Research on the Influence of the Series Compensator on Relay Protection of Distribution Networks

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Abstract: As China's economic development, social demand for electricity continues to increase, while the primary energy to the unbalanced distribution of electricity load centers resulted in our country needs long-distance, high-capacity transmission. To improve power quality, series capacitor compensation as a relatively mature technology, improve power quality, an important means to solve the problem of low voltage. Compensation capacitor in series access undermine the uniformity of the transmission line impedance, change the distribution system each point current and voltage, so bring some impact on transmission line protection.

1. Introduction

With the scale of China's distribution network increasing, the grid gradually extends in the marginal ranges, and the problems of low voltage in distribution network is also gradually emerged. Series capacitor compensation is widely used in the distribution network, and it reduces the line reactance, shorts the electrical distance. It can significantly improve the voltage quality to solve the problem of low voltage. However, when the series capacitor compensation is added to the grid, the circuit reactance of the installation circuit is changed, which causes the measuring parameters of the power line relay protection to change, such as the fault current, voltage and so on .When the end of the series capacitor compensation is faulty, relay protection is affected. This paper introduces the principle of the series capacitor compensation and the structure of the fast switch series compensation device and analyzes the influence on the current protection, the distance protection and the current-differential pilot protection system.

2. The Introduction of the Series Compensator

The principle of series compensation capacitor is shown in figure 1.

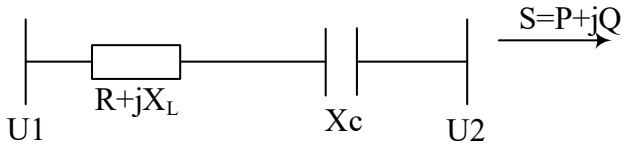

Figure 1 Series compensator line diagram.

In Figure 1, the line itself has resistance and reactance. In the transmission process, the current flow will produce a certain voltage drop and power loss in the line, when the greater the power transmission, the greater the current flow in the wire, and the greater the power loss and voltage drop. The power loss and voltage drop will cause low voltage at the end of this line, which will affect the normal operation of the motor, product quality and equipment safety operation even

threatens the stable operation of the system, resulting in the system splitting ,accidents or hidden dangers.

The main reason for the voltage drop is distributed resistance and distributed inductance of the line .The series capacitor reactance compensates line induction, reducing voltage drop in line induction caused by load current, improving the voltage of the line and reducing the voltage phase angle difference between the front and the end of this line.

3. Fast Switch Series Compensator

The traditional series compensator has the problems of complex configuration, expensive and poor performance, and it is not widely used in distribution network. Based on the fast switch, the series compensator is the application of rapid vacuum switch in the bypass device to replace the spark gap. And the entire series compensator with high reliability, small size and low cost, has been widely used in distribution network. The structure diagram is shown in figure 2.

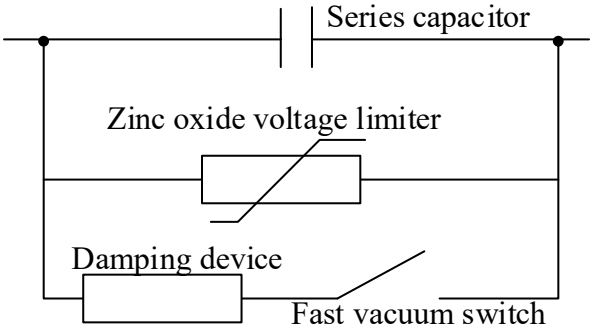

Figure 2 Fast switching series compensator schematic.

Now part of the function of fast switch series compensator is described as follows.

1) Series capacitor group: used to compensate for line voltage drop, improve voltage quality. Capacitors properly configured and connected in series during normal operation according to the requirements of compensator.

2) Zinc oxide components: used to limit the voltage across the series capacitor. It is consist of two zinc oxide varistrors in series. The voltage of the series capacitor is lower than the threshold voltage of the zinc oxide, the zinc oxide does not move; while the external short circuit, the voltage across the capacitor is limited to a low level, to protect the series capacitor from damaging.

3) Fast vacuum discharge switch: A rapid vacuum circuit breaker based on fast eddy current drive technology is used to quickly release the charge stored in the series capacitor. When the device is running normally, the fast switch is in the opening state, and the discharge circuit is connected when the circuit is short-circuited. The closing time can be controlled at about 10ms, and the opening time can be controlled within 5ms. Based on the fast vacuum circuit breaker and the rapid identification of short-circuit fault technology, it can short circuit the series compensation capacitor quickly after short circuit within 15ms, which greatly shorten the duration of over-voltage, so that the zinc oxide components capacity can be greatly reduced. The safety of the capacitor and the reduction of the capacity of the zinc oxide components lay the technical foundation for the research and development of the series compensator.

When the line is running normally, the series capacitor group is connected in series in the line, and the capacitance of the capacitor is used to compensate the line inductance to improve the line terminal voltage. When the line is faulted at the rear of the series compensator, zinc oxide components limit the voltage across the capacitor, and the switch is then closed quickly to short circuit capacitor out of operation. The whole process is completed within 15ms.

4. The Influence of Series Compensator on Relay Protection

4.1. The Influence of Series Compensator on Current Protection

1)The basic principle of current protection

In the 110kV, 35kV and 10kV voltage level of the distribution network, current protection is installed,and the following analysis is about the impact of current protection after installing series compensator .

Current protection is reflected in the current rise. According to selectivity principle of the relay starting current, it can divide into three sections of protection.

(1) The first section current protection: it is also called the instantaneous current protection, which reflects the short-circuit current amplitude incremental and acts instantaneously. As short-circuit current is very similar when short-circuit fault occurs at the end of this line protection or at the beginning of the lower line protection. It is hard to judge, so the instantaneous current protection is set to avoid the maximum short-circuit current value when short-circuit occurs at the beginning of the lower line protection. Instantaneous current protection can not protect the full length of this line.

(2) The second section current protection: it is also called time delay instantaneous current protection, and its protection range extends to the lower line with time delay, coordinating with instantaneous current protection of the lower line. The principle of setting the operating current is to avoid the maximum operating range for the instantaneous current protection of the adjacent components.

(3) The third section current protection: it is also called current protection. It works as remote backup protection when the lower line protection misstrips and circuit breaker misstrips. Meanwhile, it works as the short-range backup protection when this line primary protection misstrips, and as overload protection. The principle of setting the operating current is to avoid the maximum load current. According to the different protection action time, current protection is divided into timing current protection and inverse time over current protection.

2)The influence of series compensator on current protection

Stage current protection includes the first, second, third section current protection, which is economical, simple, reliable, and are widely used in power grid of 110kV, 35kV and below.

The current protection is the protection of the action in response to the rise of the current. The influence of the presence of the series compensation capacitor on the current protection is discussed below.

The current protection is in response to the rise of the current. The influence of the series compensation capacitor on the current protection is discussed below.

(1) The fault occurs at the front of the series compensator installation point. As the distribution network lines are single source lines, there is no ring network, so the current is from source to load, which goes through the series compensator. When the fault point is at the front of the series compensator, it does not affect the line parameters. Thus, the series compensator does not affect the relay protection device in source side.

(2) The fault occurs at the rear of the series compensator installation point. Since the series compensator capacitive reactance compensates or partially counteracts the line inductance, the impedance from the source point to the fault point is significantly reduced than before, so the short circuit current increases. Thus, the series compensator is installed to improve the sensitivity of the protection in the source side.

(3) As for time, when the fault occurs, the protection in source side takes about 20 ~ 30ms to determine the fault point to the first section current protection export. The circuit breaker operating time in source side is about 50ms, the fault duration time takes about 70 ~ 80ms, and the closing time after the short circuit can be controlled at 10ms or so. Combined with short-circuit fault rapid identification technology, it can be achieved to short circuit the series compensator within only 15ms,and the time is much shorter than the current protection action time. The protection of the source side has not act, the series compensator device has been already out of the run, therefore, fast

switch series compensator will not have an impact on the line current protection . The timing comparison is shown in Figure 3.

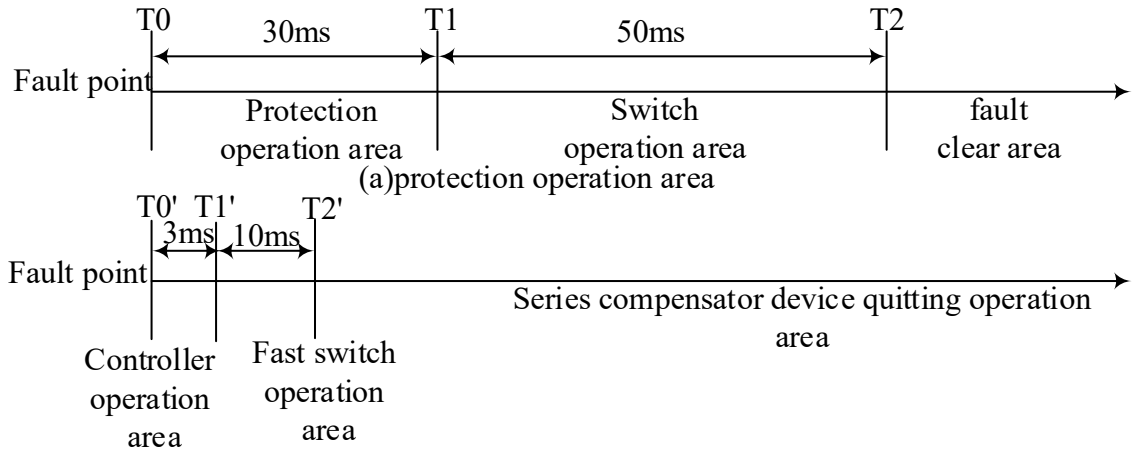

Figure 3 Fault operation time comparison diagram.

(4) If it is a single-phase ground fault, there is no large short-circuit current in the small current neutral grounding system, the protection device does not require act and trip. In the same way, the series compensator can not acquire short-circuit current information, then it will not quit operating.

4.2. The Influence of Series Compensator on Distance Protection

1)the basic principle of distance protection

In the 110kV voltage level of the distribution network, distance protection is installed, and the following analysis is about the impact of distance protection after installing distance protection.

Distance protection uses changing characteristics of voltage and current when short fault occurs to act or not, which is equal to voltage divides current. The ratio reflects the distance from the fault point to the relay protection installation point, if the distance is less than the setting value, the relay protection acts. The power system is shown in Figure 4.

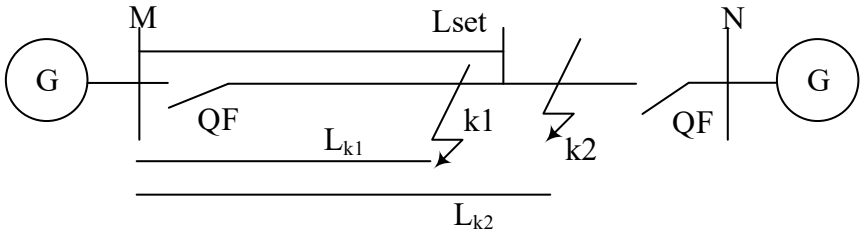

Figure 4 Distance protection setting diagram.

According to the selectivity of relay protection, the distance protection installed at both side of the line only reflects and immediately acts, where there is internal short fault between point M and point N, and the corresponding circuit breaker trips; while distance protection should not act when short fault occurs in the opposite direction or out of the protection distance. As with the instantaneous current protection, the distance protection range should be shorten than the length of MN, in order to ensure that the lower line protection does not produce misoperation when the short fault occurs in the exit of the lower line. The setting distance Lset represents protection range of the distance protection. When the short current fault occurs in the system, it is primary to figure out the fault direction. If the fault is located in the protection range, measure the distance named Lk between the fault point and the protection installation point, and compare Lset with Lk.If Lk<Lset,it means that the fault is in protection range, so protection should act and the corresponding circuit breaker should trip; if Lk>Lset, the fault should not act and the corresponding circuit breaker should not trip. If the fault is located in the opposite direction of the protection range, judge the fault as a

external fault immediately without action.

It can be seen that the fault distance can be measured by judging fault direction, whether the fault is located in the protection range, so as to decide whether to trip and realize the line protection. Distance protection can measure and judge fault distance by measuring the short circuit impedance.

2)The influence of series compensator on distance protection

Since the series compensator capacitor reduces the line reactance and destroys the uniformity of the transmission line impedance, the measured impedance of the impedance relay changes when the series compensator is short-circuited. And these changes are closely related to the zinc oxide components of the series compensator and switch action characteristics.

When the short circuit occurs, the zinc oxide components used to protect the capacitor almost instantaneously acts, and the controller developed with the short-circuit fault rapid identification technology can identify fault within 2ms and short circuit the series capacitor group within 15ms. For the relay protection, the primary protection action time is actually 20 ~ 30ms.As for the second and third section distance protection require delay action, the second section distance protection generally takes 0.5s,and 1s for interphase short circuit, the third section distance protection delay time is generally more than 2s. Therefore, as for the second and third section distance protection with time delay, the capacitor has been short-circuited, so this paper mainly discusses the impact of the first section distance protection.

In the 110kV voltage level of the line, there is no branch line, series compensator installed at the end of the line at the lower substation. Assuming the two sides of the series compensator are a and b, and b point is the entrance of the lower substation.

After the line is connected to the series compensator, the measured impedance Zm and short-circuit distance z1/k are no longer linear proportional relationship. As shown in Figure 5, the measured impedance on both side of the capacitor, namely point a and point b, occurs the impedance mutation. The analysis of its impact on the distance protection is as follows.

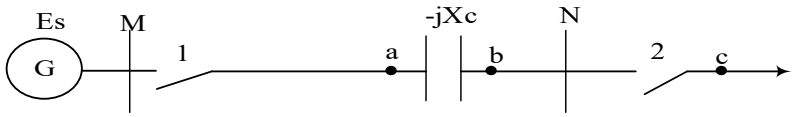

Figure 5 The connection diagram after installing compensator device.

(1) If there is a fault between the point a and the point M, and the fault point is within the protection range of the first section distance protection(ie, within the impedance circle of Figure 6), the series compensator does not feel the fault current without action.The series compensator shortens the electrical distance and increases the sensitivity of the distance protection.

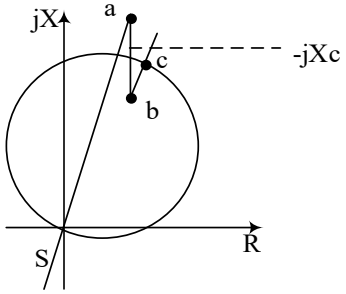

Figure 6 Distance protection impedance circle.

(2) If there is a fault between the point a and the M, and the fault point is outside the protection range of the first section distance protection (ie, outside the impedance circle of Figure 6), the series compensator does not feel the fault current without action. The distance protection I may lose the selectivity of the protection, and automatically extend the protection distance, so that the first section distance protection distance may extend to the lower level.

(3) If the fault occurs after the point b (which may occur on the N bus or on the outlet), and the fault point is outside the protection range of the superior level's the first section distance protection

(ie, outside the impedance circle of Figure 6).The series compensator feels the fault current and quickly is short-circuited, the superior the first section distance protection has not yet exported, and it will not cause the superior distance protection action. At this time, as long as the capacitor can be quickly shorted, whether bus protection or the lower level distance protection, it will not produce misoperation.

5. Conclusion

In this paper, the principle and structure of the fast switch series compensator are introduced, and the influence on the relay protection device in the distribution network is analyzed. The conclusions are as follow:

1) The fast switch series compensator has no effect on the current protection in the medium voltage network. After the installation of the series compensator, the sensitivity of source side protection will be improved.

2) The fast switch series compensator will have some influence on the distance protection. When the fault point is at the front of the series compensator installation point, and is outside the protection range of the first section distance protection, the first section distance protection may lose the selectivity, automatically widen the protection distance, so that the first section distance protection may extend to the lower level.

3) According to this situation, the best solution is to take the capacitive reactance of the series compensator into account, when set the distance protection value.

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