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Study on Protection Scheme for Low-voltage Distribution Network with Distributed Generation

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Abstract: After the distributed generation synchronization will have certain influence on distribution network. Using power system simulation software (PSSSINCAL), construct the model of low-voltage power distribution network with the distributed generation. Analyze the influence of the distributed generation on the traditional protection of the distribution network. In order to meet the demand of relay protection for low-voltage distribution network with distributed generation, put forward a protection scheme, which adds the directional element for the current protection system of the main feeder and changes the setting values of protection devices for the main feeder and branch lines and verify the feasibility of the protection scheme.

Key words: Distributed generation, distribution network, protection scheme

INTRODUCTION

Distributed Generation (DG) can satisfy the specific requirements of the user, support the economic operation of the distribution network, a kind of micro type generation systems whose capacity ranges from several kilowatts to 50 megawatts (Hu *et al*., 2006). DG is a kind of independent power supplies, which is compatible with the environment. DG contains wind power generation, fuel cell power generation, biomass energy power generation, micro turbine power generation, photovoltaic power generation and so on (Li and Li, 2005). However, after the distributed generation is connected, it will change the original structure of the distribution network and affect the configuration of the relay protection and the setting of the operating values, Through the improvement of the traditional distribution network protection device, put forward the protection scheme, which adds the directional element for the current protection system of the main feeder and changes the setting values of protection devices for the main feeder and branch lines.

GRID CONNECTION OF THE DISTRIBUTED GENERATION

Basic technical requirements of the distributed generation being connected: In order to ensure the safe operation and power supply quality of the distribution network, the distributed generation being connected, which needs to meet the following basic requirements. (Sun *et al*., 2009):

- Ensure the voltage qualified of the distribution network, the voltage deviation should be no more than the allowed value
- The normal operation current of the power distribution equipment is no more than the rated value, the dynamic and thermal current is no more than the allowed value
- Short-circuit capability is no more than the allowed value of switches, cables and so on
- The power quality is qualified, which caused the voltage surged and plunged, flicker, harmonic, plunging, flicker, harmonic that could not exceed the specified value

Choice of the connection scheme for the distributed generation: The influence of the distributed generation connected for distribution network is associated with the capacity of the distributed generation, the connected scale and the voltage level. In general, the capacity of the distributed generation is within 250 KVA to connect with the 380V/400 V Low-Voltage level of the distribution network. The distributed generation of 1-8MVA is connected with the 10kV medium voltage level of distribution network. The larger distributed generation is

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connected with the higher voltage level of the distribution network. The specific way to access the distributed generation is usually connected with the bus of the nearby substation for the distributed generation of the large capacity. in order to reduce the grid investment, the distributed generation of the small capacity is connected with the nearby distributing line. (Zhang *et al*., 2006).

Model of low-voltage distribution network with distributed generation: Set up the model of Low-Voltage distribution network with distributed generation in PSSSINCAL power system simulation software, as shown in Fig. 1, the distributed generation consists of photovoltaic battery DG1 (150 kW) and gas turbine DG2 (250 kW), including photovoltaic battery connected with feeder 1 and Gas turbine connected with feeder 2. The three kinds load of the system comprises the cold, thermal, electrical load. Consider the characteristics of the load in the process of building the model, The electrical load 2 and 3of accessing the feeder line 2 and the feeder line 3 are typical constant impedance load (the rated power are 400 kW and 200 kW, respectively). Constant power load is accessed the feeder line 1 (the rated power 300 kW, the power factor is 0.9). The loads of accessing the feeder 1, 2 are sensitive load. The demand is higher for the reliability of power supply. But the load of accessing the feeder 3 is insensitive load. The demand is not high for the reliability of power supply. The system connects into the 10 kV line of the distribution network. The connection mode of the whole system is the single-bus structure. System is connected to the low voltage distribution network through the transformer and the transformer U1/U2 = 10/0.42, Sn = 1 MVA. Overhead lines L1 = 400 m, L2 = 400 m, L3 = 300 m, r = 0.3258 ohm km^{-1}, x = 0.738 ohm km^{-1}, c = 9.98 n F km^{-1}. K1 point is set in 50% of L1, K2 point is set at the end of L2, K3 point is set at the end of L3, K4 point is set in the main feeder, K5 point is set in the midpoint of the transformer and QF4.

PROTECTION SCHEME FOR LOW-VOLTAGE DISTRIBUTION NETWORK WITH THE DISTRIBUTED GENERATION

Traditional protection scheme for low-voltage distribution network: Nowadays the protection of 400V low-voltage distribution network mainly uses time delay current instantaneous trip protection (protection ection II) and definite time over current protection (protection section III). The setting principle of time delay current instantaneous trip protection coordinates with the side of the line protection section and having enough sensitivity when the end of line faults

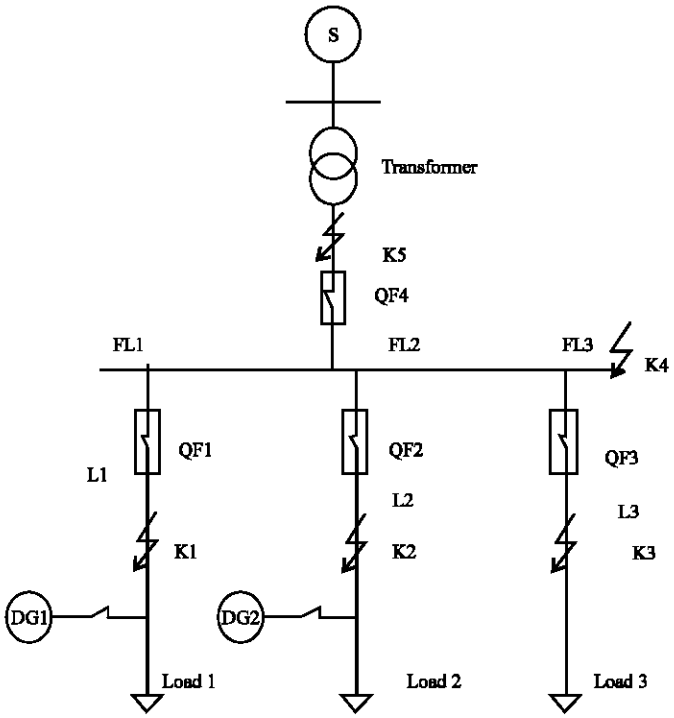

Fig. 1: Model of the distribution network with Low-Voltage distributed generation

Table 1: Protection configuration scheme for low-voltage distribution network

Circuit breaker	I^{II}_{set} ka^{-1}	I^{III}_{set} ka^{-1}	t^{II} sec^{-1}	t^{III} sec^{-1}
QF1	2.20	0.825	0.5	1
QF2	1.44	0.720	0.5	1
QF3	1.08	0.135	0.5	1
QF4	7.50	2.250	0.5	1

(He and Song, 1994). Fixed value should be able to avoid the trip when the lines of other sides fault. Definite time over current protection sets action value in the light of the method to hide from the maximum load current and coordinates with the definite time over current protection of adjacent line, it can protect the full-length of adjacent line. The settings of action time of these current protections are different but compatible. According to the model of low-voltage distribution network in figure1 (the distributed generation omitted) simulate and calculate to gain the configuration of the protection as shown in Table 1.

Influence for the protection configuration of the distribution network with the distributed generation: Running with DG, the configuration of distribution network changes from a single power radial network to a more complicated one (Feng *et al*., 2010). In the distribution network, the power flow, direction, duration and strength of fault current all will change. The action and performance of the traditional protection for low-voltage distribution network will be affected by the distributed generation.

As the example of the model 1, display the influence of the protection for the distributed network with the distributed generation in the following aspects mainly:

- Sensitivityw of the line protection is reduced and even refuses to move. As the example of K1 point, before DG1 synchronization, the short-circuit current is provided by the system, after DG1 synchronization, the short-circuit current is provided by the system and DG1,but the fault current flowing through QF1 will be reduced due to the increasing for the downstream, if the setting value of the protection does not change, the sensitivity will reduce, when it is serious, the protection will even refuse to move. DG capacity is greater, the influence for the sensitivity of the protection of low-voltage distribution network will be greater
- Lead to the protection of the line and the adjacent line moving by mistake. When the fault occurs in K2 and K4 points, before DG1 synchronization, the short-circuit current is provided by DG1 flowing through QF1, if the short-circuit current is great enough, it will cause the protection moving by mistake
- Lead to the protection of the main feeder line refusing to move. When the fault occurs in K5, before DG1 and DG2 synchronization, the fault current will not flow through QF4, so the protection will not act. After DG1 and DG2 synchronization, which will also provide fault current, the reverse fault current will flow through the protection of QF4 but due to the protection of QF4 being unidirectional, which may cause the protected of QF4 refusing to move

After the distributed generation synchronization, Use the simulation and calculation of the protection configuration for circuit breakers to check:

- When three-phase short-circuit fault occurs in the point of K1, I_{k1} = 3.519 kA,the fault current flowing through QF1 is 3.354kA, which exceeds the setting value of time delay current instantaneous trip protection for QF1, the sensitivity of the protection is 0.75, which can't meet the requirements
- When three-phase short-circuit fault occurs in the point of K2, I_{k2} = 2.08 kA,the fault current flowing through QF2 is 1.7338 kA, the sensitivity of the protection is1.08,which can't meet the requirements
- When three-phase short-circuit fault occurs in the point of K3, I_{k3} = 2.291 kA, the fault current flowing through QF3 is 2.291kA, which exceeds the setting value of time delay current instantaneous trip protection for QF3, the sensitivity of the protection is 1.38, the protection of QF3 will be tripped to cut off L3 at the time of 0.5 s, while other circuit breakers do not act, L1 and L2 can still run normally
- When three-phase short-circuit fault occurs in the point of K4, I_{k4} = 23.773 kA, the fault current flowing through QF4 is 22.698 kA, which exceeds the setting value of time delay current instantaneous trip protection for QF4, the sensitivity of the protection is 2.746, the protection of QF4 will be tripped to cut off L1, L2, L3 at the time of 0.5s, while other circuit breakers do not act, the system can still run normally
- When three-phase short-circuit fault occurs in the point of K5, I_{k5} = 30.418 kA,the fault current flowing through QF4 is 0.476 kA, the sensitivity of the protection is 0.079,which can't meet the requirements

Protection scheme for low voltage distribution network with the distributed generation: By the above known that the original protection cannot completely meet the requirements of relay protection for low-voltage distribution network with distributed generation, New protection scheme should be used, the current protection

Table 2: Protection scheme for low-voltage distribution network with distributed generation

Circuit breaker	I^{II}_{set} kA^{-1}	I^{III}_{set} kA^{-1}	t^{II} sec^{-1}	t^{III} sec^{-1}
QF1	1.3	0.62	0.5	1
QF2	0.84	0.31	0.5	1
QF3	1.08	0.40	0.5	1
QF4 (forward)	6	2.25	0.5	1
QF4 (reverse)	0.36	0.12	0.5	1

system of QF4 is added directional element, which is used to judge the direction of the trend (Set the current from top to down as forward direction). In order to meet the requirement of the sensitivity, change the setting values of QF1, QF4 and QF2 protection devices for time delay current instantaneous trip protection and definite time over current protection. According to the low-voltage distribution network with the distributed generation of figure1, simulate and calculate the model to get the protection configuration as shown in Table 2.

Use the simulation and calculation of the protection configuration for circuit breakers to validate:

- When three-phase short-circuit fault occurs in the point of K1, I_{k1} = 3.519 kA, the fault current flowing through QF 1 is 3.354 kA, which exceeds the setting value of time delay current instantaneous trip protection for QF1, the sensitivity of the protection is 1.27,the protection of QF1 will be tripped to cut off L1 at the time of 0.5 s, while other circuit breakers do not act, L2 and L3 can still run normally
- When three-phase short-circuit fault occurs in the point of K2, I_{k2} = 2.08 kA,the fault current flowing through QF2 is 1.7338kA, which exceeds the setting value of time delay current instantaneous trip protection for QF2, the sensitivity of the protection is 1.86,the protection of QF2 will be tripped to cut off L2 at the time of 0.5 s, while other circuit breakers do not act, L1 and L3 can still run normally
- When three-phase short-circuit fault occurs in the point of K3, I_{k3} = 2.291 kA, the fault current flowing through QF3 is 2.291kA, which exceeds the setting value of time delay current instantaneous trip protection for QF3, the sensitivity of the protection is 1.83, the protection of QF3 will be tripped to cut off L3 at the time of 0.5 s, while other circuit breakers do not act, L1 and L2 can still run normally
- When three-phase short-circuit fault occurs in the point of K4, I_{k4} = 23.773 kA, the fault current flowing through QF4 is 22.698 kA, which exceeds the setting value of time delay current instantaneous trip protection for QF4, the sensitivity of the protection is 3.43,the protection of QF4 will be tripped to cut off L1, L2, L3 at the time of 0.5 sec, while other circuit breakers do not act, the system can still run normally
- When three-phase short-circuit fault occurs in the point of K5, I_{k5} = 30.418 kA,the fault current flowing through QF4 is 0.476kA, the sensitivity of the protection is 1.32, the protection of QF4 will be tripped to cut off L1, L2, L3 at the time of 0.5 sec, while other circuit breakers do not act, the system can still run normally

CONCLUSION

After the distributed generation synchronization will have certain influence on the traditional protection scheme of the distribution network. In order to solve the protection problem, construct the model of low-voltage power distribution network with distributed generation. Put forward a protection scheme, which is the current protection system of the main feeder added the directional element and changes the setting values of protection devices for the main feeder and branch lines. At last verify the feasibility of the protection scheme through the simulation and calculation. When the failure of three-phase short circuit occurs in any point of the model,the new protection scheme can meet the requirements of the protection.

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