Automatic Generation Algorithm of Distribution Network Topology Map Based on GIS Drawing

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Abstract. In view of the inaccuracy and completeness of the distribution network system diagram in the current power grid, the power network structure and the business characteristics of the power industry are investigated and analyzed. The relationship model between substations is analyzed, and the inheritance circuit layout design idea is applied to the distribution. In the grid system topology diagram. The paper proposes a method of dividing the power supply area according to the line contact relationship, and develops an equal density constrained space layout algorithm. Make full use of the distribution network geographic information (GIS) drawings, carry out the power grid topology and line information maintenance, so that the system diagram covers all electrical equipment on the GIS, and can carry out the original electrical topological relationship of the gemstones, and realize the absence of each subsystem. The seams provide image support for a variety of applications. The experimental results show that the proposed spatial topology algorithm is efficient and easy to implement.

1. Introduction
The distribution network model is an important part of the power system. A complete, stable and reliable power distribution system is a reliable guarantee for providing good service to customers [1]. The traditional distribution network model, such as the dissipative network model and the component model for the distribution system, fully considers the characteristics of the distribution network and meets the requirements of distribution network modeling, but only considers the distribution network. The relationship between the physical connection and the electrical connection of the topology, completely separates the geographically distributed information for management. The GIS-based distribution vector topology model is a network model with geographical environment [2], not only for power distribution equipment objects, but also for the model of real geographical location, enhancing the visual expression of information and improving the work. The efficiency reduces the possibility of misuse. It can apply all the algorithms of the traditional model in the distribution network analysis, and can also make full use of the powerful spatial analysis capability of the GIS platform [3], which is beneficial to the realization of the distribution network analysis function and helps the system to run. Speed improvement.
2. Distribution network GIS topology model definition

Building a GIS-based topology model is the basis of topology analysis. GIS-based distribution network topology data is divided into five parts: power supply, switch, user, connection node and feeder, power supply, switch, user, and connection node are distribution network topology. The vertices in the figure, the feeder is the directed edge connecting the vertices. Therefore, the GIS-based distribution network topology model can be defined as:

\[
D = \{ N_i, L_j \mid i = 1L, m, j = 1L, n \}
\]

Where \( N_i \) represents the vertex and \( L_j \) represents the directed edge.

The specific properties of each element (except the connection node) in the GIS distribution network can be uniformly defined as the following structure: Distribution grid electrical element attributes \{FID; element class; element type; element name; element power supply state; other\}. Among them, FID is the GIS map element Feature ID, which is the ID number that uniquely identifies the spatial data of each element and its attribute data; the element class refers to the power source, switch, user, and connection node; the element type refers to the device type; the element name is the name of the device named according to the scheduling rule; the power supply status of the element refers to the power supply status of the device represented by the element; the other indicates the corresponding attribute added when the user adds the function [4].

3. Characteristics of the topological relationship of the pressure distribution network

The medium voltage distribution network consists of 10kV lines, power distribution stations, switches, switches, ring network cabinets, transformers, etc., mainly distributed public power grids. The topological relationship of the medium voltage distribution network complies with the following principles: 1) The medium voltage distribution network can be divided into several relatively independent zones according to the position and load distribution of the high voltage substation. Partitioned distribution networks have a well-defined power supply range and are generally not interleaved. The power supply range of the district distribution network will be adjusted with the increase of the newly added high-voltage distribution substation and load. 2) When the medium voltage outlet switch of the high-voltage distribution substation is deactivated, the load can be transferred through the medium-voltage network, and the user is not powered off. 3) The medium-voltage network between the high-voltage substations has enough contact capacity, and the open-loop operation is normal, and the load can be transferred when abnormal.

4. Automatic mapping preliminary layout

4.1. Calculation of the coordinate distance of the node coordinates

(1) Calculation of the moving distance under the action of gravity. The layout must first assign an ideal length value \( L_0 \) to the edge connecting the node (ie the main line):

\[
L_0 = k_1 \left( n_1 L_1 + n_2 L_2 + n_3 L_3 \right)
\]

Where: \( n_1, n_2, n_3 \) is the number of wire devices, the number of distribution transformer devices, and the number of switching devices in the original distribution network topology; \( L_1, L_2, L_3 \) is set for the wire device, distribution transformer device, and switch device respectively. The length value; \( k_1 \) is the proportional coefficient, taking the empirical value \( k_1 = 2.5 \).
(2) Calculation of the moving distance under the action of repulsion. The magnitude of the repulsion between any two nodes is related to the degree of the two nodes and the distance between the nodes. The formula for calculating repulsive force $F_r$ is as follows:

$$F_r = k_r - \frac{m_i m_j}{L_{ij}^2}$$

(3) Calculation of the moving distance under the action of repulsion. The magnitude of the repulsion between any two nodes is related to the degree of the two nodes and the distance between the nodes. The formula for calculating repulsive force $F_r$ is as follows:

Where: $k_r$ is the repulsion proportional coefficient, its size determines the speed of dispersion between nodes, taking $k_r = 20$; $m_i$ and $m_j$ are the degrees of node $V_i$ and node $V_j$, respectively; $L_{ij}$ is the actual distance between node $V_i$ and node $V_j$. The distance that any node moves during an iteration is the superposition of the moving distance under the repulsion of all nodes, i.e.

$$d_{x,r} = \sum_{j=0}^{N-1} \frac{F_r (x) - V_j (x)}{L_{ij}}$$

$$d_{y,r} = \sum_{j=0}^{N-1} \frac{F_r (y) - V_j (y)}{L_{ij}}$$

(4) Calculation of the final moving distance of the node. The distance that a node moves under the action of gravity and repulsion is the distance that the node moves during an iteration. In order to avoid the unnecessary crossing between the edges due to the excessive moving distance of the node during the moving process, the moving distance limit value $d$ is set in each movement of the node, and the value is $d = 5$. The moving distance of a node during an iteration is as shown in equation (5).

$$d_x = \max \{-d, \min \{d, (d^{-g} + d^{-r})\}\}$$

$$d_y = \max \{-d, \min \{d, (d^{-g} + d^{-r})\}\}$$

(5) Calculation of the final moving distance of the node. The distance that a node moves under the action of gravity and repulsion is the distance that the node moves during an iteration. In order to avoid the unnecessary crossing between the edges due to the excessive moving distance of the node during the moving process, the moving distance limit value $d$ is set in each movement of the node, and the value is $d = 5$. The moving distance of a node during an iteration is as shown in equation (5).

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$$d_y = \max \{-d, \min \{d, (d^{-g} + d^{-r})\}\}$$

Where: $d_x$ and $d_y$ are the moving distances of the nodes along the X and Y axes under the combined force.

4.2. Layout end conditions

Let $d_m$ denote the maximum moving distance of the node along the X-axis direction and the Y-axis direction during each iteration. When $d_m$ is less than a certain value, it means that all nodes are in a relatively stable state, and the preliminary layout process ends [5].
5. Distribution network vector data topological relationship establishment

5.1. Vector Data Collection

The distribution network has geographical features and includes two types of point objects and line objects according to the topology model. The point object mainly has data such as connection node, electric element, switch, etc., wherein the connection node and the electric element are treated as nodes without control circuit function; the switch is treated as a special node, and has the function of changing the power supply condition of the distribution network. The circuit between the switch and the next switch and its associated cell inherit the current state of the current direction switch. The line object mainly refers to the feeder line, the solid line is the ordinary line, and the dotted line is the cable. The feeder is treated as an arc segment, and the energization of each arc is determined by the nodes at both ends. As shown in Figure 1.

Fig. 1 Schematic diagram of Shenzhen distribution network vector data

5.2. Topology Relationship Establishment

The network topology is an important part of the distribution network system, and it is the basis for realizing other advanced professional analysis functions of the distribution network, and is responsible for providing data for other parts of the system. The core of topological relations in GIS is to establish the relationship between nodes, arcs and polygons. The topology relationship of distribution network refers to the relationship between the elements and the feeders, that is, the topological relationship between nodes and arcs. The establishment of the topological relationship of the distribution network adopts the real-time establishment method, that is, it is established in real time during the process of collecting and editing the graphic data of the distribution network. During the creation process, two file tables are generated, and the arc segment information associated with the nodes is recorded separately. And node information at both ends of the arc [6].

When collecting the spatial data of the distribution network, first determine the drawn electric line and the starting switch of the line, thereby determining the current direction of the electric line, and then sequentially collecting data such as nodes and feeders in the current direction. During the acquisition process, the system determines the starting point and the ending point in the feeder-node...
topology relationship according to the current direction, and establishes the topological relationship of the feeder-node, i.e., $l = l(n)$; according to the node, determine the relevant Feeder, establish the topological relationship of the node-feeder, i.e., $n = n(l)$. Figure 2 is a schematic diagram of a partial distribution network circuit.

6. Case analysis

Because the cable-based distribution network and the overhead line-based distribution network are mapped, there are huge differences in the number of branch lines, in order to effectively explain the algorithm to automatically generate various types of distribution networks. For the validity of the electrical wiring diagram, the following two examples are selected to verify the description. 1) Cable class. The topology is a power supply area composed of two 10kV feeders under a 35kV power station in a certain area, and its topology consists of cable lines and corresponding switch stations. When the pre-simplification topology and the 3-layer hierarchical topology are directly used for mapping, the number of objects that need to calculate coordinates in the initial topology, the mapping topology, the skeleton topology, and the layout topology are 669, 430, 151, and 38, respectively [7]. The simplification and stratification process of the topology greatly reduces the number of coordinate objects calculated during the drawing, and reduces the difficulty of automatically generating the electrical wiring diagram. The layout result of the layout topology based on the gravity-rejection model is shown in Figure 3.

![Schematic diagram of the local distribution network](image_url)
In Figure 3, the nodes of each representative power station are more dispersed, and the distance between the nodes with larger degrees is larger, which reserves enough space for the complete drawing and circuit wiring of the next power station, indicating the layout algorithm based on gravity-repulsion model. Effectiveness. The final mapping result of the dotted rectangular frame area in Fig. 3 is shown in Fig. 4. In the mapping results shown in Figure 4, the wiring is simple and clear, the power station is clearly drawn, and the topology of the distribution network in the area is accurately and completely represented.

The topology is a power supply area consisting of a 10kV feeder line under a 35kV power station in Shenzhen. The lines are almost all overhead lines and contain a large number of branch lines [8]. The automatic generation of electrical wiring diagrams by this algorithm is greatly improved in terms of drawing speed and efficiency compared to manual drawing. Generally speaking, for a power supply area of a general scale (consisting of several feeders), the mapping time is about 20 seconds, and the time spent on the assembly map is positively correlated with the scale of the map, and most of the time is spent in the preliminary layout process. For example, the cable routing diagram of the two feeders is as an example. The main skeleton layout process time is 9.6s, the number of iterations is 643 times, and the time from the skeleton skeleton layout result to the global specific mapping time is less than 1s. Therefore, the mapping algorithm is fully applicable to the automatic generation of electrical wiring diagrams of distribution networks of a certain scale.
7. Conclusion

The topological model is the most basic content in the distribution network GIS system. Based on the proposed vector topology model of the distribution network with GIS characteristics, the vector data acquisition is carried out, and the topology analysis is applied to the electric line scheduling simulation. Automation of distribution network management has improved work efficiency. The topology analysis algorithm proposed in this paper is only applied in the county-level city distribution system and has achieved good results. For example, if it is applied to the large-scale urban distribution network dispatch management system, it will be important to the urban distribution network. Auxiliary role can greatly improve work efficiency and management level, and bring high economic benefits.

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