Research on Reaction Phase to Phase Fault Location and Protection of Distribution Network

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Abstract. A regional differential protection device for the reaction phase to phase fault of the distribution network was designed, as a result of failure to swiftly, efficiently and accurately identify, locate and eliminate the reaction phase to phase fault of distribution network. The device is installed at each bus bar. Each incoming and outgoing data information of the bus bar is read through the RS485 bus, the communication between each regional protection device is achieved through the optical fiber connection, and the regional protection device with the most hierarchical lines on the bus bar is the host station. Exchange the real-time operation data of the line collected by the regional differential protection device in the lines between the regional differential protection devices, the regional differential protection device begins to execute identification and send fault information to the host station to composite the fault information matrix A when detected single-phase current sudden change is greater than the set value. In result, swift, efficient and accurate detection of distribution network fault, furthermore, isolation of phase to phase fault are achieved.

1. Introduction

At present, there are many branch lines in the distribution network, but not all are installed with circuit breakers, most of them exist in the form of load switch, which cannot be used to cut off fault currents [1, 2]. However, the circuit breaker access mode is mostly adopted when connecting with the distributed generation, and the cascaded switches are quite many. It is required to set a long delay in order to realize the regional protection, meanwhile relying on the segmental protection coordinated by time alone can no longer meet the requirements for rapid and accurate fault removal of the relay protection device. In this case, the rapidity and regionality of protection will form a contradiction that is difficult to reconcile. However, the research and application of limited wide-area relay protection of high-voltage transmission network makes it possible to be implemented in the distribution network. Nevertheless, the cooperation between multi-terminal differential protection and distributed generation protection is still not achieved until now due to the lack of unified technical means of information integration and interconnection [3, 4].

Based on the above background, this article proposed a regional protection architecture combined with centralization and decentralization. The protection devices of the entire feeder can communicate
with the adjacent node protection devices. When phase to phase fault occurs in the protected circuit, a differential loop will be formed in a small range to identify the fault, and act on the circuit breaker to cut off the fault. This has not only solved normal operational failure problem of the control center caused by massive data volume, but also decentralized the protection algorithm to each protection device, which contributed to the efficiency improvement of regional location, and achieved swift, high efficient and accurate detection of distribution network fault, furthermore, isolation of phase to phase fault.

2. Regional Protection Device Design
A regional differential protection device for reaction phase to phase fault of distribution network is designed, which is mainly composed of power module, CPU, analog acquisition module, AD conversion module, communication module, opening and exiting module and human-computer interaction. The regional protection device is installed at each bus bar, and each incoming and outgoing data information of the bus bar is read through the RS485 bus, the communication between each regional protection device is achieved through the optical fiber connection, and the regional protection device with the most hierarchical lines on the bus bar is the host station, its schematic diagram is shown in Fig. 1.

![Schematic diagram of the regional protection device.](image)

The protection method of the regional differential protection device is as follows: (1) Select the regional differential protection device with the most hierarchical lines as the host station, and use optical fiber communication between the host and secondary stations; (2) Exchange the real-time operation data of the line collected by the regional differential protection device through communication method of optical fiber under unified control of the host station to achieve the purpose of data sharing, and when the bus bar fails, the tripping command is directly issued by the regional differential protection device; (3) Regional differential protection device will begin to execute identification when the detected single-phase current sudden change is greater than the set value. The set value should be not less than 0.3 times the minimum load current, and not more than 0.5 times the maximum load current; (4) The fault information is sent when the differential current of minimum motion is greater than or equal to 0.7 times the sum of the braking current and the load current; (5) Send the fault information of each regional differential protection device to the host station through optical fiber to composite the fault information matrix A, and the matrix element is set to 1 if the condition of step 4 are met, otherwise set to 0, value 1 is identified as the fault area; (6) After the fault area is identified, if the differential protection of regional differential protection device is launched, a trip command will be issued directly to isolate the
fault after fault location; if the differential protection of regional differential protection device is not launched, then the fault information will display to alert. The process is shown in Fig. 2.

![Flow chart of zone differential protection device.](image)

Figure 2. Flow chart of zone differential protection device.

3. **Fault area localization based on wide area protection algorithm**

The initial condition for the implementation of the wide area protection algorithm is to collect the wide area protection information, thus in the main task scheduling process, there is always data communication between the host station and the secondary stations [5, 6]. After obtaining the collected data, according to the designed protocol, the host station will analyze the three-phase current information, calculates the differential current between each two nodes separately from each information, generates the fault information matrix, locates the fault according to the characteristics of the matrix, and finally achieves the fault area localization.

Fig. 3 is a schematic diagram of regional protection behavior, in which 1 to 5 are intelligent protection devices; A to Dare distribution network buses; DG is distributed generation. Take Figure 3 as an example. The steps of this method are as follows:
Figure 3. Schematic diagram of regional protection behavior.

Step 1: Select device 2 or device 3 as the host station. Since there is new energy feeding in at device 2, the data volume is too large, and therefore device 3 can be selected as the host station through comprehensive analysis.

Step 2: The device 2 and device 4 which directly exchange data with device 3. As can be seen from the figure, device 2 not only requires to collect the operational data on the bus B, but also requires to acquire real-time data of the device 1. It is necessary to comprehensively judge the operation state of the line L1 in combination with data of device 1. When the line operation fails, the device 2 can directly issue a signal for cutting off the fault to constitute the first level of differential protection.

Step 3: The starting criterion of the protection device adopted the method of the single-phase current sudden change greater than the set value. The setting value can be immediately adjusted according to the change of the load on the line, which should be not less than 0.3 times the minimum load current, and not more than 0.5 times the maximum load. The braking current criterion is the threshold value of regional current differential protection criterion after considering the unpredictable branching, which should avoid the maximum current possibly generated when the maximum load of the line is input, that is, the combination of current of the three terminals collected by protection device in the distribution network of this region and the load.

Step 4: The second level differential protection is composed of the host station based on multi-points operation data. When the host station aggregates other buses’ information, the fault information matrix $A$ can be composited.

\[
A = \begin{bmatrix}
  a_{11} & a_{12} & \ldots & a_{1N} \\
  a_{21} & a_{22} & \ldots & a_{2N} \\
  \vdots & \vdots & \ddots & \vdots \\
  a_{M1} & a_{M2} & \ldots & a_{MN}
\end{bmatrix}
\]  

(1)

As shown in figure 3, taking the phase to phase fault at K1 as an example when device 3 is taken as host station, the fault information matrix $A$ can be constructed. When $m=3$ and $n=4$, $a_{34}=1$, indicating that there is a fault signal between bus C and bus D. Thereby the fault location can be swiftly carried out.

Step 5: After location of the fault area, it is also required to determine how the protection should handle the fault according to the pressure plate input of the protection device. If the differential
protection of protection device is launched, then the trip command can be directly issued to isolate the fault after the fault location. If not, the display module will display the fault information to alert.

4. Conclusion
The design of the regional differential protection device for the phase to phase fault of the distribution network is completed and the basis for identifying the fault area is determined. The regional differential protection device is installed at each bus bar, each incoming and outgoing data information of the bus bar is read through the RS485 bus, the communication between each regional protection device is achieved through the optical fiber connection, and the regional protection device with the most hierarchical lines on the bus bar is the host station. Exchange the real-time operation data of the line collected by the regional differential protection device in the lines between the regional differential protection devices, the regional differential protection device begins to execute identification when detected single-phase current sudden change is greater than the set value. The fault information is sent to the host station when the differential current of minimum motion is greater than or equal to 0.7 times the sum of the braking current and the load current to composite the fault information matrix A. Thereby realized the rapid and efficient detection of the fault of the distribution network and isolation of phase to phase fault.

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