

Retraction

Retracted: Distribution Network Grid Planning and Automatic Routing Based on Cluster Analysis Algorithm

Security and Communication Networks

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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- [1] J. Cheng, Q. Jiang, G. Cheng, R. Gong, and X. Du, "Distribution Network Grid Planning and Automatic Routing Based on Cluster Analysis Algorithm," *Security and Communication Networks*, vol. 2022, Article ID 7262323, 9 pages, 2022.

Research Article

Distribution Network Grid Planning and Automatic Routing Based on Cluster Analysis Algorithm

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In order to improve the efficiency of power grid enterprises under the background of new power reform, the author proposes a set of planning ideas and methods for medium-voltage distribution networks based on the optimal division of power supply grids. First, the layout of the main channel in the planning area should be determined to ensure the reservation of land resources. Then, on the basis of clarifying the purpose and principle of grid division, based on the selection of the nearest load backup substation and the load clustering method, the optimal division of the power supply grid should be realized on a global scale. Finally, in each power supply grid, the wiring mode and the primary and secondary construction and renovation standards are selected based on the classification of the supply area, and the main line wiring planning is carried out. For the grid frame in the transition year, in order to avoid repeated reconstruction and facilitate construction, the principle of piece-by-piece construction and reconstruction is proposed. The results show that by the target year, each power supply grid in the planning area will use two substations as power points, the power supply range of the main lines of each grid is limited to this grid, the lines between grids will not be connected, and the line connection rate will reach 100% and all meet the N-1 check. The proposed method follows the basic planning concept of “technically feasible and economically optimal” on the basis of overall planning and transforms the complex global planning of distribution network into local planning within each optimized grid, and it enables different planners to obtain a basically consistent grid optimization scheme, strengthens the scientificity and certainty of planning, and provides a reference for the revision and refinement of relevant guidelines, which has been practically applied.

1. Introduction

The distribution network is an important part of the power system, scientific and reasonable distribution network planning can not only improve the economy and reliability of the operation of the power system but also ensure the power supply quality of the power grid, it can also save a lot of investment, operation, and maintenance costs for operators [1]. The main purpose of distribution network planning is to be able to meet increasing load demands in the most economical, reliable, and safe way possible. The early distribution network planning mainly includes the location and capacity determination of the substation, and the optimization of the grid structure, as shown in Figure 1. In

recent years, the development of new technologies such as distributed generation Distributed Generation (DG) and energy storage and the implementation of demand side response, it greatly enriches the content of distribution network planning, and also has a lot of influence on the planning model and planning method of distribution network [2, 3]. The addition of new participants in the electricity market environment has made the stakeholders in the distribution network more diverse, the traditional planning model that only considers one stakeholder of the distribution network operator has been expanded, at the same time, in order to reduce the adverse impact of new technologies being connected to the distribution network on the system, active management has been gradually applied in the

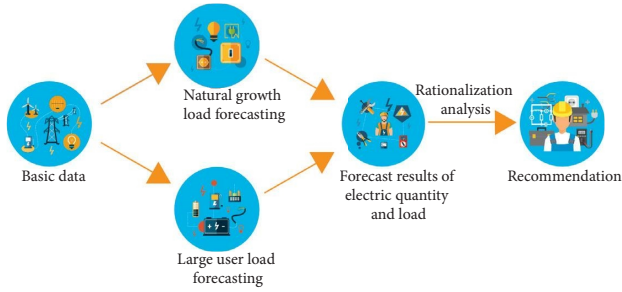


FIGURE 1: Grid planning of distribution network.

distribution network, and a distribution network planning model that considers these new influencing factors in new scenarios emerges as the times require, the development of planning models has put forward new requirements for planning methods and solving algorithms, not only has it promoted the development of planning methods but some novel intelligent optimization algorithms have also been used to solve distribution network planning problems [4].

2. Literature Review

Khalid et al. proposed a concept of “connection combination,” which is to use the directional connection direction between substations as the backbone between grids, inside the grid, relying on the segmentation of the line, the load transfer capacity between stations is optimized, the utilization rate of equipment is increased, but the control of grid load size is not clear, and the research on the interconnection structure relationship between multiple substations is not involved [5]. Sharma and Kumar proposed the “blockchain chain” networking form, and the grid division has strong operability, however, the networking form is single, which cannot reflect the interconnection structure of substations under different geographical characteristics and different load densities, and lacks flexibility [6]. According to the different topographic features and different load density distributions in the planning area, Jiang and Xia studied several power supply models of distribution network, and proposed a variety of typical power supply models such as point, chain, and block, it provides a certain reference value for the target grid planning of the domestic target year (or prospect year); however, it does not involve the research on grid-based planning of distribution network, and how to combine it with grid-based planning needs to be further studied and clarified [2]. From the above literature, it can be seen that, at present, the overall content and process of grid planning research in various places are basically the same, mainly including status analysis, load forecasting, power grid division, and grid planning. Among them, there are two ideas for grid division: first, according to the control regulations and the functional properties of the plot, the load of each grid is different and the difference is large. Second, according to the results of load forecasting, the grid is divided according to the power supply capacity of the grid connection mode. Besides, Alseiri and Farrell first performed sensitivity analysis on all the lines to be planned, and then added the lines with the best sensitivity analysis to the

distribution grid, so as to gradually expand the entire grid [7]. Another approach mentioned by Jiang and Xia is first, all planning results to be optimized are added to the distribution network, and then the results with the lowest sensitivity are discarded through sensitivity analysis to obtain the optimal solution, this method is called the step-by-step backward method [8]. Ajay and Jaya, based on the genetic algorithm, considered the geographic information in the planning area during the optimization of grid planning, in order to obtain better social benefits, the objective function not only considered the general investment and construction costs but also considered the loss factor of user power outages [9]. In view of the existing grid planning methods that do not reflect the planning concept of “technically feasible and economically optimal” on the basis of overall planning, it is difficult to obtain an optimal grid division solution, resulting in unnecessary waste, the author proposes a set of ideas and methods for medium-voltage distribution network planning based on optimal division of power supply grids [10]. On the basis of determining the layout of the main channel, the purpose and principle of grid division are firstly clarified, the definition of power supply grid is given, based on the selection of nearby load backup stations and the load clustering method, the optimal division of power supply grid in the global scope is realized, the global complex distribution network planning is transformed into a relatively independent local planning within each optimized grid. For the grid frame in the transition year, in order to avoid repeated reconstruction and facilitate construction, the principle of piece-by-piece construction and reconstruction is proposed. The author’s method has gained practical application and improved the practicality, effectiveness, and sophistication of gridded planning [11].

3. Research Methods

3.1. Master Planning Process. As shown in Figure 2, the overall process of the medium-voltage distribution network planning based on the optimal division of the power supply grid is similar to the main content and process of the existing medium-voltage distribution network planning, it mainly includes status analysis, load forecasting, substation planning, grid planning, project preparation, program evaluation, and investment decision-making [12]. The focus of the author’s method research is: spatially, the layout of trunk channels and optimal division of power supply grids based on global planning; and, temporally, in terms of time, the near and far coordination of the grid is based on the principle of interest and goal orientation.

3.2. Trunk Channel Layout. The layout of the main channel includes the distribution of sites in the planning area and the direction of the main channel (especially the communication channel between stations), in order to ensure the reservation of land resources, determine the load access direction, which is based on the substation layout, current channel, planned road network, load distribution and power supply radius, on the basis of making full use of the existing channels and in-

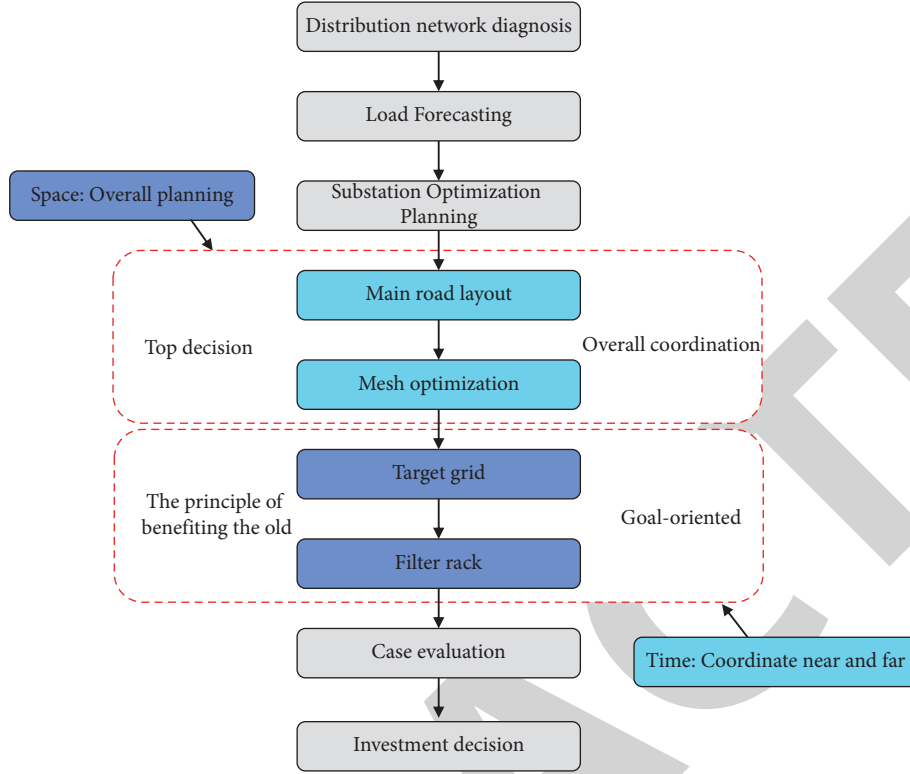


FIGURE 2: Planning process of medium voltage distribution network based on optimal division of power supply grid.

depth load center channels, the total cost (including investment and operation and maintenance costs) of the main channel is optimized and determined according to the principle of minimum, the main channel layout construction idea is shown in Figure 3 [13].

Affected by regional characteristics, load density and power channels, the layout of substations and the direction of medium-voltage lines usually show a certain pattern, the basic structure of the main channel layout can be abstracted into narrow and long, annular, checkerboard, and irregular. According to the actual planning area, the main channel layout may be composed of multiple simplified structures.

3.3. Clustering Algorithms. The author chooses the k-means algorithm for load clustering. The algorithm uses the mean square error as the objective function, as shown in the following formula [14]:

$$\min \sum_{m=1}^K \sum_{n=1}^M u_{mn} d^2(c_m, x_n). \quad (1)$$

In the formula, K is the number of categories, M is the total number of samples, $d(c_m, x_n)$ is the Euclidean distance from c_i in the m -th class to the n th sample, u_{mn} is a binary variable, equal to 1 means that the n th sample belongs to the m th class, and equal to 0 means it does not belong to this class [15]. In order to ensure that each sample can and can only be classified into a certain category, u_{mn} needs to satisfy the following formula:

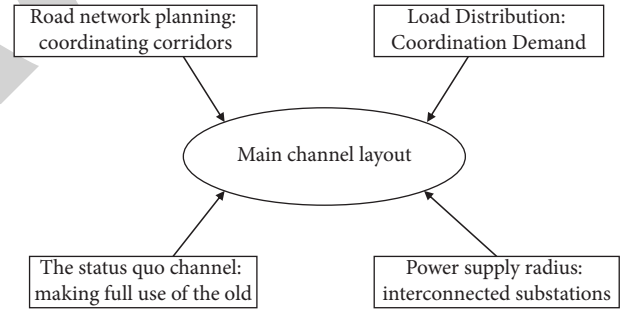


FIGURE 3: The construction idea of the main channel layout.

$$\sum_{m=1}^K u_{mn} = 1. \quad (2)$$

At the same time, in order to ensure that the classes are not empty sets, the following formula (3) needs to be satisfied:

$$\sum_{n=1}^M u_{mn} > 0. \quad (3)$$

3.4. Mesh Optimization Division

3.4.1. Purpose and Principles of Meshing. For large-scale medium-voltage distribution network planning, the main purposes of grid optimization are: ① Transform the complex grid plan of the entire area into a relatively independent

simple grid plan within each grid, and at the same time, the division of the grid should meet the basic planning principle of “technically feasible and economically optimal” for the overall grid on the basis of overall planning; ② Avoid the problem of thousands of people in the grid division scheme, and at the same time, strengthen the economy, reliability, and simplicity of the grid [16].

In order to achieve the above purpose, mesh division should follow the following principles.

- (1) Technical feasibility: under the condition of satisfying the constraints of the layout of the main channel and the power supply radius, each load in each grid can achieve the maximum realization of the transfer between the two power supply substations, in order to improve power supply reliability.
- (2) Optimal economy: for the load that can be transferred between two power supply substations, the backup substation for each load is determined according to the principle of the minimum total cost of the transfer channel, so as to realize the nearest backup of the substation and the smallest overall grid size.
- (3) The grid structure is simple: the similarity between the main supply substation (hereinafter referred to as the main supply station) and the backup substation (hereinafter referred to as the backup supply station) for each load of the same grid is maximized (regardless of the main and backup), the power supply substations in each grid area should not exceed two and the load size should be moderate (should include one to three groups of 10 kV typical wiring), and the connection degree of lines in different grids should be minimal.

3.4.2. Grid Definition and Coding. Based on the purpose and principle of meshing, the author defines the mesh as: Try to use the load area of moderate size between the main power supply and the nearby backup power supply between the two substations. For ease of management, grid codes should be unique and easily identifiable.

3.4.3. Meshing Optimization Methods. Based on the principle of selecting the nearest load backup supply station and the load clustering principle based on the layout of the main channel, according to the purpose and principle of grid division, the power supply range of the grid on a global scale should be optimally divided and coordinated, the specific steps are as follows.

(1) Determine the Main Supply Station for Each Load. First, the power supply range of each station is obtained by optimizing the substation planning, and then each substation is called the main supply station of each load within its power supply range. Taking the simplified system shown in Figure 4(a) as an example, if loads A1 and B1 belong to the power supply range of station A and station B, respectively, the main supply stations of A1 and B1 are station A and station B, respectively.

(2) Determine the Backup Supply Station for Each Load. Based on the layout of the main channel between stations and the constraints of the power supply radius, the nearest backup substations that may exist for each load are determined. Taking Figure 4(a) as an example, the backup stations for loads A1 and B1 are determined as station B and station A, respectively.

(3) Form a Grid of Contacts between Stations. The author defines the interstation connection grid as the area where the load can be transferred between the two substations, and the division method is as follows: First, the main supply station and the backup supply station with the same load are divided into one supply area, and then the two opposite supply areas of the main supply station and the backup supply station are combined into an interstation connection grid. Taking Figure 4(a) as an example, the main supply station and backup supply station of all loads (such as load A1) in supply area A1 are stations A and B, respectively, and the main supply station of all loads (such as load B1) in supply area B1 The supply station and the standby supply station are B station and A station, respectively; Supply area A1 and supply area B1 have the opposite load main supply station and backup supply station, so they can be combined into a grid of interstation connections involving substations A and B. If the interstation connection grid obtained by the above steps is too large, in order to avoid the formation of a complex network with too many interconnected lines in the grid, the grid can be further subdivided by using expert experience or load clustering method. In areas with limited channel resources or difficult power grid reconstruction, in order to adapt to the multisegment, multiconnection, and main-standby feeder wiring modes with large power supply capacity, for the case where the interstation connection grid is too small, the possibility of merging small meshes with adjacent meshes should also be considered.

(4) Form an Intrastation Connection or a Radial Wiring Grid. The author defines the interstation connection grid as the area where the load can be transferred between different lines in the same substation; The radial connection grid is defined as the area where the load has only one power supply substation and cannot be transferred through the line.

For the loads that cannot be classified into the grid of interstation connections, within the power supply range of each substation, based on expert experience or load clustering method, the corresponding supply area is obtained by dividing the load of a certain size; Then, according to the actual demand and the principle of selecting a nearby load backup supply line, under the conditions of the main channel layout and power supply radius, an intrastation connection grid or a radial connection grid is formed, as shown in Figure 4(b).

It should be noted that, similar to the grid refinement of interstation contact, the author recommends that the power supply load of about two circuits of 10 kV lines (i.e., 8 MW, the upper limit of 16 MW, the lower limit of 3 MW, depending on the specific situation is slightly different) to divide the supply area of the connection grid or radial

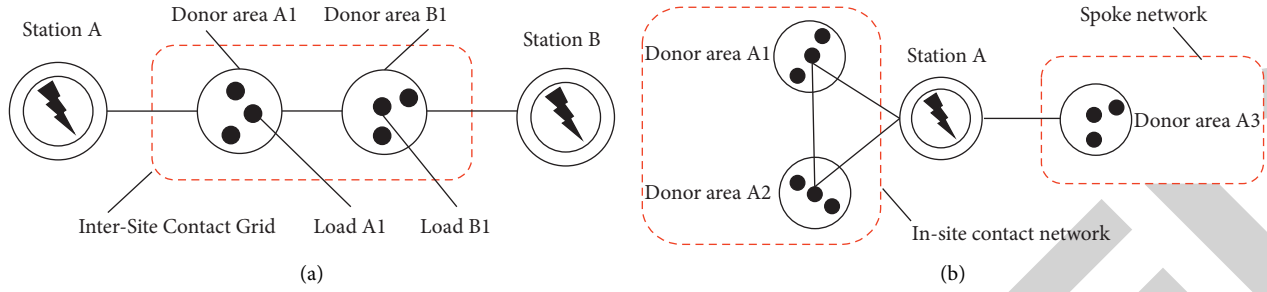


FIGURE 4: Schematic diagram of grid classification based on contact method (a) Interstation contact grid (b) In-station liaison network and spoke network.

connection grid in the station, and flexible use of different power supply capacity standard wiring adapts to the development of the load.

(5) *Manual Intervention*. For other possible concerns in grid division, such as clear physical geography and management interface, the classification level of power supply areas is the same or close, the grid load types and their power supply reliability requirements are basically the same, and the loads of two supply areas in the same grid are approximately equal, planners need to analyze based on their own experience, and make further adjustments to the grid division scheme through manual intervention.

It can be seen from the above mesh division steps: ① Since the interstation connection grid satisfies the substation “N-1,” the interstation connection grid should be generated as much as possible, and then the intrastation connection grid and the radial connection grid should be generated; ② Due to the limitation of the length of the paper, this section does not elaborate on the refinement and merging of interstation contact grids, as well as the division of intrastation contact grids and radial connection grids, and the content will be described in another article. However, compared with the traditional grid division method, based on the above grid division rules, the optimal grid division scheme for interstation connections (especially for urban distribution networks with many interstation connections) is more consistent, this reduces the subjectivity and uncertainty of the planning scheme [17].

3.4.4. *Comparison with Other Methods*. After summarizing the meshing method and other meshing methods, the division basis and mesh characteristics are summarized, and the results are shown in Table 1.

3.5. *Grid Target Grid*. Based on the results of grid optimization, the author transforms the complex target grid construction of the whole network from the global scope to the independent grid partition scope. According to the line candidate channels provided by the layout of the main channel, the manual planning method and the computer automatic routing method are combined, small-scale trunk wiring planning is carried out within each grid, respectively [18].

The author also analyzed the grids of A+, A, B, C, D, and E power supply partitions, standardized grid primary and secondary construction and transformation standards are proposed, respectively, which involve line wiring mode, load size control, and distribution automation construction, as shown in Table 2. In the Table, RS-3 indicates the reliability rate of power supply under the condition of power shortage, regardless of the lack of system power supply.

- (1) T1-type grid: The T1-type grid construction and reconstruction standards regulate a variety of grid construction schemes in areas with high reliability requirements, which can be flexibly selected and combined according to the actual situation. Among them, subcategory I is a typical recommended solution, and the wiring mode mainly adopts double-ring network and single-ring network, which is applicable to a wide range; Subcategory II is suitable for areas with tight passages, and the wiring mode mainly adopts two supplies and one backup and three supplies and one backup; Subcategory III is suitable for independent large-capacity user-intensive areas, and the wiring mode mainly adopts double-circuit direct supply switching stations.
- (2) T2-type grid: The T2-type grid construction standard regulates the urban and suburban areas where overhead lines are the mainstay, and the wiring is mainly single-connection, when the channel or interval is limited, the connection can be appropriately increased to increase the maximum allowable load rate of the line.
- (3) T3-type grid: T3-type grid construction standards regulate rural areas.
- (4) T4-type grid: T4-type grid construction standards are aimed at nonstandardized areas, it is suitable for areas that cannot be retrofitted due to factors such as users and channels, the recommended retrofit plan is mainly based on the local optimization of the existing power grid.

3.6. *Transition Grid Based on Far-Near Coordination*. In order to avoid repeated transformation and facilitate construction, the grid frame in the transition year should be

TABLE 1: Comparison of meshing methods.

Method	Division basis	Grid features
Basic method	Merge plots with consistent power supply requirements or land use functions into grids according to control regulations, or divide power supply capacity or scope based on standard wiring	Different planners may get completely different results: The control planning is more random, and the influence of electrical equipment on the grid division is ignored; there is no specific and clear standard wiring and power supply range division method
Author's method	Based on the goal of economical, reliable, and concise grid structure, follow the principle of selecting the nearest load backup station and grid load to achieve interstation transfer as much as possible, and optimize the division and coordination of the power supply range of the grid on a global scale	Different planners can get basically the same grid optimization scheme

TABLE 2: Classification of grid construction standards.

Grid standard	Supply area classification	Load/MW	Recommended typical wiring patterns	Reliability rate target (RS-3)
T1	General areas (A+, A and B cores)	32,16–48	Double ring network, “N-1”	≥99.999%
	Channel tight (A+, A and B cores)	24,16–24	Two for one spare, three for one spare	≥99.999%
	High-capacity user-intensive (A+, A, and B cores)	32,8–48	Double direct supply opening and closing	≥99.999%
T2	Class B non-core	32,16–48	Segment moderate contact, “N-1”	≥99.965%
T3	Class C and below	As the case may be	Multisegment moderate contact, “N-1,” single radiation	≥99.897% (class C) ≥99.828% (class D)
T4	Unable to oil pot due to user influence	As the case may be	As the case may be	Depends on user needs

coordinated with the goals of the long-term year, fully consider the existing grid frame and equipment, combine the construction sequence of municipal and substations, seize the construction opportunity, and carry out construction and renovation piece by piece.

3.6.1. New District. It is constructed according to the main line of the target grid, so as to “build a new piece and form a piece.”

- (1) Areas where the transition year load is close to the prospect year refer to the networking mode of the Vision Year, and the target wiring method of the power supply grid is built at one time.
- (2) When the transitional annual load is immature, the number of main supply lines in the grid can be reduced, or multiple grids can be connected in series or parallel to share the power supply; after the new station is put into operation, it will be accessed through π personnel or directly [10].

3.6.2. Easy to Transform Area. The areas that are easy to transform are the areas that are less affected by relevant factors in the transition to the target grid; however, it is not suitable for large-scale transformation and should be “renovated and perfected.”

- (1) Taking the new substation as an opportunity, transform the grid into pieces and make a reasonable transition to the target grid

- (2) Taking the new construction of medium voltage lines as an opportunity, adjust the trunk, switch branches, and make a reasonable transition to the target grid

3.6.3. Hard-to-Rebuild Areas. Difficult-to-transform areas are areas that are difficult to transition to the target grid due to factors such as users and channels, “maintain the existing pattern and clarify the relationship in part,” and appropriately adjust the trunk and branches and their contact methods.

4. Analysis of Results

The authors’ method has been successfully applied to several provincial capital cities. The following is an example of a planning area, the specific application of the medium voltage distribution network planning method based on the optimal division of the power supply grid is expounded.

4.1. Trunk Channel Layout. For the areas where the construction of the existing corridors is relatively mature, the existing corridors should be mainly used. The new channel should fully consider the feasibility of the power corridor, mainly considering the outlet of the newly put into operation substation, but it should not pass through the Grand Canal and railway in the area, and try to distribute along the main road. Taking into account the four factors of existing channels, new channels, load distribution, and newly added points, a “three horizontal and three vertical” trunk channel layout is formed.

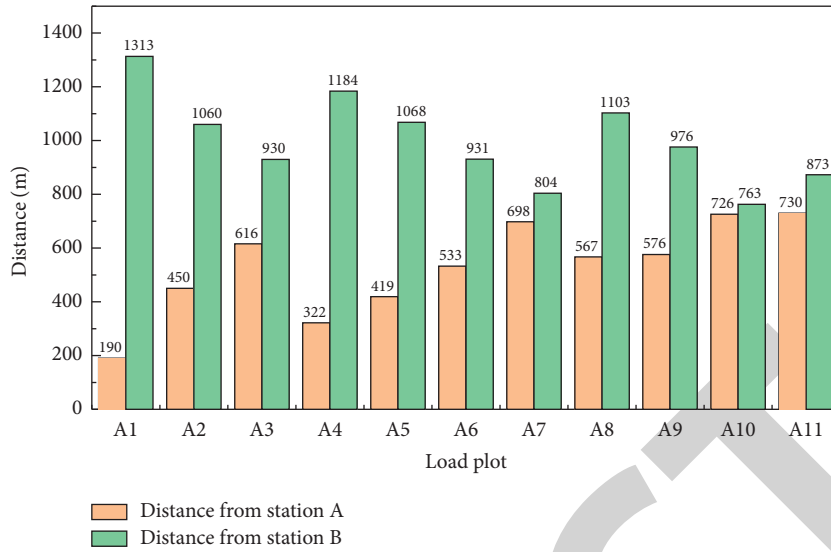


FIGURE 5: The distance between the load center and the substation of each load block in a grid (station A).

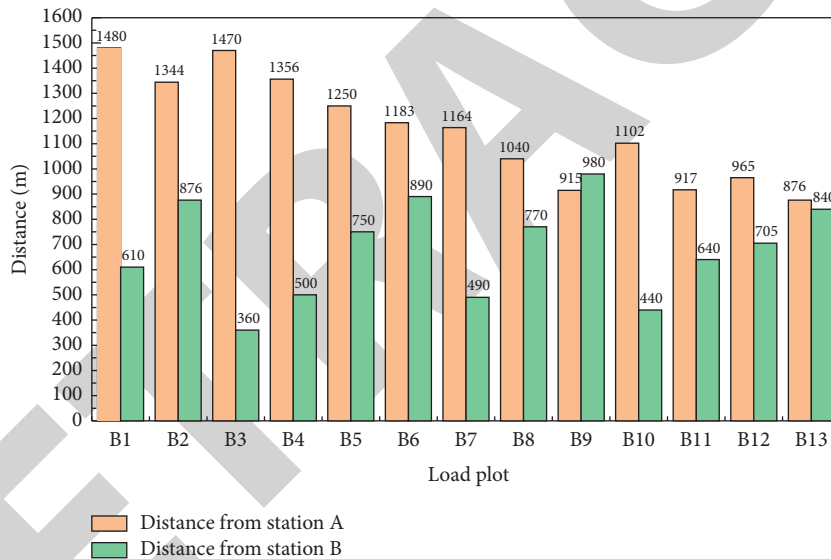


FIGURE 6: The distance between the load center and the substation of each load block in a grid (station B).

4.2. *Mesh Optimization Division.* Based on the spatial load prediction results, the substation layout planning should be carried out. There are five 110 kV substations in the planning area of the target year, there are five 110 kV substations outside the area. Constrained by the layout of the road between the stations and the grid optimization method proposed by the author, the grid chain of the target year is obtained, which contains a total of 12 contact chains. Taking Zhaohui grid as an example, considering the principle of grid division not crossing the canal and main road network, combined with the load size of each block and the distance

between the load center and the substation (approximately considered as a straight-line distance), the division results are given, as shown in Figures 5 and 6.

4.3. *Construction of Target Grid.* Combined with the layout of the main channel in the planning area and the grid chain of the target year in the planning area, the manual planning method is used to obtain the results of the medium voltage line routing along the street. By the target year, each power supply grid in the planning area will use two substations as

power points, the power supply range of the main lines of each grid is limited to this grid, the lines between grids will not be connected, and the line connection rate will reach 100%, and all meet the N-1 check.

4.4. Grid Transition Scheme. In 2018, no new substations were put into operation, and the construction and renovation projects of several more mature grids in the south were mainly arranged according to the current situation; From 2019 to 2022, the northwest grid will be gradually improved in combination with the new northwest substation, from 2022 to the target year, the northeast grid will be gradually improved in combination with the new northeast substation. Before the target grid is built, each grid is constrained by the target grid according to actual needs, focusing on solving problems such as heavy overload and not meeting N-1.

5. Conclusion

Following the basic planning concept of “technically feasible and economically optimal,” and on the basis of overall planning, the author proposes a medium-voltage distribution network planning idea and method based on the optimal division of power supply grids, the main conclusions are as follows:

- (1) The purpose and principle of grid division are clarified, and the definition of grid is given, combined with the layout of the main channel and the power supply radius constraints, a scientific and standardized grid optimization division method is proposed, so that the division results of each grid power supply range after global coordination are relatively certain or even unique, the corresponding grid planning results tend to be globally optimal, that is, economical, reliable, and concise.
- (2) Compared with the traditional mesh division method, a mesh division scheme with better consistency can be obtained according to the purpose, principle, and method of mesh optimization division, therefore, the complexity of planning can be reduced through relatively independent power grid planning in each optimized grid, and the scope and degree of influence of subjective factors on the “economically optimal” planning scheme can be reduced, and at the same time, the certainty of planning results can be better achieved.
- (3) The optimal grid division method is realized automatically by computer programming, and with manual intervention, ideal grid division results are obtained; It should be noted that, after clarifying the purpose and principle of grid optimization proposed by the author, even if only manual planning is used, a basically consistent grid optimization scheme can be obtained for different planners. This is especially true for the urban distribution network with more interstation connections.

- (4) In order to avoid repeated reconstructions and facilitate construction, the principle of piece-by-piece construction and reconstruction in transition years is proposed. For the transitional grids in the new area, the area that is easy to transform, and the area that is difficult to transform, specific countermeasures are put forward to build a new one, renovate a new one, maintain the existing pattern, and clarify the relationship between parts.

Due to the limitation of the length of the paper, the author did not elaborate on the following issues: Substation planning optimization, trunk channel layout construction, load optimization clustering method involving grid refinement of interstation connection, grid division of intrastation connection and radial connection, and automatic routing of grid trunk lines. In addition, for the situation where the influencing factors (mainly load) are relatively uncertain, on this basis, flexible planning concepts and methods that are more adaptable to future environmental changes can be introduced, which will be further studied in future work.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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