Construction and Application of Dual Q Programming Model for Medium Voltage Distribution Network

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Abstract. With the rapid development of China's economy, people's demand for electricity is increasing. In order to ensure the reliability of power supply, a dual Q programming model of distribution network is proposed. In this paper, the overview of "double Q theory" and key technologies are described, and the problems and optimization of medium voltage distribution network planning are discussed for readers' reference.

Keywords: Medium Voltage Distribution Network, Double Q Programming Model, Unit System Planning, Network Frame Research

1. Introduction

At present, there are some defects in the traditional medium voltage distribution network planning, which are mainly reflected in the distribution planning of grid stations, grid structure and planning data statistics. The optimization of medium voltage distribution network planning can improve the reliability of power supply [1]. The following discussion is carried out in combination with the construction of double Q programming model.

2. Overview and key techniques of "Double Q Theory"

2.1. Overview of "Double Q Theory"

Different reliability levels are closely related to economic levels. Reliability requirements need to be developed in coordination with economic levels [2]. The coordinated development of reliability and economy can be summarized as the answers to the following four questions:

(1) How to minimize the cost of system investment under the condition of given reliability level?
(2) How can the reliability be improved to the highest level under the given investment scale?

(3) Given the scale of investment, what is the most reasonable place to use the capital?

(4) What methods should be adopted to make the necessary selection of different schemes?

Economic coordination of reliability requires quantifying the cost of failure loss, and also minimizing the cost needed to improve reliability. The most important link is the estimation of failure consequence. Failure always causes undesirable consequences, some of which can be expressed in terms of economic loss, and some of which are difficult to be expressed in terms of money [3]. Economically speaking, the reduction of the expected failure loss cost is at least equal to the economic benefit brought by the improvement of the expected reliability. To improve reliability, a variety of options can be adopted, each with a different level of reliability and different input costs. Cost-benefit (COS/Benefit) evaluation method is generally adopted to coordinate the solution, and the one with the ratio of Benefit to cost is the best one.

The value generated by high reliability of a power system is the value generated by continuous supply to the user. For users, the value of continuous power supply depends on the benefit they get from using it. Low power supply reliability will cause frequent power outage and lack of power, and even butterfly effect, or will cause huge loss of economic benefits and social benefits. At the same time, the power grid company needs to add capacity, improve the grid structure, need to add investment, this part of investment should be borne by the user as part of the electricity bill [4]. The theory of reliability economic coordination is used to study the relationship between investment and improving the reliability level of power system.

2.2. Key technologies

2.2.1. Unit planning. In the past, distribution network planning was often "top-down". The 10kV distribution network planning project was mainly based on the upper planning, which was insufficient to connect with the regional planning, resulting in problems such as waste of funds or difficulty in implementation. Without cracking the traditional distribution network planning problems, to adapt to the regional development trend, the unit system planning is a better choice. According to the regional spatial layout planning, general settlement planning and control detailed planning, the unit system planning classifies the land plots with different land use properties and development depths in the region and divides them into several units. Then, the load prediction of each unit is carried out and the distribution network planning is formulated accordingly.

Each unit can independently undertake the normal power supply task in the region to meet the power load demand in the region, and reserve the spare capacity to meet the needs of future business expansion. A relatively independent wiring structure should be formed in each unit, and the power supply of the load in each unit should be kept independent as far as possible [5]. There is a reasonable normal operation mode for the wiring of the grid frame in each unit, and a fixed operation (contact) mode is provided for the connection in the unit. The unit system planning should be closely linked with the government-controlled planning and be regularly revised and compiled on a rolling basis. When the government control plan has a major modification, the unit plan should also be revised.
2.2.2. **Spatial load prediction.** The load of distribution network in a unit is different from the load in a large area. The load in a unit tends to have a low base and a fast growth, which makes it more and more difficult to predict by traditional methods. If the traditional load prediction is still used, there will be a large deviation in the size and geographical location of the load [6]. Spatial load prediction carries out load prediction of planned plots by referring to the data of electricity load and time growth of similar areas with different properties, and gets better prediction results than other load prediction methods.

For new development zone, have no historical load data, therefore also cannot use trend method for prediction of the spatial load forecasting methods don't have such problems: the problems often encountered in the power grid load transfer will produce a great impact on the results of conventional load forecasting method, the spatial load forecasting method is not affected by it. Conventional load forecasting method is difficult to take into account the load development situation of the village land use type change, and negative space forecasting methods can be relatively easy to do: spatial load forecasting results not only have a future values of load, and the load on the geographical distribution, which has great benefits for urban power grid planning.

2.2.3. **Grid research.** In order to determine the advantages and disadvantages of various wiring modes under different conditions, the factors affecting the wiring mode are analyzed quantitatively and qualitatively. First, the boundary conditions are determined, the comparison model is set up, and then the reliability, voltage quality, economy and adaptability of the wiring mode are analyzed [7]. Adaptability has nothing to do with load density, and it is mainly analyzed qualitatively from three aspects: line utilization rate, power supply safety and operation flexibility. Reliability, voltage quality and economy are directly related to load density and can be quantitatively analyzed.

Reliability analysis idea: consider the average annual failure rate of each component, the number of users affected by the failure and the average repair time of each component for different schemes, and consider the situation that some schemes can transfer the load, then calculate the average power availability index (ASAI).The system mean outage frequency index (SAIFI) and the system mean outage duration index (SAIDI) are used to compare the reliability of different schemes (Figure 1 for the grid of the distribution network).

![Figure 1. Grid frame of distribution network](image)

3. **Problems existing in the planning of medium voltage distribution network**

3.1. **Distribution planning of distribution network stations**
In the planning and design of urban medium voltage distribution network engineering, the most important point is the planning of distribution network station distribution, which is also the most difficult point in the planning and design [8]. Because the planning of distribution network station needs to carry out field investigation, but in order to save time, relevant planners and designers often ignore this key point, which makes the planning of distribution network station greatly different from the actual situation, and eventually leads to deviation in the planning and design of medium voltage distribution network engineering.

3.2. Problems of power grid structure

In the planning and design of urban medium voltage distribution network, the problem of network structure is very serious [9]. In the construction of the urban power grid due to urban infrastructure construction and network structure is relatively complex, grid can not be arbitrarily changed, this caused a part for the retrofit design of the planning, for example, complex urban distribution network wiring and power supply too roundabout, resulted in the special distribution circuit of main circuit, ultimately affect the operation of power grid maintenance, thus to the planning and design work caused serious trouble dc terminal connection (figure 2).

![Figure 2. DC terminal wiring](image)

3.3. Planning data statistics

The planning and design of urban medium voltage distribution network needs to rely on accurate data, and the problem of data accuracy will certainly affect the planning and design results. In order to effectively ensure the accuracy of planning data statistics, relevant data statistics departments must do a good job in data collection and processing, and conduct detailed analysis of a series of influencing factors in the planning and design of medium voltage distribution network to ensure that the data is in a controllable state. In addition, before planning and design, relevant planners should analyze the accuracy of the collected data and information to ensure that the data will not be divorced from reality.

4. Construction of medium voltage distribution network model

4.1. Technical requirements for medium voltage distribution network planning

The planning of medium voltage distribution network should meet the principles of safety, reliability and economy. Safety should be based on line type. Power supply radius and other angles are planned
in accordance with the planning guidelines (Fig.3 Power supply model).

The reliability of power supply refers to the degree of continuous power supply from the power grid to users, which should meet the specific provisions of the following two objectives: the first is the safety criterion of power supply from the power grid; the second is the degree of satisfying the user's power consumption.

Power supply safety criterion: the power supply safety of the medium voltage distribution network generally adopts the N-1 criterion, and the special important area should adopt the N-2 criterion.

To meet the user's power consumption: in case of power failure caused by power grid failure, the permitted power failure capacity and the target time of power supply recovery are as follows:

(1) Two loop power supply users, after losing the loop should not be blackout.

(2) Users with three-loop power supply should not lose power after losing the loop, and should meet 50%-70% electricity consumption after losing the primary circuit;

(3) When the user power supply of primary circuit and multi-loop power supply is completely shut down, the target time of power supply recovery is - the time of circuit fault processing.

(4) If the user loop network fault of closed loop operation needs to restore power supply through switching down operation, the target time is the required time of operation.

![Power supply model](image)

**Figure 3.** Power supply model

4.2. **Common wiring modes of medium voltage distribution network**

The medium voltage network connection mode includes single power supply radiation connection, double power supply handle ring with connection, three power supply handle ring network connection, four power supply handle ring network connection, etc.

4.2.1. **Wiring of double power pull ring network.** Two feeders from different substations or different busbars of the same substation are connected hand in hand through a contact switch. If any section fails, the contact switch is closed to transfer the load to the adjacent feeder and complete the transfer, with the reliability of N-1. Equipment utilization rate is 50%. It is suitable for third class users and second-class users with small power supply capacity.
4.2.2. **Wiring of three-power handle ring network.** The three-power handle ring network is powered by three feeders, each of which is equipped with a contact switch. The feeders can come from different substations or different busbars of the same substation. If any section fails, the contact switch is closed to transfer the load to the adjacent feeder and complete the transfer with the reliability of N-1 and the equipment utilization rate of 50%. [10] For the cable system, any section fault can be transferred to adjacent feeders through the contact switch of the ring network cabinet or the opening and closing station to ensure no loss of load; for overhead lines, any section fault can be transferred to the load of non-fault sections to adjacent lines through the contact switch. It is suitable for the second-class users with large power supply capacity but few numbers.

4.2.3. **Four power # ring network wiring.** Four-power # word ring network is to add two feeders contact on the basis of two double-power handle ring network, forming a "well" shape network. It can also be seen as a feeder on the basis of the three-power supply handle ring network. Four power supplies can be supplied from two feeders of different bus lines of two substations or four substation outgoes. Reliability and equipment utilization 67%. It is suitable for the second-class users with large power supply capacity and more numbers and the first-class users with small power supply capacity and less numbers.

5. **Conclusion**

To sum up, through the optimization of the construction of the medium voltage distribution network model, double power supply handle ring network wiring is adopted connection mode of three-power handle ring network connection and four-power # ring network connection can improve the security and stability of power supply, which is beneficial to meet people's demand for electricity.

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