Analysis and summary of the influence of distributed power supply access on relay protection of distribution network

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Abstract. After the distributed power supply is connected to the distribution network, it has a great impact on the original relay protection and brings a new challenge to the existing protection configuration scheme. This paper introduces three current protection schemes and inverse time overcurrent protection schemes which are widely used in distribution network at present. This paper summarizes some main relay protection measures including distributed generation at home and abroad as well as their advantages and disadvantages, and finally gives the improvement strategy including distributed generation.

1. Introduction

At present, the main forms of power system are large-scale centralized power generation and high-voltage long-distance transmission, while the distributed power generation is more miniaturized and diversified than the traditional power generation.

There are many types of distributed power sources, such as photovoltaic power generation, biomass power generation and cogeneration. There is no consensus on the concept of distributed power. For example, the power system commission defines distributed power generation as "a power generation mode without planning or centralized dispatching, which is generally connected to the distribution network and is a power generation mode with a small scale". However, some other organizations, such as the public utilities regulatory law commission of the United States, define distributed power supply as [1]: distributed power supply is distributed near major users, which can meet the needs of some designated users, and ensure more economical operation of the grid, thus reducing the cost. The generating power of distributed power supply is not very large, usually only 1KW - 50MW [2]. There are many features of distributed power supply, mainly including the following aspects [3]:

1. Short construction period and low capital consumption
   Generally, distributed power supply exists as a supplementary power source for large power grid. The power supply capacity is generally small and the scale is not large, so the construction period is short and the cost is low, which is very conducive to private capital investment.

2. Less environmental pollution
   Distributed power generation generally uses renewable energy sources for power generation, such as photovoltaic solar energy, wind energy, tidal energy and geothermal energy and so on. Compared with...
traditional thermal power generation, these forms of power generation generally do not cause environmental pollution, are not abandoned, the discharge of waste water and waste residue, can be applied on a large scale in the future.

(3) Can reduce the loss of electrical energy

Generally, the construction site of distributed power supply is close to users, so the electricity generated by it does not need to be transported over a long distance, but is directly consumed by nearby users [4]. This can effectively reduce the network loss caused by the long distance transmission of electricity.

This paper mainly introduces the common three-stage current protection and inverse time limit current protection in the distribution network, through summarizing the influence of DG on the relay protection of the distribution network, and gives several measures to improve the reasonable access of DG to the distribution network, thus laying a foundation for better use of distributed power supply.

2. Three-stage current protection

Three-stage current protection [5], namely, instantaneous current break protection, fixed time limit current break protection and overcurrent protection are adopted. When the current increases, the circuit will fail, then we can use the current break, the limit current break and overcurrent protection of the three kinds of protection circuit. But the selection of each setting values are needed according to the different setting principle, setting value is to make the protection the minimum starting current value, its meaning is shown by the: installed in the line of the primary side protect device reaches a certain value, at the current action will happen, so to very good protection circuit. Current instantaneous fault protection is at the moment of failure occurs, the instantaneous action and removal of the fault, its setting time is according to cannot be greater than the end of the line short circuit through the protection of the principle of maximum short-circuit current setting, but the protection of defect is not to protect line length: definite time electricity flow off the setting principle of protection is according to which the line failure occurs at the end of the high sensitivity and cooperate with the adjacent lines of transient current protection, compared with the current instantaneous fault protection, it has the advantage that can protect citizens length of the line; The principle of overcurrent protection setting is that the setting value cannot be greater than the maximum load current of this line and it must cooperate with the overcurrent protection of adjacent lines. Compared with the previous two kinds of protection, this protection has the advantage of protecting the whole length of this line and adjacent lines. In addition, because the terminal line does not need to cooperate with adjacent lines, in order to protect the full length of the line, the setting of the current break protection is based on the principle that the terminal short circuit sensitivity of this line is large enough to set.

3. Inverse time limit over current protection

Inverse time limit overcurrent protection is a kind of protection that the time limit of protection action is related to the short-circuit current in the protected circuit. At present, the basic form of the general mathematical model of inverse time limit protection commonly used at home and abroad is:

$$t = \frac{k}{\left(\frac{I}{I_p}\right)^r - 1}$$

Where, I is the fault current; to protect the starting current; R is a constant, usually between 0 and 2; K is a constant, and the dimension is time;

Inverse time overcurrent protection is superior because it is similar in principle to the fault characteristics of many loads. When circuit short-circuit current increase, the action time of circuit protection is shorten, which means that the more near the fault protection, its shorter duration of action, and the protection is far away from the point of failure, its action time limit will be relatively long, the protection is widely used in power distribution network of relay protection, because it can not only satisfy the requirement of quickness, can also meet the requirements of selectivity.
4. Influence of DG on the protection of distribution network

4.1. Influence on reclosing
At present, automatic reclosing has been widely used, which may lead to the following phenomena when the distribution network with DG fails: (1) the distribution network is in the island operation state, and part of the load is supplied by DG. At this time, the automatic reclosing action will lead to reclosing failure. (2) DG continues to supply power after the feeder circuit breaker tripping, and the arc at the fault point cannot be extinguished, resulting in automatic reclosing failure [6]. When instantaneous failure occurs, automatic reclosing can quickly restore the power supply. However, when the DG is connected to the distribution network, the corresponding distribution line will become bilateral power supply. Reclosing should take into account the time matching problem of both sides of protection and the synchronization problem of both sides of power supply [7].

4.2. Tidal current direction
When the distributed generation is connected to the distribution network, adverse tide may occur, especially when the installed capacity of the distributed generation is large, which exceeds the local power consumption, and the distribution network trend direction will change. In a traditional distribution network, the direction of power flow is fixed in a single-terminal radial network. When a short circuit occurs, the direction of fault current can also be determined. When the distributed generation is connected to the distribution network, the original topology of the distribution network will be changed. The change of power flow direction of the distribution network varies according to the different operation modes. The directionality of power flow will also cause the traditional non-directional current to misoperate.

4.3. Impact on short-circuit current
When the distributed generation is connected to the grid, even if the direction of power flow remains unchanged, the value of short-circuit current will be affected in the short circuit. The value of short-circuit current flowing through the protection will change, and the change is not directional and unpredictable. With the different fault location and running state of the distributed generation, the value of fault current flowing through the protection will increase or decrease. The specific changes of these fault current values become more complicated with the increase of the types of distributed generation and the number of access in the distribution network. If the distribution network still adopts the original protection configuration scheme, the access points, access quantity and access capacity of DG will be greatly restricted from the perspective of protection reliability.

4.4. Island operation
Faults in the distribution network are usually cleared by the protective relay closest to the fault location. If the fault occurs upstream of the DG access point, the DG will provide power for some load isolated from the distribution network. If the capacity of the DG is not enough to provide additional load, there will be overload phenomenon, which will eventually lead to the shutdown. If an isolated system is isolated from the main grid and all the load electricity is supplied by the DG, this situation is called island operation. The hazards of island operation mainly include the following: (1) maintenance personnel contact live conductor by mistake and thus cause electric shock; (2) the power quality of DG island system cannot be guaranteed; (3) after the fault occurs, some power grids are still in the island operation state. At this time, if the automatic reclosing action is taken, such power grids may further expand the fault due to asynchronous closing, thus delaying the time of power supply recovery.
5. Relay protection method of distribution network including DG

5.1. Timely removal of DG in case of distribution network failure
The access of distributed generation to the distribution network has different degrees of influence on its relay protection. In order to solve such problems, when the distribution network fails, the distributed generation should be removed in time, that is, the traditional distribution network will not be affected [8]. This method has the minimum modification and the lowest cost for the original protection, but there are still many problems: when the fault occurs, the DG unit needs to detect the fault and then exit. Nowadays, some standards require that the grid-connected DG should be cut off from the power grid after failure and before automatic reclosing. However, in actual operation, it cannot be guaranteed to do so, so it still has a great impact on the protection.

5.2. Limited DG capacity and access location
As it is not guaranteed that the distributed generation can be cut off from the distribution network in time when the fault occurs, literature [9] and literature [10] propose to reduce the influence on the distribution network by limiting the capacity of the distributed generation and changing the access position of the distribution network. Literature [11] in guarantee under the premise of relay protection and reliable action, analyses the DG access number, access to the location and combination and several aspects, such as access to its capacity of circuit parameters, the influence of the final experimental results show that if we do not change the original distribution network protection configuration, the DG access conditions will be very limited, so this method still has some shortcomings.

5.3. Change the protection configuration of the distribution network
In addition to the original protection, directional discrimination element can be installed, which can apply the mature protection principle and scheme in the transmission line to the distribution system. In addition, networked digital protection can be adopted to minimize the influence of DG. Literature [12] proposes a protection configuration scheme. This paper specifically analyzes the influence of the access of DG on the distance protection of the original distribution network. In essence, this method replaces the original distance protection scheme with the scheme of allowable directional longitudinal protection, making the distribution network more reliable.

5.4. Introduce fault limiter
The main idea is to introduce FCL when the fault occurs, reduce the fault current to the minimum or even eliminate it, and when the distribution network is in normal operation, FCL will not have any adverse effects on the distribution network. In literature [13] and literature [14], the scheme of FCL is proposed. When the releasing line fails, the current limiting device is connected to reduce the short-circuit current, and the influence of DG decreases with the increase of line impedance. The fault current limiting method can reduce the influence of DG access on the original distribution network protection, and reduce the restriction on DG access. However, this method still has some problems, such as insufficient support of DG for system stability in case of failure.

5.5. Adaptive protection
The idea of adaptive protection is to make the protection adapt to the changes of power system and improve the performance of protection. In literature [15], an adaptive protection method is proposed to store the reference information, calculate the real-time sampling of each electric quantity of the line, and then compare the two methods, so as to determine the fault range and the protection scheme for this fault according to the results. However, this method needs to collect information from each point, and the distribution network has a wide coverage and is difficult to operate and maintain. Literature [16] also puts forward adaptive protection method. This literature uses computers to monitor the operation status of power grid in real time, so that the fixed value of protection device can be dynamically adjusted according to the change of system operation mode.
6. Conclusion
After the distributed power supply is connected to the distribution network, the influence on the system relay protection has been a research hotspot. The protection action including the distributed generation distribution network is also an important index to determine the safety and stability of the system after the distributed generation is connected to the network. Therefore, the research on this aspect will be more and more and more in-depth.

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