Research Article

Research on Data-Driven Distribution Network Planning Method

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With the development of the intelligent and interactive power system, the elements of distribution network planning continue to increase. The distribution network connects the transmission system and individuals, directly affects the individual’s power consumption experience, and is a key link in the power system. A reasonable planning scheme can not only improve the power supply capacity and reliability of the distribution network but also fully apply the data of each system in the distribution network to realize the optimal planning of the medium-voltage distribution network driven by data. Firstly, this paper constructs the CIM model and the distribution network topology model and establishes the wiring pattern recognition feature library. The network reconstruction and planning method research was carried out for the target line, and a typical operation scenario of the distribution network was generated. At the same time, based on the time period network loss index, the distribution network configuration optimization model and distribution network expansion planning model are established, and the solution method of the distribution network reconstruction and expansion planning model is expounded. A reconstruction optimization scheme with the best overall network loss performance is in the network operation scenario. The experimental results of the final example show that based on the proposed time period network loss index, the overall operation loss of the distribution network in a period can be calculated more accurately, and the optimized planning scheme is more suitable for the load power consumption characteristics of the region, and the method has certain feasibility.

1. Introduction

Since the reform and opening up, my country’s economy has matured rapidly, people’s living criteria have been constantly heightened, and the demand for electric energy has continued to rise. With the continuous acceleration of my country’s socialist modernization handle, electricity plays an increasingly important role in all fields of society. Electricity supply and safety have become the basis for national, social, and economic development and are related to national security issues. With the rapid construction of modern allocation net and the construction of power big data platform, the informatization and automation level of allocation net have been greatly improved. The wide application of allocation net GIS system, production management system, operation management system, and allocation net automation system makes the data analysis between different systems of the allocation net easier, and provides a solid foundation for the application of big data to the planning and optimization of the allocation net. Base. In 2016, my country’s electricity “13th Five-Year Plan” clearly stated that it is necessary to increase the construction of the allocation net. The “13th Five-Year Plan” period, a modern allocation net that is compatible with a well-off society, will be basically built [1]. The implementation of the “13th Five-Year Plan” for electric power has significantly accelerated the transformation and construction of my country’s allocation net system, and the power supply capacity, safety, and reliable of the allocation net have been greatly improved. However, there are still many problems in the current allocation net operation, such as the speed of social development is too fast and the load is not balanced, resulting in heavy overload problems in allocation net lines and station areas [2]. Therefore, the optimization plan and structure of the
allocation net still need to be improved. The 10 kV medium-voltage allocation net is the core component of the allocation net, which directly affects the individual’s power experience and is also a key link in the power system. A suitable allocation net grid planning optimization scheme should not only have good performance in uncertain scenarios but also improve the power supply capacity, reliability, and equipment utilization of the network, which is more conducive to social and economic development [3]. If there are defects in the planning and optimization scheme of the allocation net grid, it may lead to unstable network operation, poor power supply capacity and reliability, and even detrimental to the long-term development of society [4]. Therefore, it is necessary to study the optimization planning method of 10 kV medium-voltage allocation net.

The identification of the wiring pattern of the allocation net feeder is an important part of the distribution planning and optimization work. This work mode, which mainly relies on the manual judgment of planning staff to screen and integrate different system data and problems, and then propose corresponding planning and construction projects based on experience, and then carry out corresponding calculation and analysis comparison, not only has a huge workload but also because of the data. The lack of calculation and analysis tools leads to the remediation plan relying more on manual experience and lack of rigorous calculation and analysis. In the previous allocation net optimization planning work, extreme situations are often considered, which may not match the actual situation. So as to make the allocation net optimization planning scheme more suitable for the actual allocation net, it is more necessary to consider the actual operation scenarios of the regional allocation net. With the gradual deepening of the construction of the big data platform, the allocation net planning has the opportunity to obtain more sufficient operation data than before, so that based on the data-driven idea, according to the allocation net GIS system, production management system, allocation net automation system, and operation comprehensive analysis of data from various systems such as management systems. We realize the analysis and simulation of the typical operation scene of the allocation net under the data drive. By considering typical operation scenarios, combined with the existing structural requirements of the power grid, the network can be more reasonably optimized to improve the network operation performance and better arrange the investment of capital resources. With the more and more extensive application of artificial intelligence algorithms in practical work, the work that could only be done manually in the past can be realized through intelligent discrimination and analysis of computers.

2. Research Status of Optimization Planning Methods for Distribution Network at Home and Abroad

With the rapid construction of the modern allocation net and the construction of the power big data platform, the informatization and automation level of the allocation net have been greatly improved, and the wide application of GIS systems, production management systems, and allocation net automation systems makes the data analysis of the allocation net easier and lays a solid foundation for the data-driven optimization planning of the allocation net. With the more and more extensive application of artificial intelligence algorithms in practical work, the work that could only be done manually in the past can be realized through intelligent discrimination and analysis of computers. In the actual allocation net optimization planning work, the export and comprehensive analysis of the allocation net historical data are mainly done manually, and the comparison of the implementation effects of different planning schemes requires a lot of manual calculations. This work mode, which mainly relies on the manual judgment of planning staff to screen and integrate different system data and problems, and then propose corresponding planning and construction projects based on experience, and then carry out corresponding calculation and analysis and comparison, not only has a huge workload but also because of the data. The lack of calculation and analysis tools leads to the remediation plan relying more on manual experience and lack of rigorous calculation and analysis.

2.1. Research on Optimization and Reconfiguration of Distribution Network

Distribution network reconfiguration is an allocation net optimization method that enables the allocation net to achieve the optimal operation mode by changing the opening and closing states of the segment and tie switches in the allocation net, on the premise that the allocation net is connected and radiated. The optimization goals of allocation net reconfiguration usually include balancing the load, reducing network losses, and improving power supply reliability [5–7]. On the time scale, we aimed at optimizing the network structure for the manipulation of the allocation net, while dynamic reconfiguration takes into account the time scale, and reconfigures and optimizes the manipulate of the allocation net within a period of time. Static reconstruction generally takes the typical load of a certain period as the object to optimize the allocation net structure, and the research focuses on the improvement of the optimization algorithm [8, 9]. In the literature [10], the inertia weight is introduced into the traditional firefly algorithm, and chaos is used. Theoretical adjustment of algorithm parameters, and the addition of an elite retention strategy to solve the problem of reconfiguration of allocation net with DG, improves the calculation speed and global performance of the algorithm. Dynamic reconstruction studies the real-time and dynamic optimization of the network structure during the manipulation of the allocation net. Usually, the specific operation modes of each time period are reconstructed, respectively [11, 12]. Reference [13] uses the interval number to DG and continuous load forecasting, uses the improved FCM (Fuzzy c-means) algorithm to divide the time period of the reconstruction, and uses the decimal particle swarm algorithm to solve the static reconstruction problem to achieve dynamic reconfiguration of allocation net.
The main problem of static refactoring is that refactoring in the face of a single typical operating scenario does not necessarily guarantee the optimal refactoring target for the entire period. The traditional typical scenario construction handle lacks scientificity and is often formed by using the maximum operation mode of the allocation net or the distribution transformer capacity combined with the load coefficient. Therefore, allocation net reconstruction scheme makes it to perform the best in the entire action period of allocation net. Strictly speaking, traditional allocation net reconfiguration belongs to the category of operation optimization. However, in recent years, power grid companies have put forward indicators of capital utilization efficiency and equipment utilization, and more reasonable arrangements for planning funds and planning project progress have become one of the very important considerations for planning departments. Due to the limitation of investment scale and project construction period, through reasonable transformation of distribution network, the power supply capacity of existing distribution network framework is fully explored, load distribution is balanced, network loss is reduced, and voltage level is improved. It is effective in the utilization rate of funds with equipment utilization to solve the weak links of the existing power grid.

2.2. Research on Distribution Network Planning. The research on distribution network planning develops with the development of society. The early research on allocation net planning is mainly about the location and capacity of power supply and the planning method of grid. From the perspective of time, load considerations can be divided into static load planning and dynamic load planning. From the perspective of planning objects [14–16], planning can be divided into subsystem planning and overall system planning [17–19]. Static load planning regards the load of the network as constant and considers the network planning in a relatively single scenario; dynamic load planning considers the load changes of the network and usually divides the planning into multistage planning. Subsystem planning is the planning for a single system of the allocation net, which can usually be divided into power subsystem planning and grid planning. The overall system planning is the planning for the overall system of the allocation net. The relationship is between the power supply and the grid. In the static programming model, the literature [20] used the 0, 1 mixed integer model for the first time in the circuit planning of the allocation net. In the dynamic programming model, reference [21] uses the dynamic load planning model to plan the allocation net substation, and the model solves the problems of the capacity, location, and construction time of the substation. In addition, the current allocation net planning model research includes economic model, reliability model, comprehensive model, and research on practical engineering application of allocation net planning. Reference [22] established a planning model with the goal of maximizing the annual comprehensive income of DG operators, the smallest annual comprehensive cost of power distribution companies, and the largest annual comprehensive income of individuals participating in demand-side response. Reference [23] added reliability cost calculation to the established multistage planning model and considered constraints such as energy storage charging and discharging constraints and extreme load scenarios. Reference [24] is oriented to the allocation net problem and designs a method for automatically generating planning schemes for solutions to different problems in the allocation net, and quantitatively forms an automatic generation method for various typical problems. The planning method is based on the established planning model. In terms of planning algorithms, the use of allocation net optimization planning algorithms can be roughly divided into mathematical optimization algorithms and heuristic algorithms. Because there are usually a large number of integer decision variables in the allocation net planning problem, there are often linear and nonlinear objective functions and constraints in the planning model. When solving large-scale system decision-making combinations, mathematical optimization algorithms are prone to the “curse of dimensionality” problem, so it is difficult to use traditional mathematical optimization methods to solve them directly. By contrast, heuristic algorithms are now also called artificial intelligence algorithms, which solve problems by simulating the evolution and development of things in life.

3. Building a Data-Driven Distribution Network Operation Scenario Method

A large amount of historical load data of the distribution network records the load operation characteristics of the allocation net. If an allocation net optimization planning scheme that is more in line with the regional load power consumption characteristics is required, the operating feature of the allocation net should fully considered. In this paper, the generation method of typical operation scenarios is introduced. Based on this, a period network loss exponent is put forward to assess the overall network operation wear and tear manifestation of the scheme in the whole scheduled time. The not-alike load amalgamation and each node of the allocation net are called the operation scenarios of the allocation net. Because the load points in the allocation net are different, the load type operation scenes of the allocation net are very large. Directly taking the node load value as the node load feature is able to rashly write the action scene of the allocation net at a fixed time hint, no more than its troublesome to depict the operation scene of the allocation net in a fixed time hint interval. To fully consider the historical operational site of the allocation net and reduce amount of calculation, this paper proposes a period network abrasion index in light of the typical operating scenarios obtained by clustering and the proportion of the duration of the scenarios, to achieve a practical overall evaluation of the reconstruction scheme. The allocation net is divided into several types of typical operation scenarios and their time proportions in a period of time. A network loss evaluation index is established as follows:
4.1. Distribution Network Reconstruction and Planning Based on Operation Scenario Analysis. The flow chart of distribution network expansion planning in this paper is shown in Figure 1. Through the work in the previous chapters, the current status information data of the allocation net have been obtained, including the topology structure of the allocation net and the historical load of the allocation net. On this basis, according to the installation information reported by individuals, the analysis and construction of the future allocation net are carried out, and feasible lines are pre-established. A planning model with the lowest comprehensive cost is established, and the genetic algorithm is finally used for optimization. Allocation net expansion planning refers to the reasonable expansion and optimization of lines and substations under the premise of satisfying regional development and current operation to further improve the power supply capacity and reliability of the network [25].

To improve the efficiency, the cost of the planning scheme should be reduced as much as possible while meeting the requirements of the expansion plan. In actual projects, the cost of allocation net expansion planning mainly includes the cost of new lines and the cost of operating losses after the lines are built. The goal of the allocation net expansion planning in this paper is to reduce the cost of new lines and operating losses, and establish a mathematical model with the lowest comprehensive cost as the planning optimization goal.

4.2. Genetic Algorithm for Distribution Network Reconfiguration and Planning. The distribution network reconstruction problem is a large-scale nonlinear mixed integer programming problem. It is easy to converge to the local optimum when solving so that the algorithm jumps out of the local optimum and calculates to the global optimum solution hot spot. The methods for solving nonlinear optimization problems can generally be divided into mathematical optimization algorithms and heuristic algorithms. Among them, the mathematical optimization algorithm is prone to the “curse of dimensionality” problem when solving larger system decision-making combinations. Therefore, the heuristic algorithm is more widely used in comparison, such as the use of the following algorithms: the experimental design of the three groups: the allocation net reconstruction modus in the light of the used to gain reconstruction scheme 1 as group 1, an average load scenario is established, and the reconstruction scheme 2 is solved as group 2 and is used for comparison as group 3. We calculate the period network loss index of each group of reconstruction schemes and the homologous equivalence net wear and tear power calculation, the homologous equivalence net wear, and tear power calculation under the power. The obtained reconstruction optimization scheme and corresponding index calculation are shown in Table 2.

The calculation results of the total network loss of each group of schemes are shown in Table 3. The average voltage in the node period of the allocation net under each scheme is shown in Figure 2.

It can be seen from Figure 2 that the reconfiguration optimization scheme obtained by the method proposed in this paper makes the average voltage of each node more balanced during the period, and the network operation is improved. Table 3 shows that the reconstruction scheme 1 has taken many by optimizing the network loss index of the scheme period. Compared with the reconstruction scheme 2,

\[
H_i = f_{\mu}(x)H_i, \quad (1)
\]

\[
H = \sum_{i=1}^{K} H_i, \quad (2)
\]

In formulas (1) and (2), \(f_{\mu}\) is the network fray count function in the \(i\) typical operating script, which originates from the propulsion spread calculation equation, \(x\) is the allocation net reconstruction scheme, the switching condition vector, \(t_o\) is the time occupation the \(i\) operational site ratio, \(K\) is the quantity of representative scene, \(H_i\) is the network loss index of the \(i\) scenario, and \(H\) is the network loss index of the entire period, all in power units.

Since the calculation of the time period network loss index requires the calculation of the network loss index of each typical scenario, the accuracy of the network loss index of each scene is the premise of the validity of the time period network loss index. To verify the validity of the proposed network loss index during the period, the load data of an allocation net for 30 days is analyzed and calculated in the scenario. The network loss of all actual scenarios in various scenarios is used as a comparison, and the calculation results are shown in Table 1.

The actual network loss in the scenario in Table 1 is the precise network loss obtained after the power flow calculation for all the monitoring sections classified in the typical scenario, which requires a large amount of calculation. The scenario network loss index comprehensively considers the network loss and its time proportion corresponding to typical scenarios, which is different from the network loss. However, the data in the table show that the use of the time-scenario network loss index can correctly characterize different scenarios while reducing the calculation scale. The relationship between the sizes of the network loss shows the effectiveness of the index to characterize the network loss of the allocation net.

4. Reconstruction of Distribution Network and Model Planning

Based on the idea of comprehensive analysis of distribution network representative scene, combined with time period network abrasion index, a mathematical model of allocation net reconfiguration optimization and planning is established. Due to the high global requirements of the algorithm to solve the model, a relatively mature genetic algorithm was selected to optimize the model. The algorithm coding method and the method of judging the effective solution were introduced, and the feasibility of the method was verified by an example analysis.
the performance is better in the whole period, and the actual quarterly total compared with scheme 2, the network loss is decreased by 42.54 MWh. Compared with scheme 3 without the optimization of allocation net reconstruction, the grid power scheme 2 is decreased by 298.88 MWh. From the calculation of the indicators of each scheme in Table 2, scheme 1 also shows simply using a single average load value. Instead of load characteristics, it is impossible to obtain the optimal reconstruction scheme within the allocation net. The simulation of the example verifies the feasibility of the allocation net reconstruction and planning method based on the analysis of the operation scenario. The lack of calculation and analysis tools leads to the remediation plan relying more on manual experience and lack of rigorous calculation and analysis. The results of the example show that the reconstruction and planning scheme considering the regional

Table 1: Comparison of network loss scenarios.

<table>
<thead>
<tr>
<th>Scenes</th>
<th>Scenario duration</th>
<th>Duration ratio (%)</th>
<th>Scenario network loss</th>
<th>Scenario network loss index</th>
<th>Scenario actual network loss amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>161</td>
<td>22.36</td>
<td>127.96</td>
<td>28.61</td>
<td>20.86</td>
</tr>
<tr>
<td>2</td>
<td>147</td>
<td>20.42</td>
<td>591.66</td>
<td>120.80</td>
<td>87.49</td>
</tr>
<tr>
<td>3</td>
<td>159</td>
<td>22.08</td>
<td>40.49</td>
<td>8.94</td>
<td>6.56</td>
</tr>
<tr>
<td>4</td>
<td>147</td>
<td>20.42</td>
<td>201.85</td>
<td>41.21</td>
<td>29.85</td>
</tr>
<tr>
<td>5</td>
<td>106</td>
<td>14.72</td>
<td>358.51</td>
<td>8.94</td>
<td>6.56</td>
</tr>
<tr>
<td>Sum</td>
<td>720</td>
<td>100</td>
<td>1320.47</td>
<td>252.34</td>
<td>183.08</td>
</tr>
</tbody>
</table>

Table 2: Reconfiguration solutions and corresponding performance.

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconstruction plan</td>
<td>9,14,28,33,36</td>
<td>7,9,14,28,32</td>
<td>33,34,35,36,37</td>
</tr>
<tr>
<td>Network loss index (H) during the plan period</td>
<td>154.76</td>
<td>173.8</td>
<td>307.93</td>
</tr>
<tr>
<td>Network loss (P) under the average load scenario</td>
<td>146.67</td>
<td>139.98</td>
<td>246.84</td>
</tr>
</tbody>
</table>

Table 3: Calculation results of total network loss of each solution.

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterly actual total network loss</td>
<td>343.95</td>
<td>386.49</td>
<td>685.37</td>
</tr>
<tr>
<td>Equivalent total network loss for scenario analysis</td>
<td>341.71</td>
<td>383.75</td>
<td>679.91</td>
</tr>
<tr>
<td>Calculation error</td>
<td>2.24</td>
<td>2.74</td>
<td>5.46</td>
</tr>
<tr>
<td>Equivalent total network loss for average load scenarios</td>
<td>323.85</td>
<td>309.08</td>
<td>545.02</td>
</tr>
<tr>
<td>Calculation error</td>
<td>20.1</td>
<td>77.41</td>
<td>140.35</td>
</tr>
</tbody>
</table>
allocation net operation scenario can be more effective than considering a single operation scenario. It fits the load power consumption characteristics of the region, and the overall performance is better.

5. Conclusion and Outlook

This paper mainly studies and applies the data of each system in the allocation net, and carries out the research on the optimization planning of the medium-voltage allocation net, including the identification of the wiring pattern of the medium-voltage allocation net and the optimization and expansion planning of the network frame reconstruction. The data of the method study come from the allocation net GIS system, production management system, operation management system, metering system, and allocation net automation system, based on the CIM model obtained by each system, regional historical load data, load increase, and decrease report data research. The topology analysis and wiring pattern recognition of allocation net based on CIM are realized.

5.1. Summary. Aiming at the related problems in the optimization and planning of allocation net reconfiguration, an allocation net data-driven allocation net operation scenario generation method is introduced. The typical operation scenarios of allocation net reconstruction are generated. In the region and the information of industrial expansion and installation, the planning scene of the allocation net is generated, and the effectiveness of the scene generation is analyzed. The mathematical model and solution method of allocation net reconfiguration and planning are introduced, and the mathematical model of allocation net reconfiguration and planning for operation scenario analysis is established based on the time period network loss index. Since the mathematical model has high requirements on the global convergence ability, a relatively mature genetic algorithm with strong as algorithm, and coding method of the genetic algorithm and the effective solution judgment method are introduced. The data-driven allocation net optimization planning method is as follows. Through the allocation net topology analysis and wiring pattern recognition, the wiring to be optimized with heavy overload problems is found, and the reconstruction optimization solution is given priority. We make expansion plans. The simulation of the example verifies the feasibility of the allocation net reconstruction and planning method based on the analysis of the operation scenario. The results of the example show that the reconstruction and planning scheme considering the regional allocation net operation scenario can be more effective than considering a single operation scenario. It fits the load power consumption characteristics of the region, and the overall performance is better.

5.2. Prospect. Although the research has achieved certain results, there are still many problems that need to be improved. The research prospects are as follows:

(1) The historical load data from the allocation net and how to make full use of the historical load data to construct a more realistic operation scenario can still be deeply considered and studied, in the planning research of this paper; although a certain load margin is reserved in the setting of the allocation net planning requirements, there are still many uncertain factors in the actual allocation net operation, such as the uncertainty of the future load. The research considerations such as the uncertainty of electricity prices and electricity prices are still not in-depth enough.

(2) In the proposed method for optimization, reconstruction, and expansion planning of allocation net operation, the optimization algorithm used is the
widely used genetic algorithm, but when applied to large-scale networks, local optimal results may still occur. Improvements in use can still be studied.

**Data Availability**

The dataset can be accessed upon request.

**Conflicts of Interest**

The authors declare that there are no conflicts of interest.

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**References**


