Distributed Optimization Planning of Rural Transformers Considering New Load and Low Voltage Side Interconnection

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Abstract. In order to adapt to the development needs of new load access to rural power grids, solve the problem of low utilization efficiency of related equipment, and take into account economy and power supply reliability, this paper proposes a distributed optimization planning method for rural transformers considering new load and low-voltage side interconnection. First, this paper establishes a load forecasting model that considers new types of loads such as electric heating; secondly, it builds a distributed distribution transformer network planning model with the goal of minimizing overall costs, and applies the Voronoi method to plan distribution transformers; finally, it combines the location of the distribution transformer and its power supply Scope, using the minimum spanning tree theory of graph theory to generate low-voltage line layout schemes. This paper is based on Matlab R2014a simulation platform to plan the distribution of typical power supply areas. The results of calculation examples verify the feasibility of this method, which can improve the economy and reliability of power supply by reducing losses.

1. Introduction

In recent years, a new type of load is represented by electric heating power alternative load ratio is increasing day by day, booming in [1]. The development of new type of load is not only confined to the city, covers an area of China of rural also attracted to join the new load. However different from city power grid, the rural power grid because of farmland irrigation, and electric heating load obvious seasonal characteristic, parallel operation after unfavorable to improve equipment utilization, thus power supply efficiency with the decrease of [2] [3]. Therefore, the use of the flexibility of distribution operation, the new type of load and load seasonal complementary, research distribution transformer high efficiency operation method, the new township for the future. The measures and development paths of village power grid upgrading play a guiding role.

Load forecasting is the basis for grid planning, At present, many methods are divided into regression analysis, method of elastic coefficient method, the specific method of [4] [5]. The rise of the rural economy in rural areas the corresponding distribution network planning and development are put forward new requirements, it is part of the rural power grid in power quality, power supply reliability and equipment optimization cannot meet the needs of the new town [6]. Literature [6] on the meter and distributed power supply and new type of load connected to the active power distribution network, on
the basis of a corresponding to the active power distribution network is presented based on the probability of generation and load forecasting method. The method is different in the conventional sense of load forecasting, but on the basis of load forecasting for a new load Method carries on the discussion, constructs the active distributed power installed capacity in power distribution network and prediction model, and then puts forward a distributed power supply credible output prediction method. The literature [7] in a traditional rural electric load forecasting method on the basis of further consideration to release a quantity to the potential of rural power grid load, and based on this puts forward a new era of rural residents to meet the increasing demand for electricity load forecasting method, literature in reference to the rural residents families each year, on the basis of the electricity consumption of durable goods, respectively from the provincial to the region and residents to two perspective, to predict residents load according to the corresponding power consumption and the area, and combining with the actual In addition, based on the electricity consumption of household appliances in rural areas, the paper calculates the total electricity consumption of rural users in one year, which provides a new method for the potential load prediction of rural power grid and a reference direction for the calculation of the new load prediction of electric heating adopted in this paper.

To forecast the new load and traditional rural power grid load is the foundation of the power grid construction reform. On the basis of the power grid planning needs to consider the power supply reliability and economy, including the planning of distributed transformer is mainly include optimizing the configuration of distribution transformer and the adjustable capacity distribution transformer two methods [8] [9] [10] this research presents the adaptive duty of distribution transformer, in the case of not cutting load, according to the actual situation to realize automatic transformer rated capacity operation mode switching. In literature [11] and conventional distribution transformer adopts the traditional planning method, comparing the layout scheme of a Adapt to seasonal load distribution transformer network optimal planning method, the method of a network of distribution transformer bi-level programming model was constructed, and the feasibility is verified by examples, and can reduce the loss of distribution change, improve power supply reliability and economy. But the literature before, and a new load influence on rural load, there is a difference with the actual load forecasting result.

Based on the above analysis, this paper puts forward a new type considering load and connected on the low voltage side of transformer distributed optimal planning method. Through the establishment of considering load forecasting model of new type, such as electric heating load, and the minimum comprehensive cost as the target to build a distributed distribution transformer network planning model, and apply the Voronoi method of planning and distribution transformer; Finally combining with the position of distribution transformer and power supply range, by using minimum spanning tree of graph theory to generate low line layout scheme. The method for the meter and the new development of the rural power grid load provides reference significance, not only improve the power supply reliability and economy, and to promote the new rural development and rural network reconstruction is of great significance in the future.

2. Development and forecast of new load of rural distribution network

2.1. Development of new load in rural power grid
Under the background of rural revitalization, the new load technology represented by electric heating in the market has been relatively mature after considerable development. It is divided into distributed type and centralized type according to heating mode. Centralized electric heating, such as regenerative electric boiler, has a high degree of automation, safety and reliability, and its thermal efficiency can reach 98%; Distributed electric heating heating uniform, comfortable, not dry, good safety performance, strong controllability, can realize household time-sharing control, the efficiency is close to 100%.

2.2. Considering the load characteristic modeling of new load access power network
On the basis of the known thermal load demand of direct heat and regenerative heat equipment, the load prediction of the equipment under different control strategies was carried out. In general, the control
strategy takes the minimum deviation between the actual temperature and the set value as the objective function, and the mathematical model is:

$$\begin{align*}
\min & \quad |T_t - T_{\text{set}}| \\
\text{s.t.} & \quad H_{\text{load},t} \leq Q_{\text{hp},t} \leq 1.05H_{\text{load},t} \\
& \quad 0.5P_{\text{hp},t} \leq P_{\text{hp,rate}} \leq P_{\text{hp,rate}}
\end{align*}$$

(1)

In the formulas: $T_{\text{set}}$ is the expected value of room temperature; $P_{\text{hp,rate}}$ is the electrical power output of the heat pump in time period $t$; $Q_{\text{hp,rate}}$ is the thermal power output of the heat pump at time period $t$; $T_t$ is the actual value of room temperature at time $t$; $H_{\text{load},t}$ is the thermal load demand in time period $t$.

$$\begin{align*}
\min & \quad P_{e,t}c_t \\
\text{s.t.} & \quad H_{e,t} + H_{c,t} \geq H_{\text{load},t} \\
& \quad P_{\text{min}} \leq P_{e,t} \leq P_{\text{max}} \\
& \quad 0 \leq S_t \leq S_{\text{max}}
\end{align*}$$

(2)

In the formulas: $P_{e,t}$ is the electric power of electric heating equipment at time $T$; $C_t$ is the electricity price at time $T$; $P_{\text{max}}$ and $P_{\text{min}}$ are the upper and lower limits of the electric power of the equipment. $H_{e,t}$ is the heating quantity of electric heating equipment at time $T$; $H_{c,t}$ is the heat supply quantity of the heat storage device at time $T$; $S_t$ is the heat storage of the heat storage device at time $T$.

By solving equations (1) and (2), the user's electric heating load characteristic curve can be obtained.

### 3. Distribution transformer planning based on Voronoi

#### 3.1. Distribution transformer optimization planning model based on minimum total cost

The load points are divided according to the load prediction results, and different load blocks are formed by taking geographical factors into consideration. The center point $Q_L$ of each block is determined, and the load coefficient represents the electricity proportion of the load blocks. At the same time, the power supply capacity coefficient is added to the distribution transformer point $Q_F$ to represent the power supply capacity of the distribution transformer. The load block division is shown in Figure 1.

**FIG. 1 Load block division diagram**

The traditional Voronoi diagram method is improved, and the power supply capacity coefficient is continuously optimized through multiple iterations to realize the reasonable division of the power supply scope of each distribution transformer. The power supply range is represented by the center point of each load block included.

#### 3.2. Low-voltage line generation method

The structure of rural low voltage power grid is simple, and the main power supply mode is radiation. According to the characteristics of low-voltage distribution network and combined with distribution transformer position and power supply range, the minimum spanning tree theory of graph theory is adopted to generate low-voltage line layout scheme [12]. Firstly, all lines are treated as equal, and then reasonable selection is made according to the line load according to the actual situation.
According to the power supply scope of each distribution transformer, different network frame planning areas are formed. Distribution and load points are equal to nodes in the minimum spanning tree. The location of each transformer is taken as the root node, and the specifications of each line to be planned are regarded as the same, so that all sides meet the equal requirements in graph theory. According to graph theory program, the minimum tree within each power supply area is generated to form the target network frame.

According to the formed target network frame and combined with the actual load of each line, make reasonable modifications to the target network frame to obtain the final actual low-voltage line connection scheme.

The minimum tree generated in this paper not only contains all nodes within the power supply scope of each distribution transformer, but also reflects the status of each line in the low-voltage grid.

4. Example analysis

Based on Matlab R2014a simulation platform, this paper carries out the optimization planning of transformer and low-voltage line in a class D power supply area in an area. The area is a rural power grid with a total area of about 378 mu, including 152 permanent residents. The distribution of residents is relatively dispersed. According to the load forecasting method in this paper, load forecasting is carried out for this region.

4.1. Example simulation results and analysis

By simulating an example on the MATLAB platform, the optimal distribution transformer planning scheme of the rural power grid is obtained, considering the interconnection between the new load and the low-voltage side. The specific information of the planned and installed distribution transformer is shown in Table 1, and the low-voltage grid structure of the rural power grid is shown in Figure 2.

Table 1 Transformer planning scheme

| Expense name | coordinate | capacity /kVA | Power supply range | Contact line |
|--------------|------------|---------------|--------------------|--------------|
| 1            | (107, 214) | 315           | q1, q2, q3, q4     | 0            |
| 2            | (320, 131) | 200           | q5, q6             | 0            |
| 3            | (344, 175) | 400           | q7, q8, q9, q10    | 695.3 (4)    |
| 4            | (231, 315) | 400           | q11, q12, q13, q14, q15 | 0 |
| 5            | (347, 400) | 315           | q16, q17, q18     | 0            |

According to table 1 shows the rural power grid planning of distribution transformer information, to meet the load demand in the region, considering the region characteristics of rural power grid load, and meter and added a new load distribution network in the region, the influence of the total building 5, 18 low-voltage distribution transformer lines, four link, form optimal network of rural low-voltage distribution transformer. The area is extremely cold in winter and needs a lot of heating.

FIG. 2 Diagram of low-voltage grid structure in rural power grid

The addition of new loads brings new challenges and opportunities to distribution network planning. According to the seasonal characteristics of load, changing the structure of grid, adopting different operation modes, optimizing the structure of grid, reducing no-load loss and improving the utilization
rate of grid equipment are conducive to the economic operation of distribution network. With the continuous development of rural economy, the scale of new load in rural distribution network will continue to grow, and the advantage of optimal planning of distribution transformer network considering the seasonal characteristics of new load will be more obvious.

5. Conclusion
A distributed optimization planning method for rural transformers with new loads connected to high proportion seasonal loads in rural areas is proposed in this paper. The low-voltage tie lines between the distribution transformer are established. According to the seasonal variation of load, the switching state between the tie lines is changed to change the operation mode, so that the low-load distribution transformer can quit the operation in the season. Based on the load forecasting model of new-type load access agricultural network, the distribution transformer planning model is established with the goal of minimizing the comprehensive cost, and the solution is solved by genetic algorithm, Voroni, etc. The calculation results show that the proposed method can provide new ideas for the development of rural power grids with high proportion of new loads, which is beneficial to reduce the no-load loss caused by distribution change, realize the dual goals of improving the reliability and economy of power supply, and provide reference for the upgrading measures and development paths of new rural power grids in the future.

Acknowledgements
I would like to express my gratitude to all those who have helped me during the writing of this thesis. I gratefully acknowledge the company for the help and platform. In addition, I would also like to thank all my colleagues for their patience, encouragement and professional guidance in the process of writing the paper, and for helping me when I conducted the questionnaire survey.

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