Research on the County Adjustment Setting Integrated System Based on the Extension of Protecting and Coordinating Boundary

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ABSTRACT

In order to achieve the “first-class distribution network” construction goal, the original scheme focusing on the demand of the electric power system is changed into the other one combined with the user’s demand. The line instant protection instantaneous period is with a short delay in the setting value strategy, and coordinates with boundary switch protection. It extends the original protected boundary to important users downstream, and coordinates with the transformer substation upstream, forming a set of relatively constant value based on the substation transformer. At the same time, with the coordination of boundary switch, section switch of long transmission lines and its related protection section, the characteristics of the original protection scheme are overcome, namely, relying on the length of transmission lines and failure to guarantee the selective coordination because of the influence of the operation mode. On this basis, the “county adjustment setting integrated system” can be effectively achieved so as to realize the automation of distribution network setting management.

Keywords: “First-class Distribution Network”, Protecting and Coordinating Boundary, Assignment of Transient Period, County Adjustment Setting Integrated System, Automation of Distribution Network Setting management

INTRODUCTION

The “first-class distribution network” serves as part of the smart grid, and the concept of fault management is based on full coordination of local relay protection, control of switching device and boundary switching, as well as distribution automation to maximize the use of existing resources and achieve the goals of minimizing the fault time and maximizing the reliability of power consumption. Existing protection ideas are divided into two types. One is to strengthen the construction of distribution automation, through massive information transmission, to establish the wide-area protection strategy. In this way, the reliability of relay protection is based on the reliability and timeliness of network communication [1-3]. Based on the existing protection facilities, with the aid of limited communication, the other is to look for an improved protection method to improve the quality and reliability of power supply

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of distribution network. For lack of network, the latter still depends on the coordination and correct operation while local relay protection is basically completed, guaranteeing economic rationality.

In this paper, based on the second idea, strengthening local protection technology and rapid isolation of specific fault ensures the reliability of distribution network, and improves the DG transient characteristics by quick action. At the same time, with the increase in the requirement of users for reliable power supply, the original protection idea of focusing on protection of power system equipment has been changed greatly, and the power supply companies are now looking for a balanced and effective protection strategy. That is to say, based on the protection of power system equipment, the cooperative downstream boundary is extended to the user side to leave more coordinating room for users. At the same time, through coordination between the secondary reclosing and the primary reclosing of boundary switch, the failure is remedied to eliminate the site where there is no room left for coordination, to improve the reliability of power supply for users [4-6].

This paper elaborates a new improved protection scheme based on local protection scheme, which includes user protection. The segmentation scheme focusing on the reliability of power supply for users and the secondary reclosing scheme increase the level of power supply for users to a new one. The original scheme focusing on the demand of the electric power system is changed into the other one combined with the user’s demand. The line instant protection instantaneous period is with a short delay in the set strategy, and coordinates with boundary switch protection. It extends the original protected boundary to important users downstream, and coordinates with the transformer substation upstream, forming a set of relatively stable set value based on the substation transformer. At the same time, with the coordination of boundary switch, section switch of long transmission lines and its related protection section, the characteristics of the original protection scheme are overcome, namely, relying on the length of transmission lines and failure to guarantee the selective coordination because of the influence of the operation mode. On this basis, the “county adjustment setting integrated system” can be effectively achieved so as to realize the automation of distribution network setting management.

SYSTEM BASED ON THE EXTENSION OF PROTECTING AND COORDINATING BOUNDARY

General Principles of Protecting & Coordinating

The selected centralized distribution line is generally configured with the following standards [7-10]:

1 Line circuit breaker
   It should be configured with three-section definite time-lag current protection.
   Small resistance grounding system should be configured with zero sequence overcurrent protection and high sensitive grounding protection.
   It should have the secondary reclosing function.
   Longitudinal differential protection is configured as required.

2 Section switch
   Section switch should be involved in logic judgment of feeder automation, and adopt “local-type”, “centralized-type” feeder automation.
   As for “local-type” feeder automation, it should be configured with “voltage-time type” feeder automation in the trunk line, with the current counting-type controller in the branch line.
As for “centralized-type” feeder automation, it should be configured with one-phase current for fault detection. Report it to the master station after a fault is confirmed according to voltage loss or zero flow. Small resistance grounding system should be configured with zero sequence overcurrent for fault detection. Report it to the master station after the grounding is detected.

3 Boundary circuit breaker
   It should be configured with smooth and setting double-section definite time-lag current protection, and protective action is breaker tripping.
   It should have a reclosing function.
   Small resistance grounding system should be configured with zero sequence overcurrent protection and high sensitive grounding protection.
   Neutral non-grounding or arc suppression coil grounding system should have the functions of single-phase grounding detection and isolation.

4 Users incoming line switch
   In user front-end configuration of boundary switch, the user incoming line switch is not configured with protection. In user front-end non-configuration of boundary switch, when users have two or more transformers, the user incoming line switch should be configured with protection.
   Functional configuration requirements of user incoming line switch with protection are same as those of boundary circuit breaker.

5 Distribution transformer
   800kVA or more oil-immersed transformer, 1000kVA or more dry-type transformer should be configured with double-section current protection, and protective action is breaker tripping.
   800kVA or less oil-immersed transformer, 1000kVA or less dry-type transformer should be configured with a fuse protector. For example, when 20Ie (Ie, rated current of the transformer) does not coordinate with Section II overcurrent of superior protection, it should be configured with double-section current protection, and protection action is breaker tripping.
   The protection configuration is shown in Figure 1, and the protection scheme is shown in Figure 2.

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Figure 1. Primary Diagram For Extension-Based Boundary Protection Configuration.
Figure 2. Protection Scheme for Coordinating with Boundary Extension.

Protection Setting Principle

A Line circuit breaker

(1) Instantaneous current protection:
   a) Meet the coordinating requirements of the upper level transformer for time-limit quick break protection, avoid all the low voltage side faults of distribution transformer, and set 1.7 times sensitivity for 10kV bus fault of the substation. When both are contradictory, set it according to the requirements of the upper level transformer. In order to prevent CT saturation protection failure, when the secondary value exceeds 50A, set it 50A. In the urban area, the primary value of this line section should not be less than 1400A.
   b) Operation time is 0.15s.

When a fault occurs in the overlapping protection scope of current quick break of this section and the subordinate boundary circuit breaker, this section and the boundary circuit breaker may trip simultaneously, and the second reclosing will remedy it to realize the upper and lower levels coordination.

(2) Time-limit quick break protection:
   a) Meet the requirement of the upper level transformer for over-current protection, reliably avoid the maximum load current of this line, set 1-1.1 times of rated current of the transformer with the minimum capacity. When both are contradictory, set it according to the requirements of the upper level transformer. In order to prevent the CT saturation protection failure, when the secondary value exceeds 50A, set the fixed value as 50A. In the urban area, the primary value of this line section should not be less than 1200A.
   b) Operation time is 0.55s.

(3) Timing overcurrent
   a) Ensure that a metallic short circuit in the scope of protection has the sensitivity of not less than 1.3, avoid the maximum load of this line, set 1.5 times of CT primary rated current.
When both are contradictory, set it according to the confirmed sensitivity. In the urban area, the primary value of this line section should not be less than 700A.

Operation time should coordinate with time of the subordinate boundary circuit breaker and the circuit breaker in the middle of the line, and time difference is 0.3s.

(4) Reclosing:
   a) The first reclosing time is 0.2s.
   b) The second reclosing time is 15s.

B Circuit breaker in the middle of the line:
   a) Ensure that a metallic short circuit in the scope of protection has the sensitivity of not less than 1.3, avoid the maximum load of this line, set 1.5 times of CT primary rated current. When both are contradictory, set it according to the confirmed sensitivity.
   b) Operation time should coordinate with constant overcurrent time of the subordinate boundary circuit breaker and the circuit breaker in the middle of the line, and time difference is 0.3s.

Boundary circuit breaker
   (1) Current instantaneous break-off protection:
      a) Meet the coordinating requirement of the upper level line circuit breaker for time-limit quick break, coordinate with the distribution transformer current instantaneous break-off protection or fuse protector, set it according to the line circuit breaker time-limit quick break set value divided by the coordinating coefficient of 1.05-1.1. When both are contradictory, set it according to the coordinating requirements of the upper level line. In order to prevent the CT saturation protection failure, when the secondary value exceeds 50A, set the fixed value as 50A. On the premise of meeting the coordinating requirements, set the primary value of this section of boundary circuit breaker as 1050A in the urban area.
      b) Operation time is 0s.

   Note: When a fault occurs in the overlapping protection scope of current quick break or fuse protector of this section and subordinate distribution transformer, this section and the distribution transformer circuit breaker may trip or fuse simultaneously, and the boundary switch reclosing will remedy it to realize the upper and lower levels coordination.

   (2) Timing overcurrent:
      a) Meet the coordinating requirement of the upper level line circuit breaker for timing overcurrent, coordinate with the distribution transformer current quick break or fuse protector, set it according to the timing overcurrent fixed value divided by the coordinating coefficient of 1.05-1.1. When both are contradictory, set it according to the coordinating requirements of the upper level line. In order to prevent the CT saturation protection failure, when the secondary value exceeds 50A, set the fixed value as 50A. On the premise of meeting the coordinating requirements, set the primary value of this section of boundary circuit breaker as 600A in the urban area.
      b) Operation time is 1.1s.

Reclosing time is 0.5s. Reclosing time should be more than the upper level reclosing time plus accelerating judgment time after reclosing.

C User incoming line circuit breaker

The protection setting principle of user incoming line is same as that of boundary circuit breaker, set it according to the value of related section of boundary circuit breaker divided by the coordinating coefficient of 1.05-1.1. The time is same.

D Distribution transformer protection

Selection of the fuse protector

Rated current of the fuse protector is selected according to 2 times of that of distribution transformer, and 100kVA or less distribution transformer is selected according to 3 times of
that of distribution transformer in order to avoid distribution transformer overload, inrush current, cold starting current, secondary side short circuit, lightning stroke, etc.

(1) Current protection
   Time-limit quick break protection,
   a) Avoid all the low voltage side faults of distribution transformer, meet the coordinating requirements of upper level boundary circuit breaker for current quick break, and set it according to 20 times of rated current of distribution transformer. When both are contradictory, set it according to the coordinating requirements of the upper level boundary circuit breaker. In order to prevent the CT saturation protection failure, when the secondary value exceeds 50A, set the value as 50A. The primary value of this section should not be more than 950A.
   b) Operation time is 0s.

(2) Timing over current:
   a) Ensure that it has sensitivity to a low voltage side fault of distribution transformer, avoid the maximum load current, meet the coordinating requirements of upper level boundary circuit breaker for timing over current, and set it according to 5 times of rated current of distribution transformer. At the same time, ensure the coordination with over current Section III of the upper level boundary circuit breaker. When the three are contradictory, set it according to the coordinating requirements of the upper level boundary circuit breaker.
   b) Operation time is 0.8s.

E Branch switch:
   The current counting-type controller is set according to the set of timing over current. The value ranges from the set of timing over current of substation outgoing line to that of boundary circuit breaker connected to the downstream. After twice over current counting, voltage loss trip.

Characteristic Analysis of Protection Scheme

It can be seen from the above protection scheme, the original protecting and coordinating boundary is 10KV outgoing line circuit breaker, and principle is to reduce the downstream coordination level difference as far as possible. The principle is the prerequisite to protect the safe and stable operation of electric power system major network. Therefore, when the user carries out installation and protection configuration of incoming line breaker in accordance with the grid-connected requirements, the breaker and the substation outgoing circuit breaker will trip simultaneously because of overlapping protected area. Furthermore, for such reasons as user circuit breaker properties and maintenance, a fault occurs to the user transformer, and power outage occurs in all the lines because of substation outgoing line circuit breaker tripping. Construction of existing “first-class distribution network” requests the reliability of power supply for users and high quality of power supply. At the same time, as the supervision of distribution network services is strengthened, the power supply company will further promote services along the downstream user side. Thus, it is very necessary to adopt the stable and reliable protection scheme conducive to realization of automation, changing with the change in grid scale, what is the most important, which can balance the interests of the user side.

The protection strategy currently adopted is as follows: When the protected boundary is extended to the boundary circuit breaker, 10KV boundary circuit breaker serves as the first user-oriented barrier of the electric power system, which coordinates with substation outgoing line circuit breaker, but not with the distribution transformer. In order to ensure this point, 10KV quick-acting section is cancelled, and replaced by 0.15S overcurrent Section I. At the same time, its coordinating direction is upstream to coordinate with time-limit quick
action and overcurrent of low voltage side of power station transformer, and the method to ensure sensitivity of multi-line end or overall length is not considered, different from traditional protection. On the other hand, it can be seen from the figure, over-current protection is greatly influenced by the operation mode. As shown in Figure 3, the scheme adopts the coordination with upstream transformer, and there are the following benefits:

1. Selection of substation outgoing line protection coordinates with upstream transformer, and the line length is not considered, advantageous to realize automatic calculation and automation of setting calculation. It can be seen from the above setting principle that a constant value is usually given according to the set;

2. For outgoing line coordinates with upstream transformer, the downstream line length is not considered. Therefore, when the line exceeds 8KM, the section switch should be replaced by the circuit breaker, configuration of overcurrent section III and II should coordinate with substation outgoing line to ensure protection of the entire line, especially of the long line;

3. Outgoing line circuit breaker exits through its quick-acting section, a section of protecting and coordinating space is left for boundary circuit breaker protection. When the boundary circuit breaker serves as the point to divide property rights of users, it also serves as the boundary pass for side protection of the electric power system, playing two roles of protection and boundary of property rights, which are suitable for two-in-one.

4. boundary circuit breaker is configured with one-time reclosing, substation circuit breaker is configured with two-time reclosing, and a remedy can be provided for users while transient fault tripping. Meanwhile, the problems can be avoided, namely, the substation circuit breaker and the boundary circuit breaker trip simultaneously because of actual operation time of the circuit breaker;

5. The original 1S reclosing is changed into 0.2S first-time reclosing to solve the problem of industrial motor low voltage tripping. In particular, when electric motors are overloaded, it is necessary to recover load instantaneously. At the same time, for electronic products commonly used, especially intelligent products, 0.2 seconds can be completely ignored, and not perceived by the user at all. Thus, user experience of electricity consumption is effectively improved.

6. Use of 15S reclosing is to simulate immediate power transmission by the dispatcher after a fault occurs, namely, in response to “debris” falling temporary faults. This kind of faults is caused by twigs or animals, and it takes “debris” a period of time to fall off from a conductor or an insulator.

Characteristics Analysis of Reclosing Coordination between Upper and Low Levels of Branch Switches in the Protection Scheme

In order to prevent substation circuit breaker trip caused by a fault between a branch switch and its downstream boundary circuit breaker, power outage occurs in all the lines. Branch switch is configured with a quick overcurrent counting controller, when the overcurrent branch controller opens and locks the branch switch twice, substation switch CB1 will restore power supply in all the lines after the second reclosing.

When a fault is located in the downstream of boundary circuit breaker and in the instant protection overlapping area of line circuit breaker and boundary circuit breaker, the line circuit breaker and the boundary circuit breaker connected to the downstream may trip simultaneously. After the line circuit breaker recloses in 0.2s, acceleration time is 0.1. The boundary circuit breaker recloses in 0.4S, and will instantaneously strip after a fault occurs. Outgoing line circuit breaker does not strip in 0.15s, and the counter does not work until it reaches the actuation value of voltage loss and overcurrent twice. Specific action sequences are shown in Figure 3;
According to the above analysis, the adoption of reclosing strategy is not only to improve the reliability of power supply for users, but to further lock the faulty section through upper and low levels reclosing coordination, namely, to provide one more chance for fault diagnosis.

In short, the line instant protection instantaneous period is with a short delay in the setting value strategy, and coordinates with the transformer substation upstream, forming a set of relatively stable set value. In order to improve the constant value, it is required to coordinate with boundary circuit breaker, section switch(circuit breaker) of long lines and its related protection section to the characteristics of the original protection scheme, namely, relying on the length of lines and failure to guarantee the selective coordination because of the influence of the operation mode. At the same time, the fault is further locked by means of tripping coordination of line circuit breaker and boundary circuit breaker. Based on these two aspects, the reliability of power supply can be greatly improved, and the protection scheme can give consideration to grid security and user interests.

Figure 3. Action Sequence Diagram For upper Level And Subordinate Coordination of Branch Switch In Case Of Insufficient Difference.
COUNTY ADJUSTMENTS SETTING INTEGRATED SYSTEM BASED ON THE PRINCIPLE OF PROTECTION AND COORDINATION

Overview of County Adjustment Setting Integrated System

In the case of the setting coordination system of distribution network line based on transformer capacity, after the primary system modeling of system high voltage side is completed, related setting system of distribution network line will be automatically formed. Accordingly, in essence, the system is deemed as the protection setting system of low voltage distribution network generated according to the substation transformer capacity after the completion of high voltage class modeling of the power system. After the completion of transformer modeling, through local area of power supply (length of incoming line), check it and decide whether to install the circuit breaker in the middle of the line to form the final protection scheme. Operation interface corresponding to specific flow chart is shown in the figure below: (1) create a substation; (2) build a transformer and input related modeling parameters; (3) after parameters are input, transformer primitives in the Figure 4 are changed according to the parameters, and modeling is completed.

![Flowchart](image)

Figure 4. Flowchart For High Voltage Class Modeling Of The Power System.

Specific Operating Procedures for County Adjustment Setting Integrated System

Specific operational interface and methods are as follows:

Before coordination and setting, the following operations should be completed in the area to be calculated currently: Complete generation of load path and small power supply path, complete “selection of small power supply path”, “busbar equivalence in the area” and “small power source equivalence”, and finally output busbar equivalence results.

1) According to Part 1 protection configuration in the paper, the system has been preset 10-110kV transmission line and default configuration of transformer protection. In general, modification is not required. If modification is required, right click on the margin of the tree
diagram on the left side, select [Configure protection information], and select the default configuration of protection in the pop-up window, as shown in Figure 5:

![Figure 5. Configuration of Protection Information.](image)

2) Initialization of grid model
Select the area to be calculated according to the calculation module, right click and select [Set it as the area to be edited currently], a prompt box pops up after setup is successful, asking whether the grid model and its method is changed, if changed, click on [Yes] to reinitialize the grid model; otherwise, click on [No].

3) Single protection setting calculation
In the diagram for power grid area, right click on the area for line protection installation to be calculated, click on [Calculate the line protection], or right click on the primitives of substation to be calculated, click on [Calculate the substation protection], as shown in Figure 6:

![Figure 6. Single Protection Setting Calculation.](image)

Transformation ratio input box pops up, as shown in Figure 7. The first line is the transformation ratio for current calculation protection. In general, only fill in CT transformation ratio for current protection in the first line. The following lines show two types of transformation ratio: One type is to calculate protection of the place opposite to protection installation place, and it is not required to fill. The other type is to calculate protection of main transformer or line at the next level in the place for protection installation. If the calculated protection need to coordinate with that of main transformer or line at the next level, the set coordinating with equipment protection should be calculated ahead of time. (For example, calculate the set for main transformer protection, and fill in CT transformation ratio for main transformer protection to be calculated.)
After filling in the transformation ratio, the user needs to confirm the setting principle preset in the system according to the Specification. The user can select the protection principle according to the needs, if there is no change, click on [confirm the change], as shown in Figure 8.

Next, the program will automatically calculate, after the calculation is completed, set the value in place for protecting installation, as shown in Figure 9.
In the power grid connection diagram, right click on the calculated place for protection installation, select [export the scheme or report] to export setting calculation sheet for current protection in word format, as shown in Figure 10:

![Diagram showing calculation and protection setup](image)

**Figure 10. Automatic Export Of The Constant Value For Line Protection.**

**CONCLUSIONS**

This paper introduces the protection scheme for distribution network to balance user demands. The line instant protection instantaneous period is with a short delay in the set strategy, and coordinates with boundary circuit breaker protection and coordinates with boundary circuit breaker protection. It extends the original protected boundary to important users downstream, and coordinates with the transformer substation upstream, forming a set of relatively constant set based on the substation transformer. At the same time, with the coordination of boundary circuit breaker, intermediate circuit breaker of long lines and its related protection section, the characteristics of the original protection scheme are overcome, namely, relying on the length of lines and failure to guarantee the selective coordination because of the influence of the operation mode. On this basis, the “county adjustment setting integrated system” can be effectively achieved so as to realize the automation of distribution network setting management.

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