

# Reliability and Dynamic Performance Simulation Based on Relay Protection Summary

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**Abstract.** With the development of science and technology, national security and social life can not be separated from electricity every moment, and the safety of power grid is becoming more and more important. At present, the research on relay protection model in dynamic simulation of power system in China is still in the primary stage. Because the research is not deep enough, the control law of relay protection elements can not be well grasped. The failure can not be handled well. Therefore, in order to ensure the safe operation of the power system, we must first strengthen the grid structure of the power system, improve the elasticity coefficient, distribute the reserve capacity reasonably, strengthen the adjustment ability of the tie line between the major power grids, and improve the stable reserve of the power grid. In order to improve the authenticity and reliability of dynamic simulation, it is necessary to establish a set of relay protection models, which should be consistent with the actual relay protection. In this way, the stability problem in power system can be analyzed accurately to improve the reliability of power system. The relay protection model established in this paper reduces the complexity of modeling and can reflect the dynamic characteristics of power system after interference. It is of great significance to the analysis and research of power system.

**Keywords:** Relay Protection, Reliability, Dynamic Performance

## 1. Modeling ideas of reliability and dynamic of relay protection

For a relay protection system, it has several relay protection devices and has a clear hierarchy. In this way, it is easier to model each component than the relay protection system. In addition, the protection principle of each relay protection component is relatively mature, the time of taking protection measures is also very short, and the reliability is high. In the implementation of relay dynamic simulation, it is properly simplified. At the same time, it will not affect the accuracy of the simulation. Therefore, the main protection can be simulated by circuit breaker according to the set time, so as to ensure the accuracy of the simulation. However, in the actual situation, the grid structure of the power system is different, and the habits of operation will be different. In order to describe the protection system more accurately, each process can be better described by logical judgment. Each logical

judgment process can be regarded as a relay, but these relays are not real, so they are called virtual relays.

Current relay can realize the protection of current, it is a relatively simple relay, its working principle is: if the input current is larger than the action current, the current relay will automatically close the contact; After its closed contact, only the current decreases, when it is less than the return current, the relay contact can be reopened. That is to say, the closing of the contact of the current relay is directly related to the magnitude of the current. Here the action current or return current is called the reference source of the current relay. The working principle of other relays is consistent with that of current relays. The virtual relay is the same as the conventional relay, and its contacts are divided into two types: open and closed. When the input is greater than the reference source, the contact is closed, and when the input is less than the reference source, the contact is disconnected [1].

## **2. Strengthening the capacity of power grids to withstand accidents failure**

Misoperation and abnormal operation of the power grid are inevitable. The key is that the power grid will not cause large area power outages and huge economic losses in the event of any accident, which requires strengthening the ability of the power grid itself to resist accidents:

### *2.1. Improved treatment of relay protection staff*

Improving the reliability of relay protection also involves the real understanding of the nature of relay protection work and the attention of relay protection staff as well as the specific reward and punishment system. Many relay protection staff are unwilling to engage in relay protection work for a long time, because the responsibility is too great, the whole day is worried, the work is hard, and the leader can not understand it. On the contrary, in the relay protection accident, the blame is to protect the staff. The relay protection staff, like the doctors of the power grid, should have a higher status and treatment to prevent the expansion of the power grid, so that they can love their work.

### *2.2. Reasonably determine the elastic coefficient of electric power development*

The Ministry of Power and Electrical Engineering will attach great importance to the elastic coefficient of power development. There have been special research groups and studies. But after emphasizing marketization later, the state seems to pay less attention to this problem, only if it can recover the cost in the short term, be profitable, and invest in the power generation project with a better environment, the merchant is willing to invest, which makes the growth of power generation capacity unplanned or difficult to implement. We believe that we should still study and formulate a reasonable elastic coefficient of power development according to the speed of the country's future economic growth, the period of power plant construction and the fuel supply, as the basis for the macro control of the development of power industry [2].

### *2.3. Setting of relevant indicators*

The reliability of relay protection is related to the safety of power system and has been attached importance to by relay protection researchers. Whether the evaluation index is reasonable is related to whether the way to improve the reliability of relay protection really meets the requirements of improving the safety of power grid. Improving the evaluation index can improve the safety of power grid operation, which should be the judgment standard of whether the index is reasonable. At present, the evaluation of relay protection reliability in our country mainly considers the correct action rate of the protective device, which is not reasonable [3].

### *2.4. Strengthening the backbone grid*

The development of power grid in China lags behind the development of power supply, the grid is relatively weak, and the ability to withstand accidents is poor. Even if the relay protection moves correctly in the event of failure and the fault is removed quickly, it is inevitable to expand the accident. Therefore, strengthening the backbone grid is the fundamental solution. A more economical and

effective way to strengthen the backbone grid is to build UHV transmission lines. In our country, at least 750 kV of contact lines should be set up among the power grids in each region to strengthen the ability of mutual support among the power grids in each region, so that the connection between the major power grids is closer, which is conducive to maintaining the stable operation of the system after failure.

**Table 1.** Strengthening related operation of power grid to withstand accidents

Strengthening related operation of power grid to withstand accidents	Improved treatment of relay protection staff
	Reasonably determine the elastic coefficient of electric power development
	Setting of relevant indicators
	Strengthening the backbone grid

### **3. The stability and dynamic performance of relay protection are analyzed from technical point of view**

#### *3.1. The basic operation of system relay protection*

From the stability of intelligent substation relay protection, the core system is the local main monitoring and control background system. During the operation of the primary equipment of the system, once the corresponding primary equipment has the related running obstacle or fault in the operation process, the relay protection system will issue a prompt and inform the relevant technical personnel in advance. In this way, upon receipt of the alarm, the staff member will immediately take safety measures to maintain its safe operation. In the case of not serious problems, the relevant staff can continue the previous operation after determining the state of smooth operation of the line. In general, monitoring equipment installed substation, is the core of relay protection system. The main function of the monitoring equipment is to transmit the relevant information of the intelligent substation to the network system. The relay protection device is analyzing the information and issuing the relay protection command according to the final analysis results. Then ensure the stable operation of the system [4].

#### *3.2. Innovation in digital technology*

The application of digital technology effectively reduces the frequency of relay protection failure. The application of digital technology reduces the input of human resources and avoids the malfunction caused by improper human operation. For example, the use of sensors not only improves the transmission performance of power to a certain extent, but also avoids the influence of secondary circuit route and secondary circuit grounding on the relay protection system of intelligent substation. In addition, the digital technology effectively strengthens the accuracy of power supply information, makes the transmission of power supply data real-time, plays the role of optimization and upgrading of intelligent substation relay protection system, and promotes the stable operation of the system [5].



**Figure 1.** Digital relay protection device

#### 4. Calculation method of reliability index of relay protection

For a continuous production of machinery and equipment, set  $Q$  as the production capacity per unit time of the equipment,  $Q_n$  for the production capacity of the equipment within the time  $t$ , then

$$Q_n = Q_t \quad (1)$$

The failure rate of the equipment can be expressed as economic loss

$$\Delta Q = Q \sum_{i=1}^{\infty} \Delta t_i \quad (2)$$

Relay protection device is also a continuous working equipment, which can be analyzed according to the above method, but the relay protection device has its particularity, and the production capacity of relay protection is equal to the economic loss avoided by its reliable action to remove the fault. Therefore, only when the fault occurs, the relay protection device has production results and creates economic benefits. Similarly, the economic loss caused by incorrect relay protection is equivalent to the loss caused by the shutdown of the above machinery and equipment. Therefore, the failure rate of relay protection is FR the ratio of the economic loss of power system and user caused by all its incorrect actions to the economic loss avoided by each correct action; The reliability index of relay protection should  $R$  be defined as  $(1 - F_p) \times \text{energy} \times 100$ , that is, the ratio of economic benefit created when it actually creates economic benefit and absolute reliability of work. This kind of index can urge the relay protection workers to analyze the severity of the consequences caused by the incorrect action of each protective device, and pay special attention to the protective devices which may cause serious consequences and huge economic losses. Therefore, this index can directly reflect the safety and economy of power system operation. The range of power outages and direct and indirect economic losses caused by incorrect operation of each relay protection device can be estimated, so this reliability index can be calculated.

#### 5. Simulation study on dynamic performance of relay protection device

For example, the system voltage  $U$  variable is established by creating the new variable and setting the variable type. The detailed variables of the system are shown in Table 2.

**Table 2.** Variable address allocation table

Number	Variable name	Explanatory note	Type
1	IL1	Current lamp	Memory discrete
2	IL2	Current lamp	Memory discrete
3	IL3	Current lamp	Memory discrete
4	VL1	Voltage lamp	Memory discrete
5	VL2	Voltage lamp	Memory discrete

In the startup interface system login management, this is the initial window after the system runs, mainly including the management of system permissions. The management of system user group is realized by user configuration, including: permission level, user group, system password and so on. In the startup interface, the system login and close the system by calling the system function, and judging the system permission implementation script as follows:

```
LogOff();
```

```
LogOn();
```

```
if($ Access Authority <=200)
```

```
else{ShowPicture; ClosePicture;}
```

The running interface is mainly composed of system simulation script, data display, data input, button script and indicator lamp.

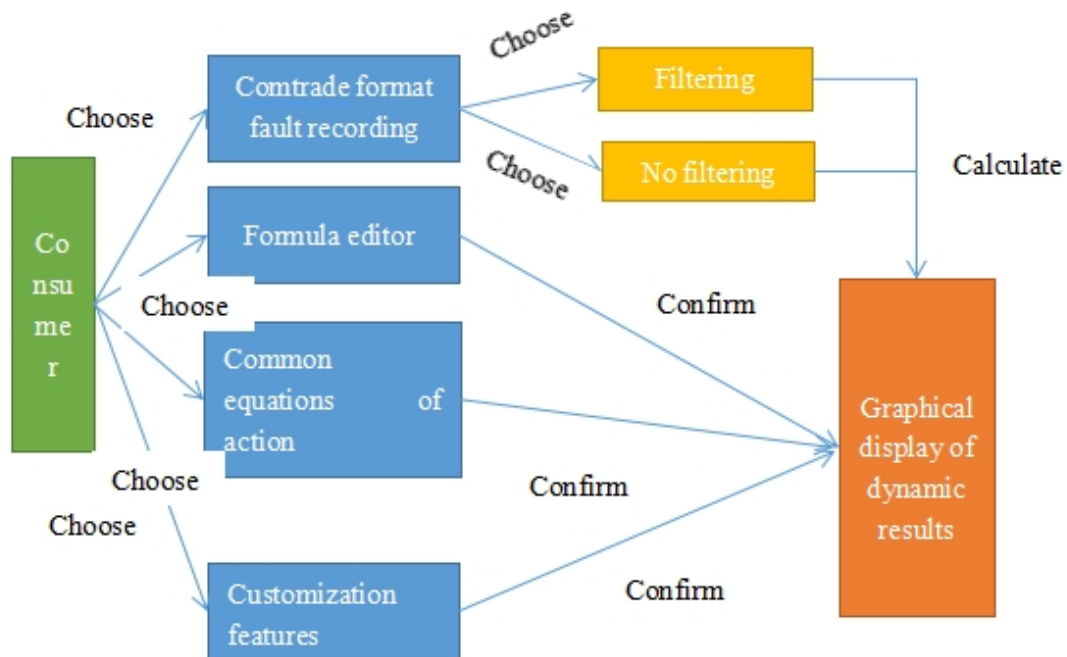
Calculating scripts. The calculation script in the design is added by the calculation button.

Indicates the script. The indicator operates through the page properties.

In the research stage, the relay protection device has to go through strict theoretical analysis and simulation research, after being made, it has to go through various static performance tests in the laboratory, and finally through dynamic simulation tests, but these tests are carried out under laboratory conditions. It is difficult to accurately simulate the real electromagnetic process when it fails at high voltage and high current. For the protection device to work reliably under any fault condition, the protection device should be repeatedly tested with a large number of on-site fault recording data under various faults, which can be done with a protection tester or RTDS, but these equipment are expensive, the test cost is very high, and the protection device in the stage of research and development can not be tested and analyzed. Therefore, it is necessary to develop a relay protection dynamic performance simulation software which can be repeatedly tested with various fault recording data in the field. In recent years, many relay protection device dynamic performance simulation software has appeared in the market. It is suggested that the test center of the power sector establish a standard, open and universal simulation software system as described above as a test means for protection development and identification. The system should not only have a large number of standard component library for drawing relay protection logic block diagram, but also the component library and its interface should be open, open and transparent. The protection manufacturer can test his own protection device with this system in advance without revealing its technical secrets. At present, the protection software developed by relay protection manufacturers in China is still in the stage of manual programming, and its shortcomings are obvious: for the same component code in different protection, different developers should be recompiled repeatedly. After the protection logic changes, the program must make a lot of modification, it is difficult to ensure correctness. Therefore, the above protection test software can also be used as a development tool for the protection manufacturer. The software developer can automatically generate the required code by connecting each component and even download it directly to the protection. Software logic in protection can also be uploaded to test software for test use [6].

For example, Tianjin University and the Relay Protection Office of Huazhong Electric Power Group Company have developed the dynamic performance simulation software of relay protection device. Its main functions are shown in the simulation interface of figure 3. All kinds of protection elements (such as starting element, oscillating locking element, breaking line locking element,

distance element, differential element, direction element, etc.) and various logic elements (such as "with" door, " or "door, " and non" door, " non "door, delay, memory, opening, etc.) have been compiled in the software. By connecting these elements according to the principle of protection setting, the user can draw the protection logic block diagram and set the value of each element in the block diagram, and then input the field recording data of the Comtrade format for simulation test. Which element action is displayed in the diagram with red label, In this way, the user can clearly see the internal action process and logical coordination relationship in the fault transient process, which is convenient to check the actual action of the protection device during the fault, find out the links and causes of the incorrect action, and carry out accident analysis. Because the speed of the simulation is adjustable and can be carried out in one step, the inspection can be carried out slowly and repeatedly. On this basis, Tianjin University and the relay protection office of East China Electric Power Group Company jointly developed the open relay protection device dynamic performance simulation system. Compared with the previous simulation system, the software has more flexibility and openness. In addition to simulating several commonly used protection principles and action characteristics, it can also simulate any custom protection principles and action characteristics. Its function is shown in figure 2.



**Figure 2.** Block diagram of dynamic performance simulation system for open relay protection device

First, the fault data of some field admission Comtrade format should be selected when using the system, and then any filtering algorithm should be selected after the data format conversion, and then filtered and sent to the action equation module. The algorithm of solving differential equation or sampling value directly can be sent to the action equation module without filtering. Then the user can select a commonly used protected action equation to send it to the action equation module, verify it with field recording data, or edit any action equation customized by the user with "formula editor" and send it to the action equation module. Check it with field recording data. The action characteristics of the protection can be selected for common features, such as circle characteristics, quadrilateral characteristics, etc., or any shape action characteristics customized by the user, and sent to the action characteristic module. The action equation module and the action characteristic module are calculated and sent to the graphics display module. In the graphic display module, the protection measurement value calculated by the action equation module is compared with the action characteristic sent by the action characteristic module. Because the speed of display can be adjusted, the process of measuring

impedance from load impedance to action area can be observed clearly and intuitively, the change process of measuring impedance in system oscillation, the whole process from load state to fault removal to overlap permanent fault to secondary resection, which is very beneficial to the inspection of protective action behavior and accident analysis. Because this kind of simulation analysis is very easy, it can carry on a large number of repeated tests to the protective device.

For a long time, the test center of power department can only give two conclusions: correct action or wrong action through dynamic mode test or protection tester to test the hardware and software of relay protection device. For the false action, neither the tester nor the developer can clearly know which module or logic in the device, hardware and software leads to the wrong action of protection, nor can they be tested with a large amount of field recording data. Therefore, it is suggested that the test center of the power sector establish a standard, open and universal simulation software system as described above as a test means for protection development and identification. The system should not only have a large number of standard component library for drawing relay protection logic block diagram, but also the component library and its interface should be open, open and transparent. The protection manufacturer can test his own protection device with this system in advance without revealing its technical secrets.

## 6. Conclusion

To sum up, this paper studies the relay protection model in dynamic simulation of power system, briefly describes the ideas and methods of modeling, and expounds the importance of dynamic performance simulation system of relay protection. It is suggested that the standard "relay protection dynamic performance simulation system" should be developed by the protection test center of power department. The simulation system should be open, and the modules and interfaces are transparent to the manufacturer. Each manufacturer can test the standard simulation system in advance or use it as a research and development tool. Through this method, the actual situation can be truly reflected, the power system can be effectively protected, the causes of sudden accidents are reasonably analyzed and corresponding measures are taken, which has certain practical significance. At the same time, the simulation calculation of relay protection is realized, which provides some reference for the expansion and supplement of the model.

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