Research and implementation of automatic generation of electrical topology based on topology optimization technology

Junfeng Qiao*[,a], Aihua Zhou[a], Lin Peng[a], Pei Yang[a], Sen Pan[a], Xingde Huang[b], Xiaofeng Shen[b]
[a]State Grid Laboratory of Power cyber-Security Protection & Monitoring Technology, State Grid Smart Grid Research Institute Co.,LTD,Nanjing, Jiangsu, 210003, China; [b]Qingpu Power Supply Company, State Grid Shanghai Electric Power Company, Shanghai, 201799, China.

ABSTRACT

Under the development and reform of the new power grid, the technology of drawing single line diagrams also needs to be developed and reformed urgently. In the past, single line diagrams were drawn mostly by manpower. On the premise of given data and topology structure, the drafters first sorted out the topological relationship between the components, and then placed the components on the canvas with the principle of minimizing line crossings, and the canvas size needs to be reduced as much as possible, And draw the graph W in a way that is easy to understand with the aid of CAD and other tools. This paper adopts a new decomposition model to solve the problem of power system single line mapping. First, the steps of electrical topology automatic mapping are decomposed into H steps. Using the knowledge of graph theory in mathematics instead of the form of polynomials, multiple processing objectives are processed separately, and H different methods are used to process them step by step. Then, the improved mapping algorithm is used to generate the plane embedding of electrical graph topology, which is used to achieve the goal of minimizing the intersection of lines. Then, the improved least cost flow graph method is used to process the graphic dexterity with the least cross. On the one hand, the graphic elements are evenly distributed, on the other hand, the horizontal and vertical orthogonal graphs are generated and the bending of the lines is minimized.

Keywords: Electrical equipment, distribution network topology, automatically generate topology, topology simplification algorithm, optimization of electrical connection

1. INTRODUCTION

Under the situation that the power grid structure is becoming increasingly network intensive, in order to avoid the security risks caused by the failure to update the manually drawn single line diagram in time [1]. China is carrying out the research and development of automatic drawing of single line diagram W and the graphic model interaction technology that integrates the relevant graphics and information. At present, the development of this kind of technology is still at an early stage [2]. For the graphic drawing method of automatic drawing of single line diagram technology, most of the current commonly used methods are the separation of layout and wiring, and the wiring method is relatively simple. There are main methods for layout, respectively aiming at different graphic categories: the first type of recursive layout method is applicable to the network structure with tree or hierarchy, and for the complex distribution network with ring network [3]. It may disturb its own level of second kind of combination optimization algorithm based on discrete grid is often converted into intelligent algorithm to achieve multi-objective optimization [4]. The intelligent algorithm itself has some defects, including that the weight of multi-objective is difficult to select, and it is easy to cause several objectives to be uncoordinated [5]. Especially for large-scale complex distribution network layout, it is impossible to balance the weight of each objective. Now it is necessary to find a new algorithm to deal with the layout of complex distribution network graphics [6].

In this paper, the mapping method is deeply analyzed for the first time, and is applied to the automatic mapping of single line diagram to open up a new idea and get rid of the old idea of separation of layout and routing to deal with the automatic mapping problem.

*1318558905@qq.com

Seventh International Conference on Mechatronics and Intelligent Robotics (ICMIR 2023), edited by Srikanta Patnaik, Tao Shen, Proc. of SPIE Vol. 12779, 1277907 · © 2023 SPIE · 0277-786X · Published under a Creative Commons Attribution CC-BY 3.0 License · doi: 10.1117/12.2688648

2. RELATED WORK

The automatic generation technology of electrical topology is a part of the integration technology of power system graphics and models [7]. The generated diagrams mainly include the power flow diagram applied to the dispatching screen, the wiring diagram with geographical location information, the single line diagram of power transmission and distribution network, and the wiring diagram inside the power station [8]. At present, the method of layout and routing decomposition is mainly used to automatically generate the above figures. Layout is to automatically generate nodes on the canvas according to the drawing rules of single line diagram, and routing is to connect the laid nodes in a way that is more consistent with the habit of reading topology [9]. In terms of layout, there are currently methods for H-type graphics: 1. recursive layout algorithm for tree structure. Universal combination optimization algorithm in grid. The first type of method is mainly based on the typical rules of conventional single line diagram drawing of power distribution [10]. Since China mainly relies on feeder distribution, that is, the tree structure. For the classic tree structure, W usually uses the typical rules of sequential interlacing of trunk and branch lines to draw, taking the longest line in the feeder or the determined line as the trunk and branch, and then interlacing the branches at all levels above and below the trunk and branch lines.

When foreign scholars discussed the problem of automatic drawing of power single line diagram, they believed that under the premise of power grid reform, power components could only be more and more. In the limited drawing area, the continuous addition of new components would eventually lead to insufficient drawing area or sacrifice the readability of the diagram. In order to improve the readability, it divides the nodes to be drawn into five levels according to the importance. The importance can be determined according to the voltage level or load capacity. The level is raised from the lowest level 1 to the highest level 5. When drawing, first draw a single line diagram of nodes with importance of 5, and then draw a single line diagram of nodes with importance of 4. The diagram with level 4 needs to include nodes with level 5 at the same time.

3. RESEARCH ON AUTOMATIC GENERATION OF ELECTRICAL TOPOLOGY

3.1 Research on electrical topology generation based on multi-objective merging algorithm

In this method, in order to minimize the line length and the number of intersections of the graph, the above two main objectives are expressed in the form of a W polynomial mathematical model. If necessary, other optimization parameters are added, such as the uniform distribution of primitives. The W weighting method of multiple objective polynomials is integrated, and then centralized optimization is performed. The two main sub objective functions of this method are shown below.

Single line diagrams usually use the mutual distance between nodes to describe the length of the line between nodes. Manhattan distance or Euclid distance are often used. Both distances have been used. W Manhattan distance is an example. The Manhattan distance of the total line length is:

$$\mathrm{L(G)} = \sum_{j=1}^{n} \sum_{j>i} \left(\left| x_i - x_j \right| + \left| y_i - y_j \right| \right) \tag{1}$$

As is shown in formula 1, where parameter i and j are subscripts of two components to be drawn, (x_i, x_j), (y_i, y_j) are the coordinates of two components respectively. When there is a direct topological connection between i and j, the result is 0.

To ensure the minimum line crossing, its mathematical model is shown in Formula 2.

$$\mathrm{Min\ C}(G) = \sum_{i=0}^{n} \sum_{j>i}^{n} C_{ij} \quad i = 1 \ldots n \tag{2}$$

First, after rapid screening, whether the two lines intersect is judged by whether the rectangle determined by the diagonal of the two W line segments intersects. This method can only quickly filter some segments that do not meet the requirements.

Secondly, the remaining unfiltered line segments are judged by the method of judging the span of line segments. If two line segments intersect, then two line segments must span each other. If segment 1 intersects segment 2, then 1 and 2 are distributed on both sides.

However, this method also has obvious shortcomings. For example, it is not easy to select the weights of each target, which requires the definition of the topology of the graph and long-term experience to achieve target selection. In

addition, the generation of electrical topology takes a long time. If there are few nodes in the graph, the time required for iterative calculation of mapping is not much. However, for the grid graph with a lot of electrical topology nodes and complex topology connection, because of the need to repeatedly calculate the position relationship between each electrical topology node, each heuristic algorithm iteration takes too much time, sometimes even close to and exceeds the time for manual topology drawing. Nowadays, most of the automatic heuristic methods are prone to be trapped in local optimization, and the mapping effect is not good, which is easy to cause too much cross or too dense connections.

3.2 Research on automatic generation algorithm of electrical topology based on intelligent matching

Electric power single line diagram is to draw the form of points and lines of each entity component in practice. Such a diagram has a special subject of graph theory in mathematics for research, and the set of points and lines is also called graph in graph theory. Both the drawing of single line graphs and the study of graphs in graph theory are based on the relationship between points and lines. The graph to be studied jointly by the two is summarized below. That is, the graph G (V, E) to be studied includes two device sets: vertex set and edge set. V represents vertex set, that is, vertex set with numbers. E is an edge set, which is a subset of set V and refers to the connecting line between two vertices with connection, That is, (x, y). E represents that there is a line between vertices X and Y.

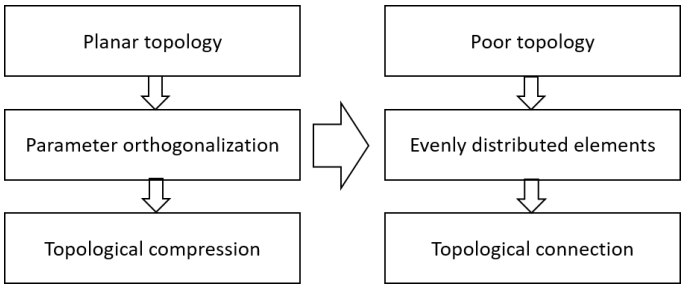

Figure 1. Automatic generation algorithm of electrical topology based on intelligent matching

As is shown in figure 1, the multi-objective decomposition method consists of six steps of planarization and compaction, which respectively resolve path retrieval problems in multiple graph theories. In the first step, planarization is used to deal with the target with the least cross connection. The second step is automatically, which deals with the graphic topology with minimal crossing. On the one hand, it achieves uniform distribution of graphic elements, on the other hand, it generates horizontal and vertical orthogonal graphs and minimizes the bending of the connecting lines. The third step is to compress and finally determine the coordinates and connecting positions of each node. The multiple steps are closely linked and correspond to the six objectives of automatic single line drawing, which stand opposite to the multi-objective combination optimization method. This method decomposes and then processes each objective separately, so that the solution has control over all objectives.

First, from the first step of planarization research, the existing methods in this part of the research mostly adopt the method of fixing the vertex first and then connecting lines. When there is a crossing between lines, avoid the crossing by detouring. If there is an unavoidable situation, first arrange the position of the line, and then connect the crossed lines after all non-crossed lines are completed. At this time, the crossing points are replaced by virtual nodes, the resulting graph only contains vertices and lines of virtual nodes without crossing.

In the step of planar zing the electrical topology connection, the intersection is reduced by changing the order of edge insertion. Experiments show that changing the order of edge drawing is indeed possible to reduce the intersection. In addition, this paper uses genetic algorithm to find the edge insertion sequence combination that can reduce the intersection. However, due to the addition of heuristic method for optimization, the mapping time increases.

4. IMPLEMENTATION OF AUTOMATIC GENERATION OF ELECTRICAL TOPOLOGY BASED ON TOPOLOGY OPTIMIZATION TECHNOLOGY

The automatic generation program of electrical topology is written in python language, which is an object-oriented interpretative programming language developed. Python is chosen because of its powerful and perfect functions, and it pays more attention to the speed of project development and the simplicity of code. The orthogonal diagramming

program of multi-objective decomposition in this paper is developed based on the object-oriented QT framework. QT is the framework for the development of graphical user interface (GUI) software. In order to facilitate users to operate computers with graphical interfaces, W mouse replaces keyboard to input instructions. Because the framework can be developed conveniently by object orientation, and can be used across platforms, it conforms to the purpose of graphic model interaction and human-computer interaction in graphic model integration technology studied in this paper, so it is more convenient to use the framework to deal with the practical problems in this paper.

On the basis of the above research results, combined with the above automatic generation algorithm, this paper develops the automatic generation software of electrical topology. The data model of this software is developed by referring to CIM61970 standard. However, because the mapping function is developed for the power system diagram, and the equipment and topology of the electrical system diagram are described by CIM, The software can analyze related objects and topology information of power system by importing CIM.RDF files. RDF is a schema file used to describe metadata, usually suffixed with RDF.

4.1 Data processing for automatic generation of electrical topology

For basic data processing of electrical topology, firstly, the data read in and analyzed by D0M shall be processed by the automatic mapping algorithm, so as to realize automatic drawing of single line diagram. By default, the mapping result is a document file in SVG format. Since SVG files also follow XML syntax, it is allowed to import attached SVG files while importing RDF metafiles.

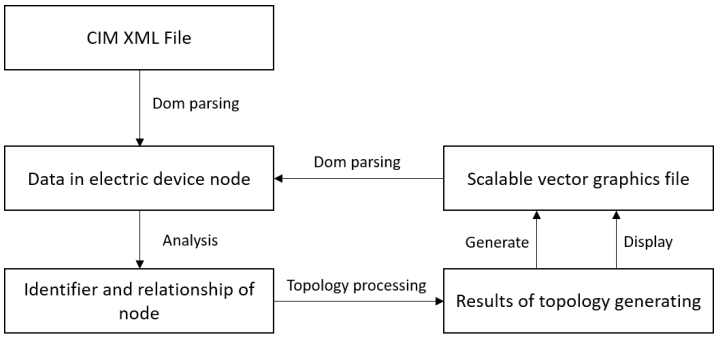

Figure 2. Data Processing for Automatic Generation of Electrical Topology

As is shown in figure 2, in this chapter, the orthogonal automatic mapping program adopts a new mapping method of multi-objective decomposition mode, which is divided into the plane orthogonal compression H steps correspond to the minimum crossing, the average layout and the shortest connecting line H objectives respectively. This method is suitable for the network intensive power grid structure. The overall processing steps of the program are: first, read the basic information such as the points to be drawn and their topological relationships from the EMS or the CIM file imported by the user, then process step by step according to the multi-objective decomposition method, and finally generate the required single line diagram in SVG format.

For the first step of planarization, the starting point of the electrical topology node needs to be calculated first. You can select the starting point manually or automatically. There are usually many important nodes in the system, such as the balance node in the transmission ring network and the starting point of the distribution feeder in the distribution network. The important node is preferred as the starting point. If there is no important node, the starting point shall be selected randomly, and the ending point shall be selected according to the farthest point of depth first search. After the selection of W, the starting point shall be connected with a line to start the calculation of topological node relationship. After the calculation is completed, the topological simplification mode shall be reduced according to the node coding order, and the existing nodes shall be matched with the topological tree from bottom to top to finally determine the appropriate point and connection topological relationship to form the largest plane sub graph, Non planar edges are inserted in the way of finding the shortest path in the dual graph to minimize the crossing.

4.2 Realization of automatic generation of electrical topology in distribution network

This chapter establishes a fuzzy comprehensive evaluation model for grid planning of distribution network based on the subjective and objective combination weighting method. On the basis of the grid comprehensive evaluation index system established in Chapter 2, the index system is subject to fuzzy comprehensive evaluation. The fuzzy comprehensive

evaluation method is divided into single-layer and multi-layer. Taking the two-layer fuzzy comprehensive evaluation model as an example, its establishment steps are as follows.

First, this chapter introduces the development of the software for automatic generation of electrical topology and the realization process of the function of the generation mode, analyzes the environment and functional structure of the software development, develops the software in accordance with the enterprise standards of the State Grid Corporation of China and other relevant specifications in order to smoothly connect the software to the energy management system, and then introduces the software realization process, analyzes the multi-objective decomposition into the national method process and the hierarchical layout method process respectively, Compare the multi-objective decomposition method to the currently used heuristic multi-objective optimization method, and finally compare the efficiency of electrical equipment topology generation of 1-2000 nodes to process and verify the progressiveness and effectiveness of the multi-objective decomposition method.

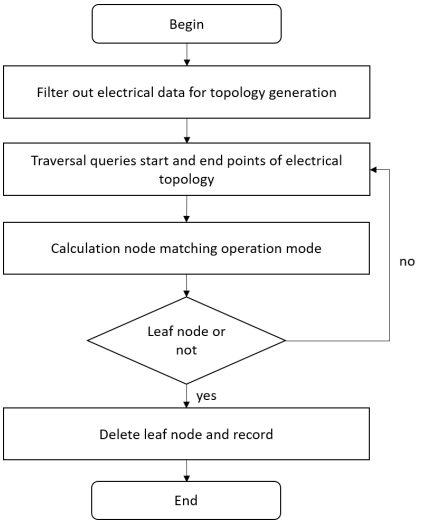

Figure 3. Functional process of electrical topology simplification of distribution network

As is shown in figure 3, the input is the plane topology diagram formed in the first step. First, determine the relationship between each point and surface. First, determine the point to surface flow path, and then determine the surface to surface flow path. Use the constraints in Chapter H to calculate the initial conditions, substitute the initial conditions into the calculation of the minimum cost flow, and use each path of runoff to determine the relationship between the point and the line.

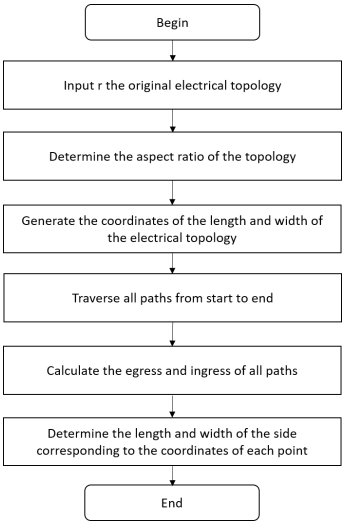

Figure 4. Functional process of electrical topology simplification of distribution network

As is shown in figure 4, the sorted input is the orthogonal graph of the second step. First, calculate the vertical and horizontal dual graphs, then search the path from the starting point to the end point, add 1 to each branch flow on the path every time a path is found, finally summarize the data of each path, calculate the flow on each branch, and determine the length of the side passing by according to the size of the flow.

This method tests the effectiveness of the orthogonal mapping method by selecting a simple network with nodes that are not easy to cross and manually drawing a more cumbersome electrical topology node network diagram. In order to verify the progressiveness and effectiveness of the multi-objective decomposition method, this paper compares it with the multi-objective optimization method using genetic algorithm. In this paper, the genetic algorithm optimization method is used to select the mathematical model based on the relationship between optimized component coordinates, and the line length is determined according to the distance between components.

Table 1. Efficiency analysis of automatic generation of electrical topology

Iterations	Fitness	Number of line crossings	Line overlap	Run time
1	18961	14	6	0.639
50	19091	7	4	5.487
200	20578	6	3	28.332
500	21813	4	3	110.878
2000	21560	3	1	511.471

As is shown in table 1, for simple electrical topology equipment nodes, genetic algorithm is used to iterate until 2000 times, which takes 511.471s. It can barely draw a suitable understandable single line circle. Through comparison, it is found that the increase of iteration times is gradually reducing the key data such as graph crossing. But it took about 8 minutes to draw manually.

It only takes about 20 minutes for the single line diagram of. For the simple electrical topology node multi-objective decomposition example, it is proved that it is roughly equivalent to the original manual single line drawing, with good mapping effect and no cross, and the density partition is equivalent to the general position of the original manual drawing, the approximate position of each component is close to the original manual drawing position, and the topological relationship is clear. The graph is easy to read, and the time for topology generation is greatly reduced.

5. APPLICATION RESULTS

In this paper, we propose an orthogonal mapping technique for analytic multi-objective decomposition processing, and apply this technique to the automatic drawing of single line diagrams. Instead of polynomial optimization, we use more targeted graph theory knowledge for drawing graphs to deal with objective functions. At present, China has made remarkable achievements in the development of system automation. The developing ultra-high voltage transmission and distributed generation, as well as the upcoming micro grid technology, are promoting the innovation of existing technologies in China. The mapping method in use has some defects in dealing with the mapping target of single line graph, because the target itself is mostly a problem of connection errors, and most of them use multinomial method to combine and optimize multi-objective weights, leading to the fuzziness and complexity of the original problem. Now, by decomposing various graphic problems, we can use more professional mathematical graph theory knowledge to deal with these problems, which can effectively avoid the problems caused by the existing polynomial way of drawing, and can independently adjust each goal, which not only optimizes the effect of graphic drawing, but also broadens the thinking of mapping technology research.

The research results of this paper have been applied in the distribution network planning of power companies and other fields, with good response. All users of power companies believe that the research results play a very significant role in the automatic generation of electrical topology. Compared with the traditional manual drawing of single line diagram, the drawing efficiency has been greatly improved, the time efficiency has been improved by more than 90%, saving a lot of manual operation time, It can improve the quality and efficiency of relevant departments and lay a data and technical foundation for expanding more electrical topology services.

ACKNOWLEDGMENTS

This work was supported by State Grid Corporation of China's Science and Technology Project (5400-202258431A-2-0-ZN) which is 'Research on deep data fusion and resource sharing technology of new distribution network'.

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