New Design and Implementation of Power Distribution Network Management System

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***Abstract*—Due to the rapid development of the power grid, the number of power users has continued to increase, the scale and structure of the low-voltage distribution power system have become increasingly large and complex, Monolithic architecture systems can no longer handle complex applications, large amounts of data, and high concurrency. Therefore, we propose a new power distribution network management system(DNMS) based on the framework called Spring Boot+SSM. The DNMS system uses a front-end and back-end separation method. The front-end uses a Bootstrap framework and the back-end uses a combination of Spring Boot + SSM framework. This improves the efficiency of system development and enhances the scalability and maintainability of the system. Functionally, a load forecasting model is built through the LSTM model, analyzing the state of the power system, then helping us to control the distribution network better and provide early warning and risk assessment. The users-transformer relationship module is based on the relationship between the base and the coordinates in the linear space by using big data technology to help us identify the relationship between households and transformers to realize, then make better management.**

Keywords—Power distribution system, Distribution network management system, Data process, Relationship detection, Load forecasting.

I. INTRODUCTION

With the rapid development of social economy and the continuous advancement of power reform, the Chinese power industry has shown a good and rapid development trend. As people's higher requirements for power supply quality, the scale of distribution networks become more and more large and complex. Therefore, it is necessary to have better management for the power distribution system.

Most distribution network management systems(DNMS) are implemented by using a single architecture. The traditional monolithic architecture integrates all functions of presentation layers, business logic layers, data access layers, and static resources into one project. As business systems become more complex and more functional, more and more developers are involved, as well as the problems, including more code and test difficulty, worse readability, less maintainability and scalability, limited concurrency capabilities leading to bad user experience when rush time and low fault tolerance rate, especially system paralysis.

To solve the problem of monolithic architecture, the industry proposes a new software architecture: micro-service architecture[1]. The architecture service granularity is more fine-grained, which is conducive to reuse resources and improve development efficiency. It can also formulate the optimization scheme of each service accurately and improve system maintainability. Moreover, it adopts the AP architecture in the CAP theory, which has high availability and partition features of fault tolerance.

At present, applications based on service-oriented architecture are more and more widely used, mainly including SOA architecture and micro-service architecture. The methods of literature [2-3] are based on the SOA architecture and adopt a combination of B / S and C / S modes to split the system logic functions, then reduce the load on the client side, and solve the problem of high coupling between the modules of the monolithic architecture. The flexibility of each functional module is also guaranteed, but the system involves more middleware, so it is difficult to integrate and has poor maintainability. References [4-6] are based on the SSH framework (Struct + Spring + Hibernate), which reduces the coupling of the system and improves the system's modifiability and portability, but poorly in the scalability of the database and more resources consuming especially facing a large amount of data. The methods of literature [7-11] separate the front and back ends through the SSM framework, solving the problem of integrating all functions of the single architecture into one project, making the functions of each level of the system more clear, and also ensuring the manageability, scalability, and Maintainability, but still have the room for improvement in development efficiency. Reference [12] introduces a method based on the Spring Cloud micro-service architecture for the overall architecture design of the system, separates the sub-services to achieve system miniaturization and simplification. The method presented by reference [13] is based on the Spring Cloud Ribbon client load balancing technology, which can not only improve the high reliability of the software system but also horizontally expand the server and reduce the pressure of the individual servers especially facing more requests. The method of reference [14] called Spring Cloud, an open source distributed service framework, which simplifies development and improves development efficiency uses Ribbon technology to achieve client load balancing and Eureka technology for service registration that can achieve a rapid response and stable operation of the platform. Reference [15] introduces a micro-service architecture which can decouple advanced EMS applications, deploy each micro-service on a cloud platform to build a management mechanism for unified data and resource monitoring. Literature [16] provides a standardized Dubbo service development and practice which is based on Spring Boot. The mode of Maven + Dubbo + Spring Boot makes the development of micro-services simpler, clearer, standardized and normalized, and promotes developers focusing on business function development and shortening the software development life cycle.

Therefore, in order to improve the management of the distribution network, we establish an intelligent distribution network management system which is based on the multi-layer architecture design idea of B / S construction, then combining the technical advantages of Bootstrap and AJAX front-end framework with the MySQL database which is based on the integration of Spring Boot framework and SSM

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(Spring + SpringMVC + MyBatis) framework. The system has three built-in modules, including data processing module, load forecasting module, and users-transformer relationship module. The system is not only based on the Spring Boot + SSM framework, which can make the development, configuration, and deployment of the system conveniently, and system fault tolerance is greatly improved. Thus, we can globally grasp the operating characteristics of the distribution area, then facilitate refined management of the distribution network.

A. Introduction of Spring Boot Framework

The Spring Boot framework is a lightweight open source framework based on java, The advent of frameworks has greatly improved the efficiency of development

- The Characteristics of Spring Boot

1) It depends on starting, then define transitive dependencies on other libraries and package them.

2) Automatic configuration. Spring Boot framework using "@Conditional" annotation, then reasonably infers the beans required by the application, and automates the configuration.

3) Command line interface. After Spring Boot framework starts, the "run" method of all beans implementing the "CommandLineRunner" interface will be automatically called and combines automatic configuration to further simplify the development of Spring applications;

4) Embedded servlet container.The Spring Boot framework embeds a servlet container, so that the project can run quickly.

5) Application monitoring. Spring Boot provides actuator components. You only need to add the spring-boot-starter-actuator dependency to the configuration. By inheriting the AbstractHealthIndicator abstract class and then detecting the service health method in the doHealthCheck () method, you can implement a simple monitoring.

- The Advantages of Spring Boot

Depending on the characteristics we mentioned above, Spring Boot consequently has the advantages below:

1) Make coding simple. Through various annotations provided by the Spring Boot framework, rich service functions can be realized, which greatly reduces the amount of code writing. The annotation is in the form of java code, and no complicated xml file needs to be configured. It is simple and convenient to use.

2) Make configuration simple. Spring framework has a variety of XML, config or annotation configuration, while Spring Boot only requires simple properties or yml file configuration.

3) Make deployment simple. Spring Boot can package the program into a jar file and start it with one click, without pre-deploying various application servers. At the same time, its basic requirements for the operating environment have been reduced, requiring only the JDK.

4) Make monitoring easy. The program can be monitored through spring-boot-actuator library of Spring Boot. You can view its property configuration, thread working status, environment variables, and various performance indicators of the JVM through http requests..

B. Introduction of SSM Framework

The SSM framework is the integration of Spring, MyBatis and Spring MVC framework. It divides the entire system into four layers: the Controller layer ,the View layer, the Service layer, and the DAO layer. Decoupling the entire system function and clear structure. Three frameworks each perform their duties, The SSM framework uses the function of Spring MVC framework to achieve request forwarding and view management and uses Spring framework to implement business object management, making MyBatis serves as a persistence engine for data objects. The SSM framework is suitable for building various large-scale enterprise-level application systems. Using the SSM framework can not only greatly simplify development, but also improve system reliability, portability, and maintainability.

Introduction of the three frameworks:

1) Spring framework

The Spring framework is a lightweight Java open source framework. The idea of aspect-oriented programming (AOP) and inversion of control (IoC) is used as its core. IoC can centrally manage resources, realize configurable and easy management of resources, and reduce the coupling between computer code. AOP can separates business logic from application services, enabling highly cohesive development. Application objects focus only on business logic and are no longer responsible for other system issues.

2) Spring MVC framework

The Spring MVC framework is a technology framework based on model2 implementation. It separates page code from background code. The Spring MVC framework improves the maintainability of the system and is conducive to software engineering management. Its main role in the SSM framework is to receive and execute user requests and return results.

3) MyBatis framework

The MyBatis framework is an excellent source data persistence layer framework. It encapsulates the process of operating the database by JDBC, so that developers only need to pay attention to the SQL itself, and do not need to spend energy to deal with complicated process code of JDBC such as registration driver, connection creation, statement creation, manual setting parameters, and result set retrieval. The MyBatis framework is easy to get started, and it is very simple to develop, and it is also very easy to combine with spring.

C. Introduction of Bootstrap

Bootstrap is a front-end open source framework that supports responsive layout, which can be very convenient to design good-looking page effects. It has a lot of attractive features: excellent compatibility, friendly learning curve, responsive design, style guide document. Bootstrap is easy to use, it provides a simple and unified solution for developers to create interfaces, and it includes powerful built-in components for easy customization. Based on the features mentioned above, Web development can be made faster and easier, and the interface more flexible and friendly.

D. Introduction of MySQL

MySQL is a free, efficient, flexible and easy-to-use relational database management system (RDBMS). It has the

characteristics of small size, high portability, and open source, and it also optimizes the SQL query algorithm, which can effectively improve the query speed. Therefore, MySQL is very popular and is widely used in small and medium-sized websites on the Internet.

E. Introduction of AJAX

AJAX (Asynchronous JavaScript And XML) refers to a web development technology for creating interactive web applications. AJAX uses an asynchronous method to communicate with the server, and only partially refreshes the page. After the request is issued, the browser can perform other operations without waiting for the server to respond. Therefore, using AJAX can improve system performance and response speed, balance front-end and back-end loads, and give users a very good experience.

II. DAMAND ANALYSIS

With the rapid development of the power grid, the number of power users has continued to increase, the scale and structure of low-voltage distribution power system have become increasingly large and complex. The refined management of the low-voltage distribution network can not only affect the line loss management of the complex low-voltage distribution station area, but also affect the economic benefits of the distribution network operation. It can also better improve the services provided by the power company and the experience of client.

1) The advent of the digital information age and the gradual popularization of big data and artificial intelligence technologies have led to explosive data growth in a lot of fields. Therefore how to effectively receive and process valuable data resources becomes a new challenge for the companies in this field.

2) The rapid growth of power demand have caused the continuous rise in productive and domestic power loads, the heavy overload pressure on power supply equipment has become increasingly serious. At present, it has threatened the safe and stable operation of the power grid. Especially during the peak load time, if the capacity of the distribution transformer was insufficient, it would lead to the restriction of power for client, and even cause the transformer to burn out, which threatens people's daily production and life. At the same time, if power grid equipment was in a heavy overload state for a long time, it would accelerate the devices to death. The overload can also bring hidden trouble and operational risks to the power grid. The distribution network is closely related to users, once a 10kV distribution transformer failed, it would directly affect the power supply for people. Therefore, it is necessary to perform load prediction on the distribution network station area so as to let us be able to better regulate the low-voltage station area where heavy overload may occur.

Furthermore, due to the demand for refined management, it is imperative to grasp the real-time users-transformer relationship. However, the lines in some old neighborhoods are complicated, and the user information in some areas is often inaccurate or even missing. Finding the users-transformer relationship without cutting the power of clients is definitely needed.

As mentioned above, we need an integrated management system which can not only process the daily collected electrical information of the distribution network in real time, but also have load forecasting and users-transformer relationship identification modules, so that we can have a better management for distribution network through the models built based on massive historical data. The ensemble system need to have the function of data processing, load forecasting, users-transformer relationship identifying, so as to help us better manage the low-voltage area of distribution power system.

III. OVERALL SYSTEM DESIGN

A. System Architecture Design

The intelligent distribution network management system adopts the B / S architecture, follows the MVC design concept, and makes a detailed division of the system. So this system mainly includes View (view layer), Controller (control layer), Service (business logic layer) and Dao (data persistence layer). Through the layering, each layer is focused on the work itself, following the principle of opening and closing, which is easy to modify and expand. Based on the Spring Boot microservice framework and the popular SMM framework, we can make it accelerate the development and expansion of the system. At the same time, the application of Bootstrap makes the system have a beautiful interface and a good user interaction experience.

The system uses the principle of "contract-first configuration" of the Spring Boot framework to reduce the system's XML configuration. At the view layer, it uses the style provided by Bootstrap, then send the request data to the Controller layer through AJAX requests. After receiving the request from the front end, the Controller layer uses JSONObject for parsing and injects the Service layer for business logic processing through @Autowired. The business logic layer performs database operations by calling the interface of the Dao layer and the related mapping XML file. The returned result in the form of JSONObject is passed to the front-end page for processing. The main hardware architecture diagram and technical architecture diagram of the system are shown below:

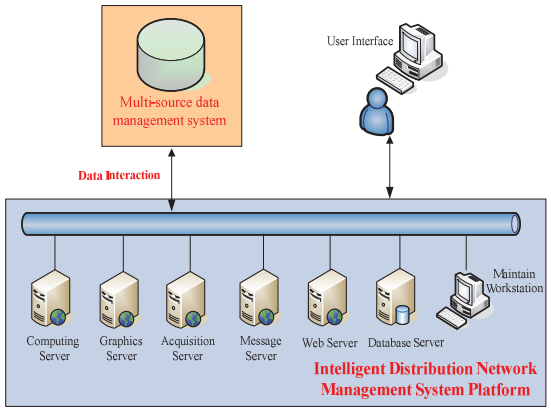


Fig. 1. Hardware architecture diagram

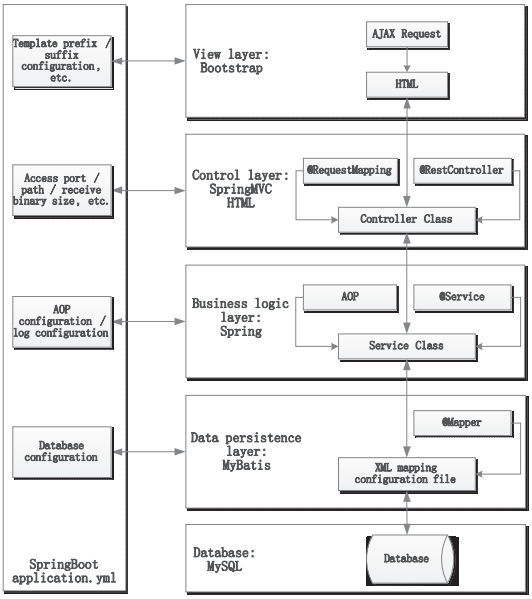


Fig. 2. Technical architecture diagram

B. System Function Module Design

The system has 3 module to help us improve the management, including data processing module, load forecasting module and users-transformer relationship module which are based on the collected data from daily electrical devices, including active power, reactive power, voltage, intensity and time information.

- Data Processing Module

1) Abnormal data dection and modification. We use the quantile to detect the abnormal data by defining variable D.

$$\begin{cases} IQR = Q3 - Q1 \\ D > Q3 + 2IQR \\ D < Q1 - 2IQR \end{cases} \quad (1)$$

Then, we use the data of t-1 to modify the abnormal data we detected.

2) Default value padding. The default value is handled in a large number of ways, and different processing methods are selected according to different practical problems. Since the power measurement parameters have time continuity feature, and there is often no jump in a short time at the non-fault conditions, the default value at time t is approximately filled with the value at time t-1.

3) Min-Max Scaler. Because of sensitive character of the deep learning model we use, we need to scale the input data in order to get better result.

$$\tilde{x}_i^n = \frac{x_i^{(n)} - \min(x^{(n)})}{\max(x^{(n)}) - \min(x^{(n)})} \quad (2)$$

In this equation, $x_i^{(n)}$ refers to the nth feature of the ith sample, the symbol min() refers to the minimum value and max() to the maximum.

- Load Forecasting Module

According to the processing module, we get the higher quality data from the raw data, then we use the data as input to feed our model which is constructed by LSTM and fully connected layer. The structure is showing below.

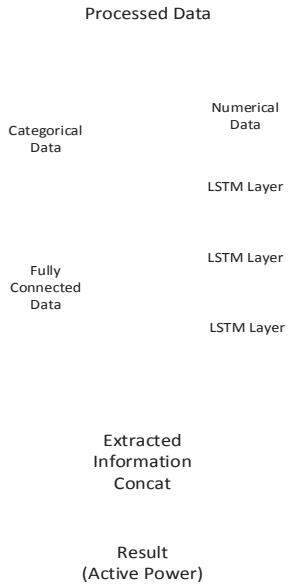


Fig. 3. Flow Chart Of Load Forecasting Module

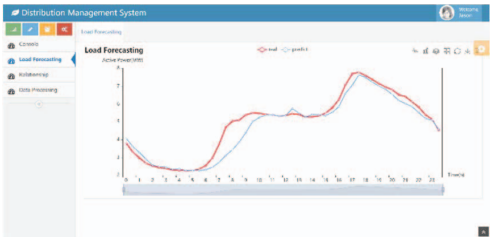


Fig. 4. Load prediction result curve

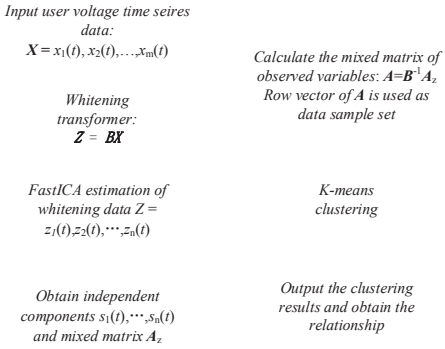
- Users-Transformer Relationship

The similarity between the row vectors of the mixed matrix M can easily reflect the similarity between the observed variables x(t) based on the relationship between the base and the coordinates in the linear space. We can therefore achieve clustering of observed variables by clustering the row vectors of the matrix M. And the clustering analysis complexity is obviously reduced because of the independent M at time t. Therefore, we use a new k-means algorithm to cluster the time series data of the electric users to help us solve the users-transformer relationship better. The equation is showed below:

$$J_c = \sum_{i=1}^{k} \sum_{j=1}^{n_i} d_{ij}^2 \left(x_j - c_i \right) \quad (3)$$

The variable Dij refers to the Euclidean distance between the clustering center and the sample, K refers to the number of clustering category, ni denotes the ith and Oi refers to the

ith clustering center. If we got the clustering result, we could easily obtain the information about the relationship between the users and the transformer. The flowchart is showed below:



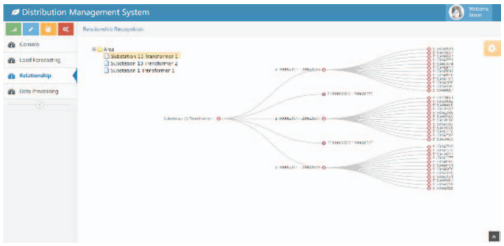


Fig. 6. Household change relationship

IV. CONCLUSION

Aiming at the problems of large scale and complex structure of urban power distribution station area and difficult management, we build an intelligent power distribution management system based on the integration of Spring Boot and SSM framework. The SSM (Sping + SpringMVC + MyBatis) framework has the IOC features of the Spring framework, Spring framework therefore can control the dependencies between objects, which facilitates the decoupling of targets and simplifies development. The Spring framework can integrate several duplicate modules, then control the transactions, logs and permissions of the system by using the AOP feature. The frame Spring MVC seamless connection with the Spring Framework, making data validation and formatting more flexible, and implementing a data binding mechanism. The MyBatis framework enables the operation of the database to be configured with an xml file, which decouples SQL from code. The MyBatis framework can not only provide mapping labels, support mapping between objects and database fields, but also support object relationship mapping labels, then support the establishment of object relationships. The total framework which combines the SSM framework with the Spring Boot framework can make the development of the system simpler, then make the logic clear, standardized and normalized. The front-end Bootstrap framework's responsive layout design makes the interface more beautiful and provides users with a better visual experience. The system has a data processing module, a load forecasting module, and a household transformer relationship identification, which facilitates fine-grained management of the distribution network, and also provides an important reference for the design of similar systems.

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