerating the realization of enterprise goals and promoting the implementation of company strategies.

### 4. System Design

#### 4.1. Overall Architecture Design

Relying on the basic infrastructures, EIP manages the mass data of electrical equipment for supporting
the business by integrating itself with the related systems. The overall architecture of EIP, which is divided into three parts, is depicted in Figure 1.

The cloud infrastructures are the necessary conditions of data acquisition, data transmission, data procession, and data storage, which requires the hardware support of sensor, transmission network, storage database, and computing device.

On this basis, EIP is designed for a six-layer architecture which reveals the infrastructure service layer, technology service layer, business service layer, business logic layer, application service layer, and application presentation layer from bottom to top.

Further, in order to support the six-layer architecture, relevant systems need to be integrated to complete the docking between functions and applications. These systems involve Supplier Production System (SPS), Supplier Data Acquisition Center (SDAC), Mobile Device Management Platform (MDMP), E-Commerce Platform (ECP), Intelligence Operation Center (IOC), Structured Storage Database (SSDB), Unstructured Storage Database (USDB), e-mail platform, Short Message Service Platform (SMSP), and Identity Security Center (ISC). MDMP, ECP, and IOC are connected through the Data Middle Platform (DMP) to finish the interaction between EIP and the systems, while the others are connected directly with EIP for the integrated applications.

4.2. Function Module Design

On the basis of the architecture design, the system functions of EIP are divided into three aspects of enterprise-oriented, supplier-oriented, and data-oriented. For electrical equipment enterprises, the function modules are designed for real-time online supervision, order monitoring in manufacturing, capacity allocation, and online support service. For suppliers, the function modules are designed for quality evaluation and supplier collaboration. For data management, the function modules are designed for data acquisition in factory side, IoT data integration, category management, and information and business fusion. The 10 function modules can be further subdivided into 37 function submodules, and the overall module design is depicted as Figure 2.

The division of above functional modules aims to improve the efficiency and effectiveness of the intelligence IoT management for electrical equipment to achieve the high-quality development in the industry.
4.3. Database Design

4.3.1. Data integration

According to the overall architecture, EIP is integrated with 10 external systems with the data integration process depicted in Figure 3.

Firstly, EIP is combined with ISC to realize the authority authentication of system users, during the period of which the external users log in EIP with the verification message by SMSP and the internal users log in EIP with the verification e-mail by e-mail platform. Secondly, users having logged in EIP acquires the production data, experiment data, and video data from SDAC. Meanwhile, integrating with SPS, EIP provides the purchase orders to equipment suppliers from which EIP receives the sales orders and production orders in return. Thirdly, through the intermediary agent of DMP, EIP acquires the order data, contract data, project data, etc. from ECP to achieve related functions such as order monitoring and capacity allocation, acquires the major supplier data from MDMP to track the logistics information,
and acquires the related evaluation data on equipment quality from IOC to support the improved services. Finally, all the data is stored in SSDB, which includes the structured data such as document, text, table, etc., and USDB, which includes the unstructured data and semi-structured data such as image, audio, video, etc., by classification for the flexible call of EIP.

4.3.2. Data logic model
EIP mainly involves three types of data which are respectively common business data, category management business data, and IoT management data. The logic model of common business data describes the relationship of data entities which are suppliers, orders, schedules, etc., as is shown in Figure 4.

![Figure 4. Logic model of common business data.](image)

The logic model of category management business data describes the relationship of data entities which are electrical equipment, orders, production and test data, etc., as is shown in Figure 5.

![Figure 5. Logic model of category management business data.](image)

5. Conclusion
With the increasingly development of the new information and communication technologies, China has proposed the integration of new information technology, electrical equipment, and intelligent IoT system to accelerate the innovative development of the manufacturing industry. However, the information isolation and data scattering cause the poor services of electrical equipment. Aiming at the question, the preliminary construction of EIP is carried out in this article, through system analysis and system design build platform, help enterprises to improve the quality of manufacturing, realizing the transformation and upgrading and healthy development of the enterprise to enhance the core competitiveness for the electrical equipment manufacturing industry.

The development prospect of EIP is very broad, and its constant upgrade and wide application contribute to the several benefits: (1) It solves the problem on standardized access of differentiated data in
equipment production. (2) It realizes the objective, scientific, and systematic quality evaluation of electrical equipment. (3) It builds a shared data security system of information interaction between Internet and Intranet and entity interconnection covering nearly ten thousand equipment suppliers. (4) It boosts the speed of data processing by realizing the calculation of mass data in the edge side. However, the construction of EIP is still in its preliminary stages, thus more technical and methodological breakthroughs are needed to improve the system, which is also the key research content in the future work.

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