Automatic Planning Software for Low Voltage Governance of 10kV Distribution Network

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Abstract. As for the scheme design for low voltage governance of 10kV distribution network, the one-click automatic planning software system which based on the single-line diagram is developed using C# programming language. One-click automatic planning prioritizes the replacement of the line, combining with reactive power compensation and configuration of the voltage regulator to generate the low-voltage governance scheme. In addition, the software can provide the function named guided single-step planning. According to the different requirements of the low-voltage, such as the governance effect, the economic benefit and the ability of resisting the growing load, the decision-maker could preferentially select one of the three measures (replacement of the line, reactive power compensation and configuration of the voltage regulator) to govern the problem of low voltage and it can choose automatic planning basing on guided single-step governance. Finally, the practicality and applicability of the software are verified by a case.

Introduction

The low voltage problem of 10kV power distribution circuit is the phenomenon that the voltage at the end of the line is 7% less than the nominal voltage, which is called the low voltage problem of the 10kV distribution network [1]. Due to the diversification of the structure of the 10kV distribution line, the causes of the low voltage of the distribution network are different. Therefore, it is necessary to adopt the specific governance scheme to carry out the targeted governance. In order to effectively improve the efficiency of governance for low voltage problems, it is of great significance to design automatic planning software. There have been some softwares used in the distribution network. In [2], the key technology of applying the software to the distribution network is analyzed, then the characteristics and design ideas of the corresponding software structure and its corresponding functions are introduced. In [3], urban distribution network planning simulation software is designed based on CYME software. The software power flow calculation function is used to simulate the optimal configuration and load balance analysis of the distribution network. The software has nice usability and function comprehensive. The work in [4,5] based on GIS technology, designs the distribution network planning software, but only takes into account the distribution network economy, the low-voltage problem at the end of the distribution line is not involve.

At present, the method for low voltage governance of distribution network still has to rely on the relevant practitioners, which is inefficient and lack of objectivity. Basing on the C# programming language, this paper designs the automatic planning software for the low voltage governance of the distribution network. According to the different low voltage conditions and the reasonable management flow, the software can plan the governance scheme for low voltage problems which are caused by different reasons automatically.
Introduction the Overall Structure of the Software

In order to generate a governance scheme quickly and effectively, the software needs to generate appropriate governance schemes reasonably according to low voltage conditions in different regions. In this paper, the software could get the power flow distribution of the power network by inputting the basic data of the corresponding line for the power flow calculation, so as to obtain the voltage level of the area that will be governed. The software designs a reasonable governance process for the low voltage problems caused by different reasons, so that the software realizes the function of planning the governance scheme only with one-click. According to the different needs of the decision maker, the software can also decide the governance scheme by single-step with the help of the software’s guidance. And the results of one-click planning and guided single-step planning of the governance scheme are presented in a single-line diagram.

![Figure 1. The structure of the software.](image)

Automatic Planning for Low Voltage Governance

The software for low voltage governance mainly relies on the following key technologies:

**Power Flow Calculation**

This software uses Newton-Raphson method to realize the function of power flow calculation[6]. Every time the software takes measures to govern the low voltage problems, it needs to use the power flow calculation to get the power flow distribution. Analyzing the results, the software will know the low voltage problems whether have been resolved or not. And it can determine the next step to govern the low voltage problems.

**Topology Map Drawing**

The software draws the topology map basing on the single-line diagram system [7,8]. It can draw the following equipment: power supply point, towers, wires, distribution transformers, reactive power compensation devices and voltage regulator. Each device can be entered the appropriate configuration by “property”, which is necessary information for the power flow calculation. Using these drawing tools, filling in the corresponding properties, decision-makers can draw the corresponding topology, also providing the appropriate data for the power flow calculation and the generation of the governance scheme.

**One-Click Automatic Planning for Low Voltage Governance**

By clicking on the “one-click planning” menu after the complement of the single-line drawing of 10kV distribution network and the status quo configuration, decision-makers could generate the governance scheme only by one click. According to the flow chart shown in Fig 2, the software automatically generates the governance scheme and then it can display the governance information on the single-line diagram at the same time.
One-click automatic planning is preferred to replace the distribution lines, combing with reactive power compensation and the configuration of the voltage regulator method to generate the governance plan, the specific process is as follows:

(1) Draw the topology of the 10kV line according to its structure. Fill in the required information and calculate the power flow.

(2) According to the result of power flow calculation, if the low voltage problems occur, the software will firstly choose to replace the wire. It will traverse all the lines with low voltage problems from the power supply point. If there are multiple low-voltage lines, it will prioritize the branch line with the highest voltage. And it is set to replace only a wire each time and get the result of the power flow calculation at the same time. In the light of the results of calculation, it will determine the necessity of continued governance. Whether to replace the wires or not is based on whether the transmission capacity of the line is more than its economic transmission capacity. If so, the wire will be replaced by corresponding wire according to its transmission capacity. The software will start the replacement from the power supply point until the power flow calculation shows that the governance has been completed or all the transmission capacities of the wires are less than the corresponding economic transmission capacities of the wires.

(3) If the replacement of the wires can’t completely govern the low voltage problems and the power factors of the lines which exist low voltage problems are lower than 0.9, then the software will take the reactive power compensation method. In order to increase the power factor to 0.9, the parallel reactive compensation (PRC) device with corresponding compensation capacity will be added to the tower at the end of the line that exists low voltage problem. Each time it adds a PRC device, it will also calculate the power flow. Then according to the results of the power flow to determine whether it’s still necessary for governance. So repeated until all the power factors of the nodes existing low voltage problems are more than 0.9 or the low voltage problems have already been governed.

(4) If the reactive power compensation still can’t completely govern the low voltage problems, the software will take the method of adding the voltage regulator. Starting from the end node to the direction of the power supply point among the lines where the low voltage problems occur, it will
select the node whose voltage is closest to 9.5kV and it will install the voltage regulator near this node.

**Manual Adjustment and Guided Single-Step Planning of the Governance Scheme for Low Voltage Problems**

One-click automatic planning can quickly provide effective governance for decision-makers. Besides, the software also provides the function of guided single-step planning in order to meet the specific needs, including restrictions on economic costs or new arising low-voltage issues because of the rapid development of regional economies.

Decision-makers can choose to carry out one-click automatic planning or guided single-step planning when he is deciding the governance schemes. Guided single-step planning firstly provides three measures (replacement of the line, adding PRC device and configuration voltage regulator), but only one of the three measures is selected each time. Once the measure is selected, it only carries out single-step of the measures, that is, if you choose replacement of lines, each time it will replace just one wire. And if you choose adding PRC device, it will add only one each time. Because that guided single-step planning is set to add only one voltage regulator, it will prompt you to choose other ways if it has added it. Each time it completes a governance, a power flow calculation follows. It will determine whether the governance has completed according to the result of power flow calculation, if not, it’ll let you re-select the measures from the beginning on the basis of the single-step governance it just has carried out. So repeated until the results of the power flow calculation shows that governance is complete.

![Flow chart of manual adjustment and guided planning for the governance scheme.](image)

Figure 3. The flow chart of manual adjustment and guided planning for the governance scheme.

Besides the guided single-step planning, in order to meet the special requirements of the decision-makers for economic and regional development, it also provides the function of manually adjusting the governance measures. The decision-makers can change the diameters of the wires, the positions and numbers of PRC devices and voltage regulators.
The process of manual adjustment and guided single-step planning is shown in Fig 3.

Applications

This chapter takes the governance process of 10kV 911 Yanshan line in Jiangxi Province as an example to verify the feasibility of automatic planning for low voltage governance. According to the structure and historical operational data of Yanshan line, this paper draws its topology and fills in the corresponding equipment properties. According to the collected data, the active power and reactive power of the load are obtained by the capacity of the distribution transformers and its corresponding capacity ratio. Using the software designed by this paper to govern the low voltage problems of Yanshan line. The specific process of one-click automatic planning is as follows:

1. Draw the topology of Yanshan line and fill in the properties of the corresponding devices.

Figure 4. Calculation result of the power flow calculation of Yanshan line.

Figure 5. Results of the one-click automatic planning.

(1) Draw the topology of Yanshan line and fill in the properties of the corresponding devices.
(2) Apply the function of power flow calculation to get the power distribution of the line, and the result shows that some nodes have low voltage problems, as shown in Fig 4:

As Fig 4 shows, node voltages at the end of the gray lines are lower than 9.3kV exceeding the lower limit. What’s worse, the minimum voltage reaches 6.651kV.

(3) Apply one-click automatic planning to govern the low voltage problems of Yanshan line. The wires between node number 0 and node number 57 are replaced with LGJ-120, and the wires between node number 57 and node number 149 are replaced with LGJ-95. The reactive power compensations device are added at the node number 149XZ73, 149XZ81 and 333 respectively. The voltage regulator is set at the node number 57. The result of governance is shown in Fig 5:

As Fig 5 shows, all the voltages are more than 9.3kV after governance, low voltage problems in the region have been resolved.

From the above process, we can see that this software could effectively govern the low voltage problems according to the data of Yanshan line, which verifies that the software is practical and applicable. In addition, the whole process is simple to operate, and the user doesn’t need to have strong professional knowledge. What’s more, the software interface is simple and the graphical governance process is easier to accept, too.

Conclusion

This paper designs the automatic planning software for low voltage governance of distribution network basing on C# programming language. The software can realize the functions of topology drawing, power flow calculation, one-click automatic planning, guided single-step planning and so on. It can generate a reasonable and effective governance scheme coping with different low voltage problems quickly. Finally, this paper takes the example of 10kV 911 Yanshan line in Jiangxi Province, verifying the practicality of the software.

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