Research on Grid Planning Method of Distribution Network Based on Artificial Intelligence Technology

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Abstract. In order to improve the reliability of distribution network, a grid planning method of distribution network based on artificial intelligence technology is studied. Firstly, according to the principle of grid division, the planning area is divided into several planning grids reasonably; the existing problems of the existing distribution network are analyzed systematically, and the weak links of the existing distribution network are summarized. According to the current grid structure, load forecasting results and planning objectives of planning grid, the target grid and transition grid of planning grid are determined, and the load forecasting method of distribution network is designed to improve the scientificity of distribution grid division. The experiments show that after the grid planning of the distribution network in a planning area, the target grid of the distribution network is strong, the power supply range is clear, and the power supply reliability is high, which verifies the effectiveness and scientificity of the method.

Keywords: Artificial intelligence · Distribution network · Grid planning · Load forecasting

1 Introduction

With the development of society, power resources have become the main driving force for social development. As an important part of the entire power grid, the distribution network is mainly responsible for providing continuous and stable power supply to end users [1]. Especially with the rapid growth of social power consumption, traditional distribution network planning methods can no longer meet the large-scale medium-voltage distribution network. Under this situation, it is necessary to strengthen the reform of the distribution network to ensure the current power system The reliability and safety of power supply, so the rationality of distribution network planning is directly related to its power supply capacity and power supply quality [2]. The distribution network is an important part of the smart grid. It directly faces the end users and is an important infrastructure serving the people's livelihood. Therefore, the distribution network must be built into a strong, safe, reliable, green, low-carbon, cost-effective, and powerful

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resource. First-class distribution network with configuration capability, service guarantee capability and risk resistance capability. In the traditional "top-down" power grid planning, there are many problems, which restrict the quality of power supply. The grid power planning based on power demand and regional regulatory planning can improve the work efficiency and service level of distribution network. This paper mainly takes the grid planning of medium voltage distribution network as the research breakthrough point, and makes a detailed study on the grid planning of power grid, so as to improve the comprehensive benefits of distribution network planning, ensure the reliability and safety of power supply of the whole distribution network, and meet the power demand of power users to the greatest extent.

2 Grid Planning Method of Distribution Network

2.1 Grid Division Principle of Planning Area

In recent years, in order to build a strong distribution network and meet the growing power demand of urban construction and residents, power grid enterprises focus on the development of distribution network, actively connect with government departments, and carry out planning results evaluation [3]. In this context, the "grid" distribution network planning mechanism is proposed, and the partition load forecasting model is constructed to improve the rationality and practicability of the medium voltage distribution network planning. In this process, it is necessary to first determine the zoning principle and count the nature of the partition, so as to lay the foundation for the next step of the zonal load forecasting.

The use of artificial intelligence technology in the grid planning of the distribution network is to divide the area to be planned into several areas according to the classification of the distribution network power supply area, the difference in the nature of the land, and the degree of development. The power supply ranges of these areas are relatively independent and will not overlap, starting from the terminal demand of the power market, meeting the needs of users as the goal and guide, breaking the previous top-down planning method, turning to bottom-up, adopting the planning concept of low voltage first, high voltage, refer to the typical load forecasting model carries out differentiated system load forecasting. Through the optimization and improvement of traditional methods, it is expected to realize the appropriate medium-voltage grid structure in different areas, and extend this idea to the high-voltage distribution network structure and layout. Taking into account communication, power distribution automation and other content, the planning goal is finally completed and balanced with the development of the planned area [4]. The distribution network planning scheme is shown in Fig. 1.

Through practice and calculation, the following problems exist in the urban distribution network planning scheme.

(1) When the power grid is in full operation, the short circuit often occurs in the power system;
(2) The variable capacitance can not meet the supply and demand gradually;
(3) The load of distribution line is too large;
(4) Distribution network construction funds are insufficient.

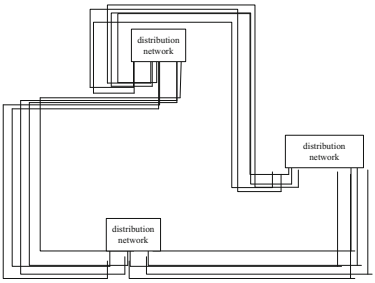

Fig. 1. Traditional distribution network planning scheme

Based on this, it is necessary to clarify the basic expected planning goals when carrying out grid planning. This article mainly uses artificial intelligence technology to determine the scope and content of the plan, determine the base year, level year and saturation year of the plan, and propose relevant planning methods and evaluation standards, and then successively carry out planning for the target area [5]. The structure of regional distribution network is shown in Fig. 2.

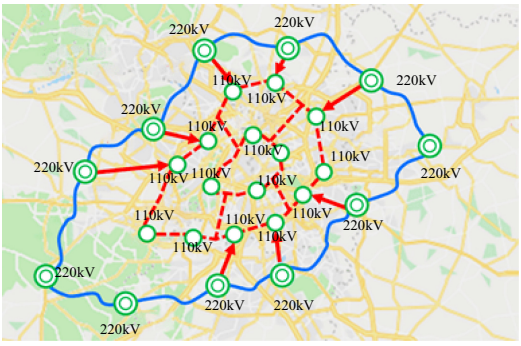

Fig. 2. Regional distribution network structure

In the above process, the use of artificial intelligence technology for grid division, load forecasting and distribution network structure is the core of grid planning. Distribution network structure planning includes three items: substation site selection, power supply range determination, and distribution network line planning [6]. Determine the approximate scope of each power supply area according to the regional scope and administrative level, and make corresponding supplements to the load density requirements of each power supply area according to artificial intelligence technology. There are overlapping parts in each power supply area and should be classified to a higher level power supply area.

The main principles of grid division of planning area are as follows:

Grid division principle of planning area 1: Based on the current situation of medium voltage distribution network, the blocks with different land use properties and development depth are classified according to the regional regulatory detailed planning [7]. At

the same time, the load forecasting results of each plot are standardized, and the planning area is subdivided into several grids according to the location of the station source point, the area size of each plot, the load nature, and the conditions of river water area and long-term road planning.

The grid division principle of the planning area 2: The size of each grid should be determined according to the power supply capacity of a set of standard wiring. Each grid should be able to independently undertake the normal power supply tasks in the area, meet the power load demand in the area, and reserve spare capacity to meet the future load growth needs.

The principle of grid division of the planning area 3: The layout of medium and long-term substations should be planned in combination with artificial intelligence technology, and each grid power point should be determined. The selection of power points should meet the principle of proximity.

Principle 4 of grid division in planning area: in principle, the power supply points in each grid shall be from two different substations, and the power supply lines of the same substation shall be from different bus sections.

2.2 Optimization of Grid Generation Method for Distribution Network

Based on the research and analysis of the theory and application of grid planning for domestic distribution networks, and relying on the support of actual engineering projects, an optimization method suitable for grid planning is proposed [8]. Grid is the smallest unit of grid planning and an important foundation for user access, operation management, maintenance management, reliability management, and subsequent project expansion. The usual method of grid division is to divide several small-area plots in a certain sub-region in the planning area into a grid. The plots in the same grid are adjacent and have the same level of power supply area. The nature of the land is, the load density and the power quality requirements are basically the same. Repeat the operation until the entire planning area is divided into the smallest functional unit grid.

According to the relevant power supply area division standards, combined with artificial intelligence technology to determine the planning area power supply category, and use the corresponding technical standards for distribution network construction [9]. On this basis, the grid structure, equipment, operation and other indicators, such as power supply reliability rate RS-3, line power supply radius, insulation rate and other indicators should be taken into account. Combined with the construction and transformation scheme of primary grid structure and equipment, the main indicators of distribution network in the target year of the planning area are proposed. According to the various problems of the current distribution network analysis, combined with the grid division of the planning area, the project scheme is reasonably formulated by using the principle of differentiated planning. Based on the analysis of the current situation and the project schemes in the planning level year, the artificial intelligence technology is used for closed-loop evaluation, and the planning indicators are compared intuitively to verify the planning effect of the grid planning method for distribution network. The optimization of the grid planning process of the distribution network is shown in Fig. 3.

According to the degree of power consumption, the basic grid can be divided into the following three cases:

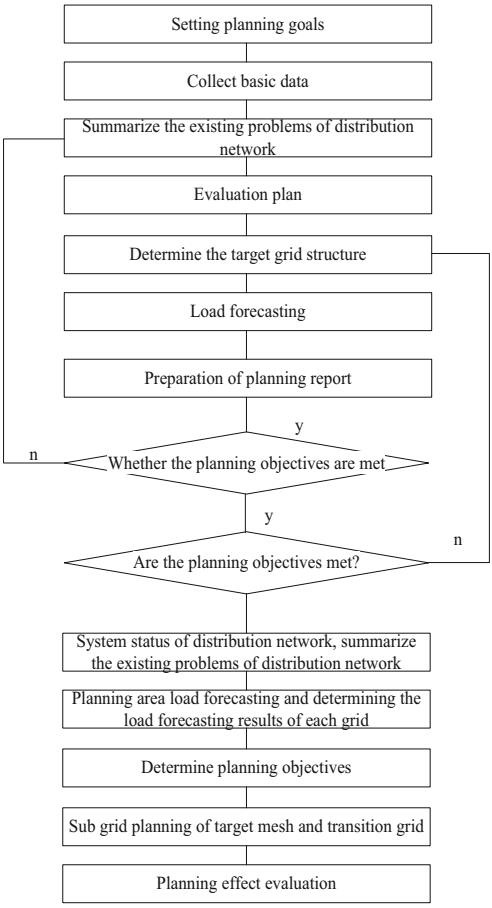

Fig. 3. Optimization of grid planning process for distribution network

The load in the mature grid is concentrated in dense areas such as the city center. This area has been developed to the greatest extent, with high load density and low scalability, and the load has become saturated. Developing grids are generally located in new urban development zones and planned areas. This kind of land has a good room for economic growth and a faster development speed. The load density and power consumption are also increasing year by year following the economic development speed, and the prospective load and increase the space is very clear. Uncertain grids are generally located in the suburbs at a certain distance from the city center. Residents of this kind of plot have limited electricity consumption and low load density. Municipal planning and construction and investment in plant construction are not clear. There is no room for increase in electricity load. After the grid is divided, large-scale adjustments are generally not carried out. In some cases, there is a big gap between the load increase and the expected, and the municipal planning and construction plan has to be adjusted and changed. The divided grid needs to be re-adjusted. The method is as follows:

The load growth in the grid is far more than expected, and it is close to the extreme conditions of the line load, and even overload operation for a long time, the power supply quality and reliability are significantly reduced, which affects the safe operation of the distribution network. At this time, the original grid should be divided into two, three or more sub grids through system analysis according to the distribution of roads and users' electricity in the grid the connection structure of grid structure shall be adjusted accordingly [10]. In this case, if the load growth rate of adjacent grids is also slow, the original grid and adjacent grid can be combined into a new grid. After a period of time, the municipal planning has been adjusted, and the nature of land use in the grid has been determined. In this case, the grid should be re divided, and the load forecast of the target area with reference to the historical experience data, and the number of grid splits can be determined according to the results.

2.3 Distribution Grid Coding

After grid division, each grid needs to be coded. In order to facilitate management, uniform coding rules should be set up, and the grid coding should have good recognition characteristics. The grid coding is composed of grid number and grid features to ensure that the coding of each grid is not repeated. The first item of grid number is the first letter of local city Pinyin, the second item is the first letter of district or county, the third item is the first letter of Pinyin of street or development zone, and the last item is the sequence number of grid. Each item is connected by the character "one". The serial number of grid is numbered according to the sequence rules of left to right (from west to East) and from top to bottom (from south to North). The grid feature code is composed of four items, with a total of five characters. Its representation format is abnnc, the details are shown in Fig. 4.

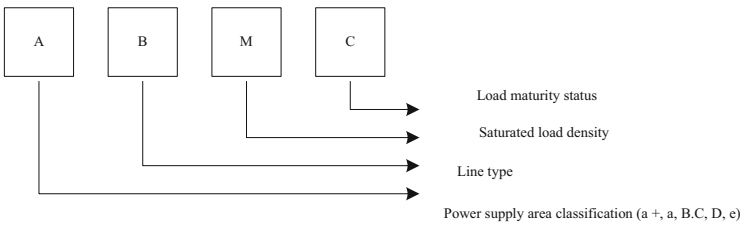

Fig. 4. Composition of grid feature code

The lines in Fig. 1 represent different transmission lines. The first item (A) of the feature code indicates the classification of the grid's power supply area, which occupies one character. According to the DLT5729-2016 guideline, the power supply area can be divided into six types from A+ to E; the second item (B) represents the network the line form in the grid, which occupies one character, is divided into three forms: full cable (A), cable and overhead line combination (B), and full overhead line (C); the third item (nn) represents the saturation load of the grid Density value (unit MW/km^2), occupies two characters, generally rounded to two integers; the fourth item (C) represents the

maturity of the load in the grid, occupies one character, and is divided into mature and stable areas (A), basic built-up area (B), under-construction area (C) and uncertain area (D).

In the process of traditional distribution network operation, there are often some problems such as unreasonable distribution of substations, unbalanced load, low capacity utilization efficiency, overlapping of power supply areas, etc., which often lead to the sharp increase of management workload and maintenance difficulty in the later stage, which can not realize fine management. In order to avoid these problems, a hierarchical structure is established for the grid of the distribution network. According to the three voltage levels of high, medium and low, the distribution network is divided into three layers: L1, L2 and L3, as shown in the Fig. 5.

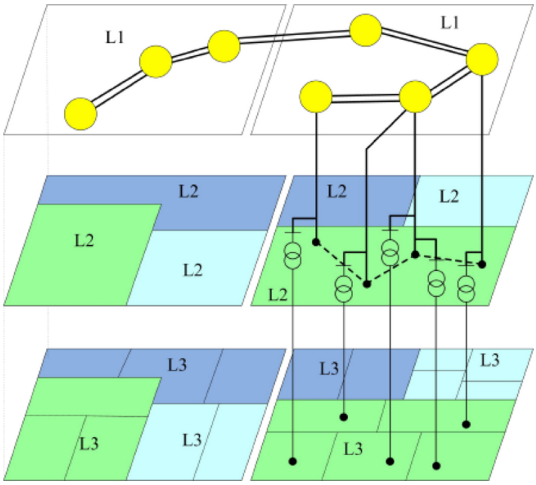

Fig. 5. Schematic diagram of grid layered structure

After the power distribution network is divided into grids, it can ensure that the scope of power supply is extremely clear, so that the large area can be divided into several small areas to ensure the rationality of power supply and distribution, and effectively avoid the phenomenon of cross power supply during the power supply process. In this way, the stability of the power supply in each area can be guaranteed, and the occurrence of short circuits in other phenomena can be avoided. Ensuring power supply from more than two power points in each area can effectively avoid the limitation of power supply from one power point. If only one power point is used for power supply, once a circuit failure occurs, stable power supply in the area cannot be achieved and the distribution network is gridded planning can make the power supply more flexible and improve maintenance efficiency. Grid divides the power distribution into different small areas. When a fault occurs, only one area needs to be repaired. When a power failure occurs, only one area needs to be stopped to avoid large-scale power outages. Affect people's normal life.

According to the concept of grid planning, a bottom-up approach is adopted to carry out layered work on the distribution grid, namely the form of L3 → L2 → L1. The specific process is as follows:

According to the user's reported capacity and the nature of electricity consumption, in order to meet the user's electricity demand as the guide, according to the nature of land use, load nature, plot size, rivers, roads and other physical and geographical boundary conditions, the target area is divided into several grids, each grid has a single basic function. At this time, the grid level is layer L3, and then load system is carried out for the target area. According to the planning objectives, load forecasting is carried out in the planning area, and the existing distribution network situation is evaluated.

According to the load situation and grid division situation of the L3 layer grid, combined with the target area distribution network structure planning, distribution network capacity and physical geographical conditions and other factors, for the purpose of optimal power supply, several power consumption properties are similar and geographically located the adjacently connected L3 layer grids are combined to initially generate L3 layer grids.

According to the combination and division of L2 grid, combined with the urban construction planning scheme of the target area, the power supply scope and power supply capacity of the existing substation, the required new substation capacity is calculated, and the location of the substation is planned according to the grid structure of the target area, so as to meet the corresponding power supply capacity and outgoing line demand. After the L1 network scheme is formed, the L1 grid layout is solidified, According to the relevant grid division and distribution network planning evaluation index, the rationality of the combination scheme of L2 grid generation is comprehensively evaluated. According to the evaluation results, the L2 grid is modified and adjusted to achieve the optimal division scheme.

2.4 Grid Load Forecasting of Distribution Network

The primary content of grid planning is to divide the target planning area into grids with a single function according to the nature of electricity consumption and natural geographical conditions. Different application scenarios adopt different forecasting methods. In the grid planning load forecasting process, not only the total area load must be predicted, but also the growth characteristics and location of the load must be clarified. It has very obvious spatial characteristics. Load forecasting must adopt a spatial load forecasting model that can reflect the distribution of urban power supply areas to ensure that the "grid" load forecasting results have the smallest error. According to the different forecasting time and duration in the future, load forecasting can usually be divided into the following categories, as shown in the Table 1.

According to the current social development trend and the progressive mode of the distribution network, the traditional power distribution method can no longer meet the needs of social development. Therefore, relevant departments and staff must re-examine the reasonable planning of the distribution network, change their ideas, and innovate the way of distribution network planning. Based on this, the load forecasting method of distribution grid planning is analyzed, including:

Table 1. Classification method of load forecasting.

Category	Entry	Characteristic
Time classification	Long term load forecasting	10–30 years
	Medium term load forecasting	5–10 years
	Shorter term load forecasting	1–5 years
	Short term load forecasting	Within 48 h

District load forecasting: the relevant departments and staff should refuse the simplification of the forecasting method, conduct in-depth research and analysis from multiple perspectives, use diversified load forecasting methods to predict the power consumption of each power supply area, and get the average value from it, so as to minimize the prediction error, optimize the distribution mode, and put forward constructive distribution scheme according to the prediction results.

Spatial load forecasting: According to the division of different power supply areas, relevant departments and staff make statistics on the current load status of each block based on the actual situation of regional power distribution. Spatial load forecasting is based on the demand for land parcels, combined with load forecasting models to predict the long-term load situation of the land parcel, formulate a forecasting plan suitable for the long-term development of the land parcel, and further make a reasonable distribution network grid Planning scheme.

Suppose that an L2 level network contains n L3 level grids with single function, l is the maximum load of each L3 level grid, and S is the corresponding land use area of each L3 level grid. Then the load density of each L3 layer grid is as follows:

$$\rho_i = L_i / S_i \tag{1}$$

For the built community, according to the development status of the community and the load density of the typical mature area, set the load density index of each L3 layer grid in the future m year or saturation year as p; for the community under construction, according to empirical data, select the load density index for the future saturation year. Let r be the load weighting coefficient of each L3 layer grid, and k be the load simultaneous rate of each L3 layer grid in the m-th year or saturation year. Then the predicted load of the nth year or saturation year of the L2 grid is

$$P = \sum_{i=1}^{n} r_i k_i \hat{\rho}_i S_i \tag{2}$$

Preprocess the collected information, analyze the processing results, and analyze the relationship between the information output and input components. The specific calculation formula is as follows:

$$\mathrm{f}(\mathrm{x}_n, y_m) = P \frac{\lambda(\mathrm{x}_n, y_m)}{\sqrt{(\mathrm{x}_n)(y_m)}} \tag{3}$$

Among them: $\lambda(x_n, y_m)$ represents the covariance between input information x_n and output information y_m; k represents the total amount of information. According to the formula, the normalized calculation formula of input information x_n and output information y_m can be obtained:

$$x_n^{'} = \frac{x_n - x_{\min}}{x_{\max} - x_{\min}}, y_n^{'} = \frac{y_n - y_{\min}}{y_{\max} - y_{\min}} \tag{4}$$

The formula is weighted to obtain the input data vector expression, as shown in the formula:

$$x = \left(f_1\left(x_1', y'\right)x_i', f_2\left(x_2', y'\right)x_{i-1}', ..., f_1\left(x_j', y'\right)x'\right)^T \tag{5}$$

In the formula: T represents a cycle, and the weighted input information vector can be obtained by this formula. The results of short-term load forecasting are usually used to guide the calculation of generator start-up and shutdown plans, maintenance plans, power distribution and operating costs. Medium- and long-term load forecasting is an important part of power grid planning. The forecast results usually determine the distribution network scale, network structure and investment quota in the target planning area. Medium- and long-term load forecasting is usually coordinated with the municipal planning, which is related to the future economic development speed and scale of the planned target area. Load forecasting is to predict the future electricity consumption situation. Due to various uncertain factors such as weather changes, holidays, emergencies, the accuracy of historical data, municipal planning adjustments, and human factors, the predicted results will have certain errors. In order to reduce the error and improve the accuracy of the forecast, the usual practice is to ensure the completeness and accuracy of the data when collecting historical load data, predict the load of different types and scenarios, and check and correct the forecast results. This improves the accuracy and scientificity of grid planning for the distribution network.

3 Analysis of Experimental Results

Based on the analysis and summary of the current situation of a planned regional power grid, there is still a big gap between the "first-class distribution network" in the connection rate of medium voltage lines, n−1 passing rate of medium voltage lines, average power supply radius of medium voltage lines, insulation rate of medium voltage lines, and power supply reliability rate (RS-3). Written according to the requirements of C++, Microsoft can add multiple functions, including the system throughout the windows program, as well as user interface and file operation. The load forecasting results of a planning area in the target year are shown in the Table 2.

Based on the test results in the above table, it can be seen that in the actual application process, the proposed distribution network grid planning method based on artificial intelligence has relatively high accuracy for regional distribution network load forecasting, which is basically consistent with the target predicted value. Further comparison is made between the current method and the distribution network grid planning error under this method, as shown in Fig. 6.

Table 2. Grid load forecast results of distribution network.

Region	Total load/MW	Target load/MW
Grid 1	6.08	6.10
Grid 2	10.24	10.25
Grid 3	13.46	10.44
Grid 4	17.82	17.80
Grid 5	20.44	20.40
Grid 6	22.45	22.45
Total/considering the simultaneity rate of 0.7	66.35	66.20

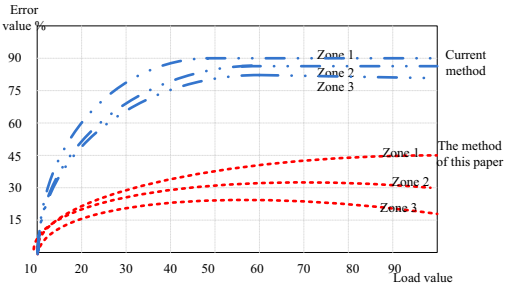

Fig. 6. Comparison test results

Based on the above detection results, it can be seen that the error degree of the grid planning method based on artificial intelligence is relatively low in the practical application process, which proves that the practical application effect of the method is better. Through the grid planning, the main indicators of the distribution network reach the level of "first-class distribution network". The distribution network structure is strong and the power supply reliability is high, which verifies the effectiveness and scientificity of the distribution network grid planning method. In this paper, a grid planning method of distribution network is proposed. The grid planning of the planning area can achieve the following effects.

(1) The power supply range of the medium voltage line of the distribution network is clear.
(2) The target grid and transition grid of the distribution network are strong and reliable.
(3) The main planning indicators of the distribution network can reach the level of "first-class distribution network", and promote the scientific development of the distribution network.
(4) Applying the above method to grid distribution network planning in a certain district of a city, the planning effect is obvious, which verifies the effectiveness and scientificity of the method.

4 Conclusion

With the increase of social production and domestic electricity consumption, power enterprises must carry out grid planning of distribution network to provide power supply quality of distribution network. This requires that in the process of grid planning of medium voltage distribution network, strictly follow its planning principles, and fully combine with the economic development level of distribution grid region, continuously promote the grid planning of medium voltage distribution network, In order to ensure that the power supply of the whole distribution network is more reliable and safe, so as to meet the power demand of power users to the maximum extent.

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