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Regional Grid Power Supply Radius Planning—A Sensitivity Constraint-Based Approach

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Abstract: This paper addresses the correlation between the coverage of regional power grid supply and the sensitivity of line backup protection. Through a theoretical analysis of the calculation method for line backup protection sensitivity in power grids, and in accordance with grid regulations, this paper proposes a planning method for the supply range of power grid lines that meets sensitivity constraints. And the reliability of this method in calculating and evaluating the optimal power supply radius of lines is verified by taking the example of an actual 66 kV grid in a region. This method can be used to optimise network structure, improve the reliability and economy of the grid, and guide the planning and construction of regional grids.

Keywords: sensitivity; line impedance; power supply radius; planning methodology

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1. Introduction

The planning of the power supply radius of the regional power grid, as a transition grid connecting the UHV transmission grid and the medium- and low-voltage distribution networks, is very important for improving economic efficiency and power supply reliability [1,2]. By carefully planning regional power grid lines and accurately calculating their power supply radius under various conditions, we can significantly improve the return on investment of power grid engineering construction projects. This can not only effectively solve the problem of power quality degradation caused by improper line selection and long power supply distance, but can also fundamentally improve the short service life of grid lines and unstable power supply, so as to provide a more reliable and high-quality electric power service for the majority of users [3].

When assessing the power supply capacity of urban distribution networks, the most commonly used method is based on a series of technical statistical indicators, such as voltage pass rate, line loss rate, average line load ratio, etc., which can comprehensively reflect the power supply performance of distribution networks in different dimensions. According to reference [4], under the condition of constant load density, as the capacity of the distribution transformer increases, the radius of the power supply will increase accordingly, and this process is not affected by the cross-section of the conductor. In other words, when the distribution transformer capacity is kept constant, a change in the cross-section of the conductor does not cause a change in the supply radius. There is a positive relationship between the supply radius and distribution transformer capacity. Meanwhile, reference [5] pointed out that the long supply radius of 10 kV lines may negatively affect the reliability and quality of the power supply of the distribution network. Reference [6] further emphasised that too long a supply radius in agricultural networks may lead to low-voltage problems. In order to optimise the supply radius, reference [7] theoretically calculated the optimal supply radius of a substation, with the objective of minimising the annual cost per unit of supply area, taking into account the voltage quality calibration, and gave macro-recommended values for different supply areas. However, these recommended values have some limitations in guiding fine feeder-level load access. In addition, reference [8] establishes a grid structure planning model and an objective function for the annual cost per unit area of a supply area with an unknown supply radius, and solves for the optimal supply radius, with the allowable voltage deviation as a constraint. However, the high degree of model simplification leads to the possibility of large errors in the final calculation results.

Although the traditional methods of assessing the power supply capacity of regional power grids can reveal the performance of power grids from different sides and degrees to a certain extent, they lack the perspective of comprehensively evaluating the reliability of the power supply of power grids, especially in terms of the correlation between the protection sensitivity of 66 kV lines and the power supply radius, which is not in-depth enough, and thus, it is difficult to directly guide the planning of the power supply radius of regional power grids. In this paper, the key parameters affecting the sensitivity of 66 kV line backup protection are analysed in depth, and the sensitivity-based constraints are used to plan and evaluate the power supply radius of regional power grids in detail, taking into account the normative standards of the power supply radius of regional power grids. Through the analysis of examples, our method is verified to be scientific and reasonable, and can effectively meet actual needs in engineering practise.

2. Power System Line Protection and Sensitivity Factors

2.1. Primary and Backup Protection

All parts of the power system should be reliably protected so that the protective devices act only on the occurrence of a fault [9]. There are some single protective devices that actuate only when a fault occurs within a protected section. Some other protective devices can detect faults not only within a specific zone but also in neighbouring zones and act as a backup to the main protection of the neighbouring zone. In this way, the faulty section can be isolated even when the main protection of the neighbouring section is not operating. Therefore, whenever possible, every section of a power system should be equipped with both primary and backup protection.

In cases of failure of a line or other power equipment, its main protection should be actuated in time every time. The protection range of a single protective device may monitor and protect one or more pieces of equipment in the system, such as transformers, transmission lines, busbars, etc. Power equipment may also be equipped with more than one main protection. However, this does not mean that all these protections have to operate when the same fault occurs.

If the primary protection does not operate for any reason, the backup protection will operate. Regardless of whether the criteria for the primary and backup protections are the same, the backup protection can be configured with a time delay to allow the primary protection to operate first. A single protective device can provide backup protection for several devices at the same time. Similarly, a line can have more than one backup protection device. One protective device serves as the main protection for a line and, at the same time, as the backup protection for another line. The backup protection supplements the primary protection with an appropriate delay in operation.

2.2. Power System Line Protection Sensitivity

Power system line protection sensitivity is the ability to respond in the event of a fault within a given protection area [10,11]. When the main protection of a faulty line refuses to operate, the fault should be removed by the backup protection of the faulty line, and it should not be removed by the backup protection of the higher-level line of the faulty line. Therefore, the backup protection of the rectified line is required to have sufficient sensitivity to the fault at the end of this line, and the backup protection of the rectified line should be cooperated with the backup protection of the cooperating line, not with the main protection of the cooperating line.

To ensure that the full length of this line is protected, the time-limited current-failure protection system must demonstrate adequate response capability if a two-phase short-circuit occurs at the end of the line when the power system is in the minimum mode of operation. This capability is usually assessed quantitatively by means of a sensitivity factor, Ks, which ensures a rapid and accurate response in the event of an emergency.

The operating current of the distant backup current protection should be set based on the rated current of the transformer being bypassed, i.e.,

$$I_{op} = \frac{K_{rel}}{K_r} I_e \tag{1}$$

where K_{rel} is the reliability factor, ranging from 1.2 to 1.3; the K_r is return factor, ranging from 0.85 to 0.95; and I_e is the secondary rated current of the transformer.

Typically, the setting current value is 1.2 to 1.5 times the rated current value.

The sensitivity coefficient verification for distant backup current protection is given by:

$$K_{sen} = \frac{I_{k,min}^{(2)}}{I_{op} n_a} \tag{2}$$

where $I_{k,min}^{(2)}$ is the minimum short-circuit current flowing through the protection at the end of the backup protection zone when two phases are short-circuited. It should be $\geq$1.3 (near backup) or 1.2 (distant backup), where n_a is the transformation ratio coefficient.

As a backup protection measure for neighbouring lines, we should check the current value when a two-phase short-circuit occurs at the end of neighbouring lines under the minimum operation mode. In this process, the sensitivity coefficient Ks must meet the requirement of more than 1.2 to ensure the effectiveness and reliability of the backup protection system.

2.3. Parameters Affecting Sensitivity

Based on the above regulations for setting the operating current of distant backup current protection and the sensitivity coefficient verification formula, it is evident that sensitivity is determined by the minimum short-circuit current and the rated current setting. The minimum short-circuit current and rated current are influenced by key factors such as the system's main transformer capacity, connection method, high and medium backup types, and line impedance [12]. In particular, for the 66 kV busbar system, the sensitivity is directly related to the minor mode impedance, line resistance, line reactance, and backup protection rating. Under the condition that the equivalent unit resistance and equivalent unit reactance remain constant, adjusting the line resistance and line reactance is practically equivalent to changing the length of the line, which is the supply radius. It should be noted that there is a negative correlation between line length and remote-backup sensitivity, i.e., the longer the line, the lower the remote-backup sensitivity.

3. Sensitivity-Based Power Supply Radius Planning Method for Regional Power Grids

3.1. Provisions Related to Power Supply Radius Planning

The core objectives of urban distribution network planning are to ensure that the power supply area receives a safe and reliable power supply, to achieve flexible power dispatch, to guarantee power quality, and at the same time, to simplify the wiring of the urban distribution network and rationally configure the voltage levels. This planning process [13,14] covers a number of key aspects, such as status quo analysis, load forecasting, substation optimisation, distribution network framework optimisation, distribution network trend calculation, reliability analysis, investment estimation, and benefit analysis. Among them, load forecasting, voltage level planning, and distribution network planning form the basis and core of distribution network planning.

As shown in Figure 1, in the distribution network planning process, we first precisely set the layout of the 66 kV distribution network based on the results of load forecasting in each sub-district and with reference to the technical principles and power supply facility standards for 66 kV distribution networks. This layout covers the capacity and location of the planned substations, as well as the power supply areas of the existing and planned substations. It also determines the direction and structure of the 66 kV distribution lines, which actually refers to the specific characteristics of the lines, such as line type, length, and other key parameters. In addition, the planning of the supply radius is essentially the definition of the geographical radius of the supply area, which directly reflects the actual length of the line [15,16].

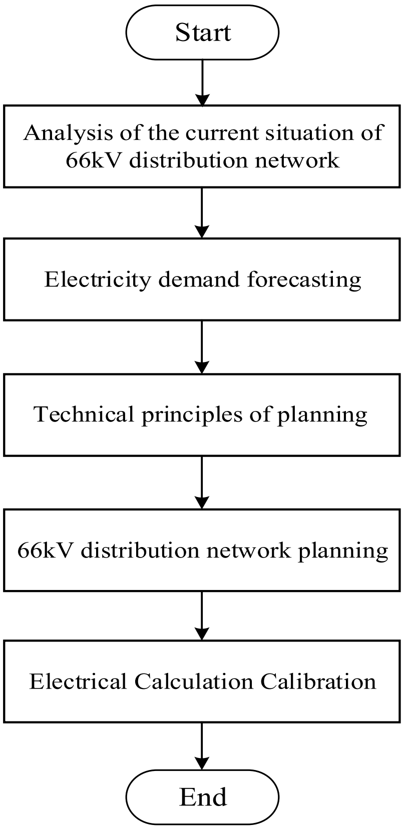


Figure 1. Flowchart of 66 kV distribution network planning.

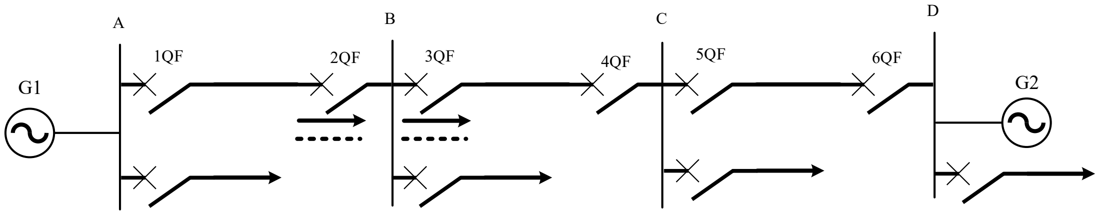
Based on the data in Table 1, we can draw the following conclusions: The supply radius of the 20 kV distribution network is about 1.6 times larger than that of the 10 kV distribution network, while its supply area is about 2.6 times larger than that of the latter. For the 66 kV distribution network, the radius of supply is about 1.9 times larger and the area of supply is about 3.6 times larger compared to the 10 kV distribution network. The radius of the 66 kV distribution network is approximately 1.5 times larger than that of the 20 kV distribution network, and the area of supply is approximately 2.2 times larger.

Table 1. Transmission radius for different voltage levels.

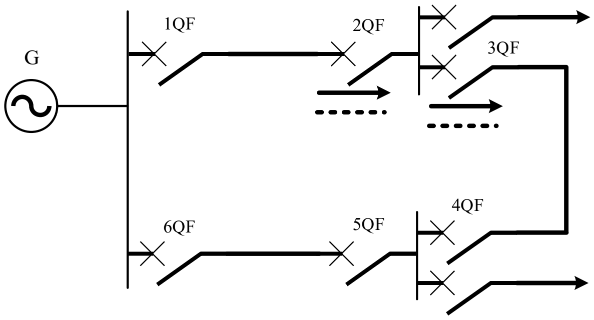
Load Density (MW/km^2)	Conveyance Distance to Meet Voltage Requirements (km)		
	66 kV	**20 kV**	**10 kV**
0.1–1	6.0–13.0	3.0–6.5	1.9–4.1
1–2	4.8–6.0	2.4–3.0	1.5–1.9
2–15	2.4–4.8	1.2–2.4	0.8–1.5

3.2. Far-Backup Protection Sensitivity Constraints

The 66 kV power supply network is used for the radial power supply mode [17,18], both a dual power supply contact line and a dual power supply are used at both ends of the power supply mode, and a line channel generally contains 2 back lines or cables, as shown in Figure 2. The analysis and calculation of the supply radius discussed in this paper mainly focus on the lengths of the lines depicted in the power supply network diagram in Figure 2.



(**a**) Bilateral power grids



(**b**) Single-side power ring network

Figure 2. Main power supply of 66 kV network.

The operation mode of the 66 kV line in the substation is highly flexible, and there are many factors affecting the sensitivity of its remote-backup protection, including the main transformer capacity, the wiring mode of the low-voltage side of the main transformer, the main transformer's operation strategy, the impedance of the line, and the length of the line. The consideration of sensitivity coefficients mainly includes a remote-backup current sensitivity coefficient, a remote-backup low-voltage sensitivity coefficient, and a remote-backup negative-sequence voltage sensitivity coefficient, and their specific values are as follows: the remote-backup current sensitivity coefficient needs to reach or exceed 1.2, the remote-backup low-voltage sensitivity coefficient also needs to satisfy or exceed the standard of 1.2, and the remote-backup negative-sequence voltage sensitivity coefficient is required to be no less than 1.5.

3.3. Sensitivity Constraint-Based Planning Method for Supply Radius

The sensitivity coefficient adjustment analysis focuses on those items that do not meet the standard, and aims to adjust the sensitivity coefficients to a satisfactory level by optimising the core parameters that affect sensitivity. These adjustable parameters can be broadly classified into two categories, station-wide and line-based, and each adjustment measure needs to be technically feasible. Specifically, the means of adjustment cover the regulation of key elements such as the main transformer capacity, main transformer operation strategy, line length, and protection value. Adjustments can be made in a variety of ways, either by increasing or decreasing the parameter values, or by changing the mode of operation. In terms of priority, line-type factors are considered first, where the adjustment of protection values takes precedence over line length (including adjustment of the nature or structure of the line). For station-wide-type factors, the adjustment of the main transformer wiring method takes precedence over the adjustment of capacity. This order of adjustment is designed to ensure that the adjustment process is both efficient and economical, while ensuring the stable operation of the grid.

Take the far-backup current sensitivity as an example. Let the line length be L, Z be the 66 kV bus small-signal impedance, S be the line resistance per unit length, T be the line reactance per unit length, and X be the backup protection current.

Assuming the system capacity is 100 MVA, with a high backup voltage of 220 kV and a medium backup voltage of 66 kV, if the type of backup protection is high backup and the wiring method of the main transformer's low-voltage side is Y-type wiring, then the far-backup current sensitivity is

$$K = \frac{\frac{\sqrt{3}}{2}\cdot\frac{100\cdot 10^6}{\sqrt{3}\cdot 220\cdot 10^3}}{\sqrt{L^2S^2+(Z+LT)^2}\cdot X} = \frac{227.758}{\sqrt{L^2S^2+(Z+LT)^2}\cdot X} \tag{3}$$

If the backup protection type is high backup and the wiring mode of the low-voltage side of the main transformer is D-type wiring, the system capacity is 100 MVA, and the high backup voltage is 220 kV, then the remote-backup current sensitivity is

$$K = \frac{\frac{100\cdot 10^6}{\sqrt{3}\cdot 220\cdot 10^3}}{\sqrt{L^2S^2+(Z+LT)^2}\cdot X} = \frac{263}{\sqrt{L^2S^2+(Z+LT)^2}\cdot X} \tag{4}$$

If the backup protection type is medium backup, there is no need to look at the way the low-voltage side of the main transformer is wired, and the far-backup current sensitivity is calculated as follows:

$$K = \frac{\frac{\sqrt{3}}{2}\cdot\frac{100\cdot 10^6}{\sqrt{3}\cdot 66\cdot 10^3}}{\sqrt{L^2S^2+(Z+LT)^2}\cdot X} = \frac{757.75}{\sqrt{L^2S^2+(Z+LT)^2}\cdot X} \tag{5}$$

Formulas (1)–(5) refer to DL/T 684-2012 [19] (large generator-transformer relay protection setting calculation guidelines); this standard specifies the large generator-transformer relay protection setting calculation principles and methods in terms of design, scientific research, operations, commissioning, and manufacturing. This standard is applicable to the capacity range of generators and transformers specified in GB/T 14285-2006 [20], and focuses on the setting calculation principles and methods of relay protection for generators of 300 MW and above and transformers of 220 kV and above. The setting calculation of the small-capacity generator and low-voltage transformer is carried out through reference. From Equations (3)–(5), in order to better calculate the sensitivity of the remote-backup current, the determination of the rated current in this paper adopts the principle of "round 1 round". Therefore, when the system capacity is 100 MVA, the rated current is 263 when the rated voltage is 220 kV, and when the rated voltage is 66 kV, the rated current is 875. It can be seen that both the line-type factor and the total station factor can be simplified into the functional relationship between the three variables of length, system impedance and fixed value X, and the sensitivity coefficient. If it is assumed that the wiring mode of the main transformer and the capacity of the upstream system remain unchanged, the sensitivity coefficient is inversely proportional to the line length L, that is, the impedance of the line. If the system-related parameters do not change, they are inversely proportional to the set protection current value X.

Taking the typical impedance values of the line Z = 0.0829, S = 0.00147, and T = 0.0086, X = 720 A into Formula (3), and varying the protection current setting value X within ±5%, a functional relationship change diagram between the line length and backup protection current sensitivity is obtained, as shown in Figure 3. The following impedance values are based on field data analysis, taking into account a variety of circumstances to draw a comprehensive conclusion, which can be applied to most cases of transformer capacity and line length.

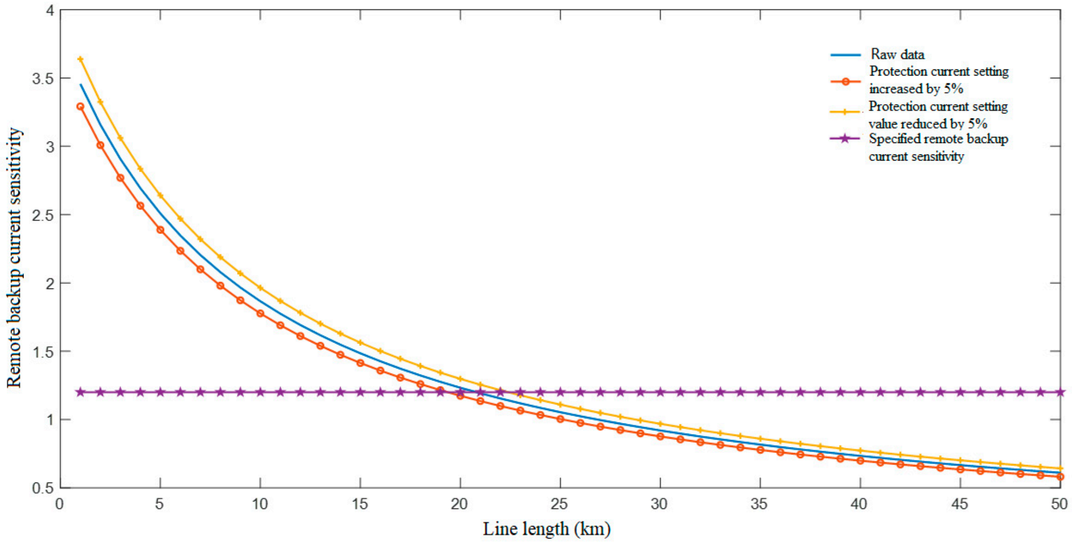


Figure 3. Functional relationship between line length and backup protection current sensitivity.

As shown in Figure 3, the horizontal line represents the minimum sensitivity coefficient of 1.2, as specified in the regulations. The functional relationship between the line length and the sensitivity coefficient of the backup protection current is an inverse proportional relationship, where the sensitivity coefficient of the remote-backup protection decreases as the line length increases. When the length of the same line is the same, the sensitivity coefficient can be adjusted by adjusting the protection current setting. In addition, it can be seen from Figure 3 that reducing the protection current setting can improve the sensitivity coefficient, and vice versa.

Considering that the line is divided into an overhead line and a cable line, the same length has different line impedance, so under the same constraint of the sensitivity coefficient, the power supply radius of lines with different properties is different. In the optimal operation state, the economic transmission capacity of the overhead system is higher than that of the cable system, and the power supply radius is larger. From Figure 3, it can be seen that there is an intersection point between the horizontal line representing the minimum sensitivity coefficient of 1.2 required by the regulation and the curve, which indicates the maximum theoretical power supply radius.

In practise, considering the difference between lines divided into overhead lines and cable lines, there are different line impedances for the same length, so the radius of the power supply is not the same for lines of different natures under the same constraints of sensitivity coefficients. Under optimal operation, the overhead system has a higher economic transmission capacity than the cable system and has a larger supply radius.

4. Example Analysis of the Radius of the Power Supply

4.1. Constraints on a local grid system

Taking the 66 kV line of a local power grid as an example, the operation strategy of the 66 kV line of this system in the substation is extremely flexible. The evaluation of the sensitivity coefficients mainly includes the remote-backup current sensitivity coefficient, remote-backup low-voltage sensitivity coefficient, and remote-backup negative-sequence voltage sensitivity coefficient, each of which has to satisfy the following criteria: a remote-backup current sensitivity coefficient of no less than 1.2, a remote-backup low-voltage sensitivity coefficient of no less than 1.2, and a remote-backup negative-sequence voltage sensitivity coefficient reaching or exceeding 1.5. The Table 2 shows the statistics of the pass rate of these sensitivity coefficients in sections of the line of different lengths.

Table 2. Line length pass rate statistics.

Satisfactory Rate \ **Line Length**	**<=5 km**	**(5, 10] km**	**(10, 20] km**	**(20, 30] km**	**(30, 40] km**	**>40 km**
Current pass rate	100.00%	99.89%	96.78%	56.21%	21.76%	0.84%
Low-voltage compliance rate	100.00%	98.52%	60.37%	9.47%	3.44%	0.84%
Negative-sequence voltage pass rate	100.00%	100.00%	94.81%	78.70%	50.76%	24.37%
Three compliance rates	100.00%	98.52%	60.37%	9.17%	2.29%	0.84%
Three-phase non-conformance rate	0.11%	0.00%	1.45%	14.50%	44.66%	76.47%

As shown in Figure 4, the increase in line length shows a negative correlation trend with the pass rate of the sensitivity factor. In particular, the pass rate of the sensitivity coefficient is relatively high when the line length is less than 20 kilometres. However, once the line length exceeds 20 kilometres, the pass rate of the sensitivity coefficient decreases gradually. For power lines with a length greater than 20 km, we can further improve the sensitivity by changing the main transformer capacity, the wiring mode of the low-voltage side of the main transformer, the operation mode of the main transformer, the line impedance, and other related parameters. Based on this finding, when the line sensitivity coefficient is kept within a reasonable range, we can provide a strong theoretical basis for the planning or adjustment of the line power supply radius by adjusting the value of the coefficient and recalculating the line length.

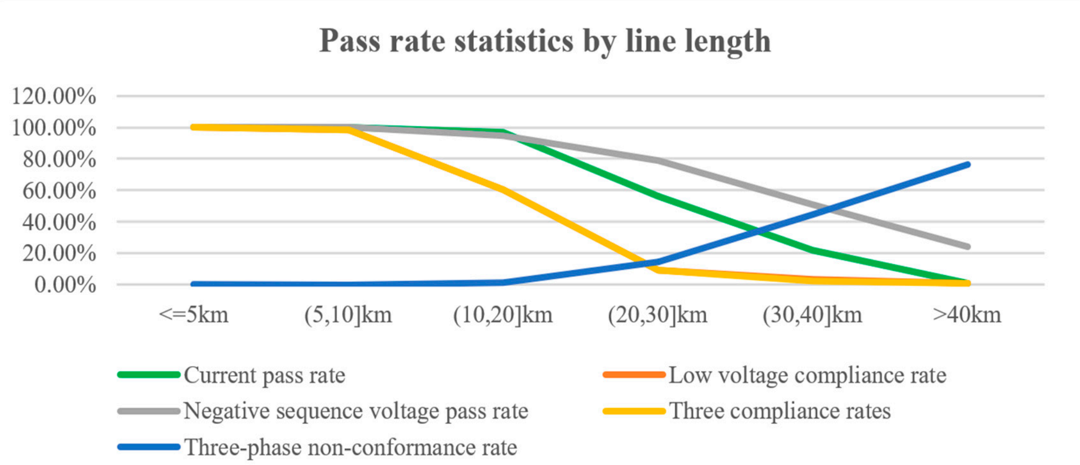


Figure 4. Sensitivity factor pass rate statistics within segments with different line lengths.

4.2. Values of Correlation Coefficients

According to Equations (2)–(4), it can be seen that there are more parameters that can affect the sensitivity of the remote-backup protection, such as the main transformer capacity, main transformer operation mode, line impedance, line length, etc. This paper selects the typical parameters of the lines to be analysed. The lines are selected from 13 substations, with a main transformer capacity of 120 MVA for 3, 180 MVA for 8, and 90 MVA and 240 MVA for 1 each. The main transformer operation mode is divided operation. Table 3 shows the relevant parameters of the selected lines.

Table 3. Table of relevant parameters after adjusting sensitivity coefficients for selected lines.

Line Name	Line Length (km)	Equivalent Unit of Resistance	Equivalent Unit Reactance	66 kV Small-Signal Impedance	Far-Backup Current Sensitivity	Far-Backup Low-Voltage Sensitivity	Far-Backup Negative-Sequence Voltage Sensitivity
Cheng bao No.2	101.723	0.0005	0.0021	0.0865	1.2	0.96	1.98
Zhang mai yi	47.631	0.0008	0.0046	0.0829	1.2	0.88	1.67
Qiao lu zuo	31.376	0.0011	0.0058	0.0854	1.2	1.01	1.79
Shu liu yi	40.310	0.0014	0.0062	0.0713	1.2	0.88	1.52
Yi pei #1	30.766	0.0062	0.0092	0.1318	1.2	0.79	1.33
Wen hai zuo	27.574	0.0018	0.0060	0.098	1.2	1.02	1.88
Qian wang	102.505	0.0006	0.0015	0.0661	1.2	0.81	1.14
Ying xi No.2	44.176	0.0022	0.0071	0.1374	1.2	0.94	1.92
Xin huang No.2	55.248	0.0011	0.0031	0.127	1.2	0.92	1.50
Lv shi #1	53.000	0.0025	0.0080	0.1702	1.2	0.94	1.88
An fu	26.325	0.0015	0.0059	0.1385	1.2	1.23	3.15
Ping sun jia	59.124	0.0012	0.0028	0.0935	1.2	1.01	2.36
Hua kuan No.2	33.355	0.0015	0.0059	0.2239	1.2	1.21	3.09

As shown in Figure 3, the length of the 13 selected lines ranges from 2 km to 30 km, and their remote-backup current sensitivity coefficients meet the requirements and are distributed from 1.26 to 4.0. The other remote-backup low-voltage sensitivity and remote-backup negative-sequence voltage sensitivity coefficients are in accordance with the regulations.

Closely related to the line length are the resistance and reactance per unit length. Since at the beginning of the design and construction, there are differences in the models of each line according to the initial planning. The equivalent unit reactances and equivalent unit resistances listed in Table 4 were provided by the design organisation, but the specific models and nature of the lines were not provided.

Table 4. Table of relevant parameters for selected lines.

Line Name	Line Length (km)	Equivalent Unit of Resistance	Equivalent Unit Reactance	66 kV Small-Signal Impedance	Far-Backup Current Sensitivity	Far-Backup Low-Voltage Sensitivity	Far-Backup Negative-Sequence Voltage Sensitivity
Cheng bao No.2	2.320	0.0005	0.0021	0.0865	4.00	12.41	6.82
Zhang mai yi	4.590	0.0008	0.0046	0.0829	3.50	3.06	4.95
Qiao lu zuo	3.830	0.0011	0.0058	0.0854	3.00	3.25	4.54
Shu liu yi	6.021	0.0014	0.0062	0.0713	3.59	1.93	4.64
Yi pei #1	5.204	0.0062	0.0092	0.1318	3.00	1.82	3.41
Wen hai zuo	5.018	0.0018	0.0060	0.098	2.50	2.50	4.20
Qian wang	16.000	0.0006	0.0015	0.0661	3.03	2.03	2.96
Ying xi No.2	11.770	0.0022	0.0071	0.1374	2.50	1.63	4.20
Xin huang No.2	17.810	0.0011	0.0031	0.127	2.00	1.63	2.66
Lv shi #1	23.515	0.0025	0.0080	0.1702	2.01	1.24	3.21
An fu	20.880	0.0015	0.0059	0.1385	1.35	1.36	3.56
Ping sun jia	33.286	0.0012	0.0028	0.0935	1.70	1.27	3.38
Hua kuan No.2	30.100	0.0015	0.0059	0.2239	1.26	1.26	3.27

4.3. Calculation Result

According to the setting criteria for the line sensitivity factor, we require that the remote-backup current sensitivity factor and the remote-backup low-voltage sensitivity factor reach at least 1.2, while the remote-backup negative-sequence voltage sensitivity factor should meet the minimum requirement of 1.5. For these 13 selected lines, the first task is to adjust the far-backup current sensitivity factor to ensure that it meets the set standard of 1.2. Immediately thereafter, we will calculate and predict the possible line lengths based on these adjusted parameters. At the same time, we will continuously monitor the real-time dynamics of the remote-backup low-voltage sensitivity factor and the remote-backup negative-sequence voltage sensitivity factor to ensure that they always meet or exceed the set criteria.

As shown in Table 4, after the adjustment of the far-backup current sensitivity factor, the potential supply radii of the lines all show different degrees of increase. It is worth noting that the change in the far-backup negative-sequence voltage sensitivity factor is not significant, with only two lines failing to meet the predetermined target. However, the change in the far-backup low-voltage sensitivity factor is more significant, with most of the lines being below the standard. The main reason for this phenomenon is that the increase in line length leads to an increase in line losses, which, in turn, triggers a significant shift in the voltage at the end of the line, ultimately affecting the sensitivity of the LV protection.

Given the difference between the equivalent unit reactance and equivalent unit resistance, and the fact that the line type has not yet been clarified, the change in line length is actually only an equivalent change. It is possible to make a preliminary qualitative estimate of the change in supply radius, but if a precise quantitative analysis of specific line lengths is required, detailed information on the nature or type of the line, such as whether it is an overhead line, a cable line, or a mixture of the two, will need to be clearly provided. This information is essential for an accurate assessment of changes in line lengths.

5. Conclusions

This paper focuses on the correlation between 66 kV line protection sensitivity and the supply radius, and then proposes a sensitivity constraint-based supply radius planning method, which is particularly applicable to regional power grids. This method comprehensively considers various factors that are closely related to the sensitivity coefficient, such as power-side parameters, main transformer parameters, and line parameters. Through in-depth calculations and analyses, we successfully simplify these complex factors into a functional relationship between four core variables and the sensitivity factor, and analyse in detail how the sensitivity factor varies with line length. To verify the practicality of this method, we take an actual 66 kV grid in a region as an example to demonstrate its accuracy in calculating and evaluating the optimal power supply radius of a line. This method not only helps to optimise the grid network structure and improve the reliability and economy of the grid, but also provides valuable guidance for the planning and construction of regional power grids.

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