Research on the Construction of a Visualized Urban Power Supply Capacity Map with improved Power Grid Load Forecasting Methods

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Abstract. This article conducts in-depth research on the construction of urban power supply capacity maps, and achieves real-time display and prediction of power supply capacity through grid load prediction algorithms and GIS visualization technology. Firstly, a distribution network line model library was established to obtain accurate distribution of power supply capacity through multi-source data fusion technology. Secondly, LDI and neural network methods are used to analyze and predict power grid load data. Finally, the power supply capacity data is presented in a vivid and comprehensive manner through the GIS visualization platform, providing an intuitive and comprehensive view, enabling users to quickly obtain information on the power supply capacity of the regional distribution network. These research results not only have important value for decision-making in the power grid, but also provide useful reference information for government departments to support urban power planning and development.

Keywords: Load forecasting, GIS, power supply capacity map,visualization.

1 Introduction

With the accelerated development of urbanization and industrialization, the demand for electricity is increasing day by day, posing higher requirements for the reliability and efficiency of electricity supply. The distribution and changing trends of urban power supply capacity are of great significance. In order to better plan and manage power resources, it is necessary to accurately calculate and evaluate power supply capacity[1,2], and provide an intuitive and comprehensive view of power supply capacity. The research purpose of this article is to develop a power supply capacity map visualization system based on a distribution network model library and GIS[3,4], which can display the distribution of urban power supply capacity in real-time and accurately predict power grid load based on historical data analysis.

2 Construction ideas

The construction of a visual power supply capability map is based on the development of a distribution network model library and GIS platform.The overall construction process is shown in Figure 1:

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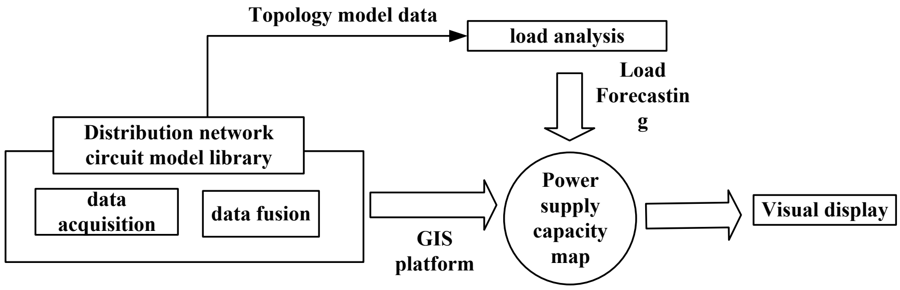

Figure 1. Overall construction ideas.

Among them, the construction of distribution network line model library is the data foundation for displaying and analyzing power supply capacity. Through multi-source data collection and cleaning, reliable and available real-time data of the power grid is obtained; Introducing LDI and neural network methods to analyze load data in load forecasting, in order to accurately predict the development trend of power grid load for scheduling prediction; The distribution network topology model and load data are comprehensively displayed on the GIS visualization platform to obtain an intuitive view.

3 Construction of distribution network line model library

The distribution network line model library is the foundation of the entire power supply capacity map construction. The model library can intuitively display the planning and geographic information of the distribution network, which helps to achieve important functions such as load forecasting, reliability analysis, and network optimization. It can also achieve spatial data processing and network analysis in power maps[5,6]. The following data needs to be collected during the construction process of the distribution network line model:

(1) Topological structure data: Various nodes in the distribution network (such as transformers, circuit breakers, isolation switches, etc.) and their connection relationships.

(2) Common information model data: The static connection relationships and attribute parameters of various electrical components in the target area's power grid, such as the main parameters of voltage transformers, lines, generators, etc.

(3) Historical statistical data: including electricity consumption data, electricity transmission data, etc., obtained through the internal statistical system of the power company.

(4) Measured data: including real-time operating data of power equipment, such as voltage, current, power factor, etc., obtained through the power monitoring system and dynamically connected to the system.

(5) Text data: including maintenance records and fault handling records of power equipment, obtained through document management or database systems.

After data collection is completed, multi-source data fusion technology is used to reduce the dimensionality and feature extraction of operational status data from different data sources, reducing data redundancy and dimensionality, and establishing a distribution network line database.

Based on the distribution network line database and topology structure information, perform distribution network topology and typical structure definition, and complete the construction of the topology model library. The main process is shown in Figure 2:

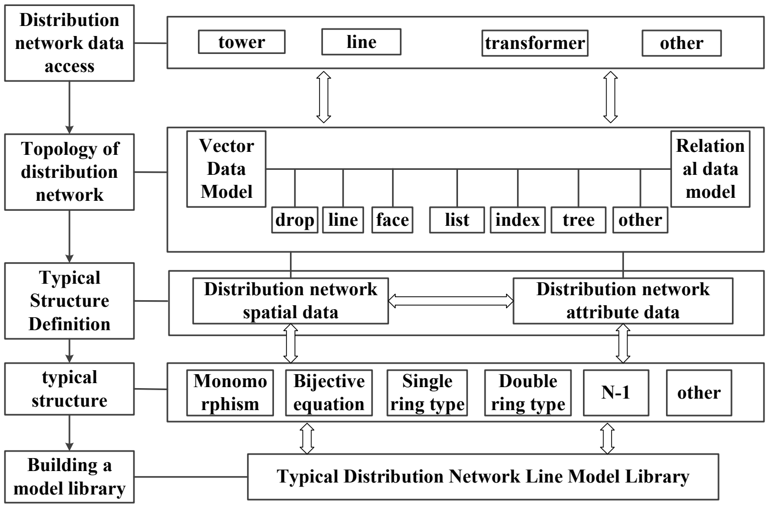

Figure 2. Construction of distribution network line model library.

4 Construction of power supply capacity map

The focus of power supply capacity map construction includes two major parts: data processing and platform construction. Among them, data processing mainly includes grassroots analysis data provided by the distribution network line database and prediction data processed by algorithms. Here, a brief introduction is given to the algorithm processing of power supply load prediction. The platform construction mainly combines the visualization needs of the power grid with the software and hardware transformation of the GIS platform to meet the purpose of data query, display, and analysis prediction.

4.1 Power supply load prediction

This article uses a combination of load density index (LDI) and neural network to predict the power supply load of the power grid[7].

The LDI method is a prediction method based on load density[8,9], which predicts future power loads by correlating power consumption with power loads and considering factors such as land use, population distribution, and economic conditions. This method has higher accuracy in predicting power loads in urban and rural areas compared to traditional time series and regression analysis methods. However, the LDI method cannot cover all factors that affect power load, such as weather, season, lifestyle habits, etc. Therefore, this article introduces neural network methods[10-13] to compensate for the shortcomings of LDI. The neural network method is a computational model that simulates the structure of human brain neural networks, with strong nonlinear mapping ability and self-learning ability. By combining the LDI method with neural networks, the nonlinear mapping ability of neural networks can be utilized to further learn and predict the load density data obtained by the LDI method, thereby improving prediction accuracy.

The method of combining LDI and neural networks for power grid load forecasting can be divided into two steps: data preprocessing and load forecasting. Among them, data preprocessing requires historical load data over a period of time, including actual load data and timestamp, temperature, weather conditions, holidays, predicted loads, and other related data source parameters of the power grid, to be obtained from the distribution network database.

The process for building a calculator for power grid load forecasting by combining LDI and neural networks is as follows:

(1) Data collection and preparation

Retrieve historical load data and related feature data from the database. For example, time features (hours, days of the week, etc.), weather features (temperature, humidity, etc.), historical load features (load values from previous hours or days, etc.) can be extracted and organized into a dataset.

(2) Define LDI training model

Using the LDI method, the historical load data and feature data are divided into a training set and a validation set.

Construct a Convolutional Neural Network (CNN) model, defining two convolutional layers and one fully connected layer for extracting and processing features for load forecasting, and inputting feature data into the model for training. In each iteration step, according to the requirements of the LDI method, the input data is processed according to the rules of time difference integration, and then the gradient is cleared to zero. The processed data is passed to the model, and the output of the model is calculated. Calculate the loss function, then backpropagate the gradient and update the model parameters.

It should be noted that since load forecasting processes time series data, it is necessary to use the input dimension as the channel number of the convolution kernel and extract features through one-dimensional convolution. Finally, the extracted features are mapped to the output dimension using a fully connected layer to obtain the load prediction results.

(3) Model prediction

Use trained models to predict future loads. Prepare the required feature data for prediction, such as future weather forecast data, date and time, etc. Input feature data into the trained model to obtain load prediction results.

Overall, this method combines the LDI method by creating a convolutional neural network model and training it using historical load data and feature data. During the training process, the input data is processed according to the rules of the LDI method, and the trained model and LDI method are used to predict future loads.

4.2 GIS visualization map construction

The power supply capacity map utilizes GIS technology to manage the basic data of the power system by computer, thereby managing the graphical information and non graphical parameters of the distribution network on the geographical background map, truly reflecting the actual direction of the power grid line, the geographical location of various power equipment, and the power supply methods of the power users they belong to. At the same time, combined with real-time control and offline applications in DMS, the actual operation status of the power system is displayed on a geographical background map.

The hardware for visualizing the power supply capability map includes data servers, Ethernet, internal processors, and external computers, with the architecture shown in the following figure 3 :

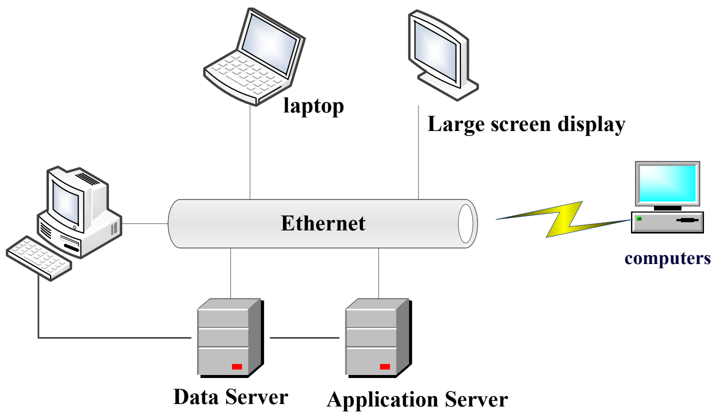

Figure 3. Visual Map Hardware Architecture.

The focus of the software architecture construction for visual maps is on database connectivity, tool and application layer construction. The main body consists of the following five parts, see Figure 4.

(1) Basic component layer

Provide the basic components of a GIS platform, including map DEM elevation data, image data, vector data, map elements, interactive components, etc. These basic components provide support and functional implementation for upper level applications.

(2) System Environment Layer

The system environment layer is mainly responsible for the environmental configuration of the GIS platform, system parameter settings, and the provision of various system interfaces. This layer provides the necessary environment and support for the operation of the GIS platform.

(3) Database Connection Layer

The database connection layer is responsible for connecting and interacting with various databases, achieving data storage, reading, updating, and other operations. The data sources of the GIS platform come from various databases, and the database connection layer is the key to ensuring smooth interaction of these data.

(4) Tool layer

This layer mainly provides tools for creating, editing, and querying graphics and data, as well as functions such as data format conversion and data sharing. It allows users to perform various graphical and data operations on the GIS platform, such as drawing power lines, transformers, etc., and querying the location, attributes, and other information of power facilities. These data can be obtained through various methods such as digital scanning, on-site survey, remote sensing technology, and require dedicated personnel to conduct daily maintenance through data input channels. Among them, real-time load and sensor data of the power grid are remotely transmitted to the cloud through IoT technology for real-time dynamic refresh.

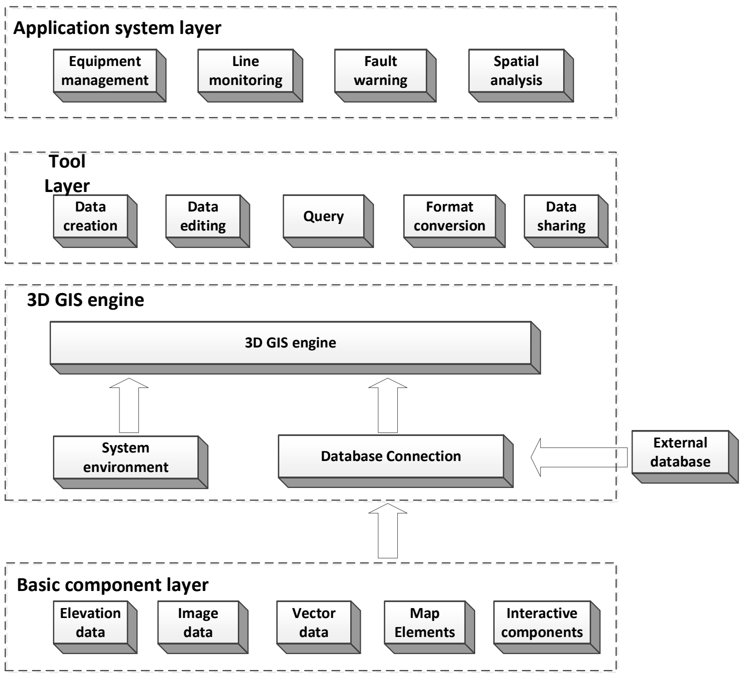

Figure 4. Power Supply Capability Map Business Framework.

(5) Application system layer

The application system layer is an application program based on the GIS platform, which includes the operation and management of power equipment, real-time monitoring of lines, fault warning and troubleshooting, etc. The application system layer utilizes the functions of the first four layers to provide query services for regional terrain, power grid resources, equipment ledger, electrical topology, graphics, and other data, achieving various applications of power supply capacity, including:

a) Data display and analysis: Display the operational data of power grid equipment, including the energy flow situation, current, load, line loss, and other operational information of power lines. At the same time, data analysis and prediction can be used to provide real-time alarms for abnormal situations such as faults, short circuit impacts, overloads, overheating, etc.

b) Geographic information display: Display the geographic location, distribution, and terrain information of power grid equipment.

c) Operation simulation: Through simulation technology, simulate and predict the operation of power grid equipment.

After interface processing, the visualization map interface display can achieve data query and real-time display functions, as shown in the following figure 5 :

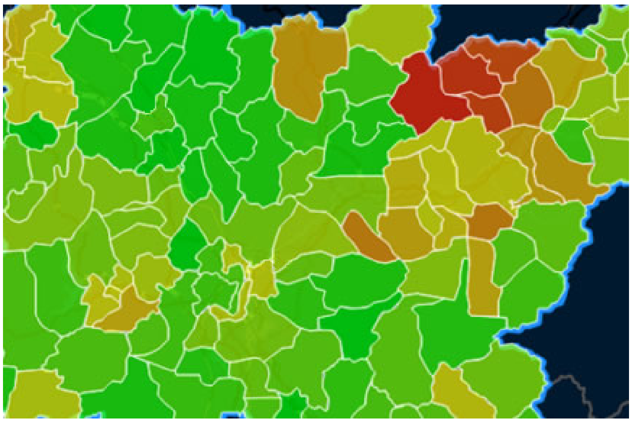

Figure 5. Load map visualization display.

5 Conclusion

This article studies the power supply capacity map of cities and displays it using visualization technology. By establishing a distribution network line model database and topology model, combined with GIS maps and the distribution of power supply capacity, a visual power supply capacity map has been constructed. This scheme introduces an improved algorithm based on the combination of LDI and neural network to achieve accurate prediction of power grid load, thereby improving the speed and accuracy of relevant personnel in obtaining information on the power supply capacity of the regional distribution network. The research results of this article are of great significance for decision-making in the power sector and government departments, and also provide useful references for further development in power supply capacity calculation and visualization technology in the future.

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