Application of Adaptive Over Current Protection for Distributed Generation

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Abstract— This paper focuses to realize the needs of a special and time variant system like, distribution grids with DG penetration by evolving methodology that permits a protection system. Adaptive protection approaches some of the shortcomings of traditional protection by adapting the obligation of nature of fault, numerous deviations in topology configuration, and operational state of power system. By calculate and modifying the setting values based on the sort of fault and the system impedance. Adaptive over current protection system is capable to react to system variations automatically, to ensure quick response during fault incidents and reliable protection action. The basic philosophy and verification rules of adaptive current protection are presented. Results of mathematically verification and simulation analysis indicate that this system has a large protection zone as compared to conventional system and feature of rapid setting speed and prevailing adaptive capability. The selectivity and sensitivity of protective relays, the reliability and safety of power supply can be advanced improved its application.

Index Terms— Distributed generation, Renewable energies, Adaptive Protection, Protective relays, Protection zone, System impedance, operational state

1 Introduction

These days, demand of electrical energy has been increased in most of electric utilities. The distributed generation (DG) as expected, is going to be an alternative for supplying power to consumers. Small size of generation (kilowatts to few megawatts), connected at substation, distribution feeder or customer load level is said to be Distributed generation (DG). It is noticed that DG technology is cost-effective as compared with traditional transmission and distribution. This is cause to withstand the growing of load by installing DG rather than escalating transmission and distribution (T&D) [1]. So, these technologies are entering a period of speedy development and commercialization, which is shown in fig1. By this tendency abundant benefits are attained with development of Distributed Generation, but also arise complications and challenges that requires instantly rid off by actual engineering.

The protection setting of traditional distribution system is designed based on one utility source supplying the whole system because of radial structure. DG connected network, the system is no more radial and fault is fed from all sources coupled to the power system at fault condition. That's why the fault current level is altered compared with the conventional radial structure. Consequently, unique fixed setting for the protective relay cannot respond the constantly dynamic system arrangement. It is necessary desirable to make relay setting adapt to changing conditions which the relay would really face most of time. Thus, relays have to be adaptively matched for each new system structure to accomplish exact fault clearance process.

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The performance of the protection regime is improved with adaptive protection by amending it online line with respect to the deviations occuring in the power system that it protects [2]. In this feature, settings are to be updated to fulfil with real system operating situations rather than being set on the worst case condition [3].

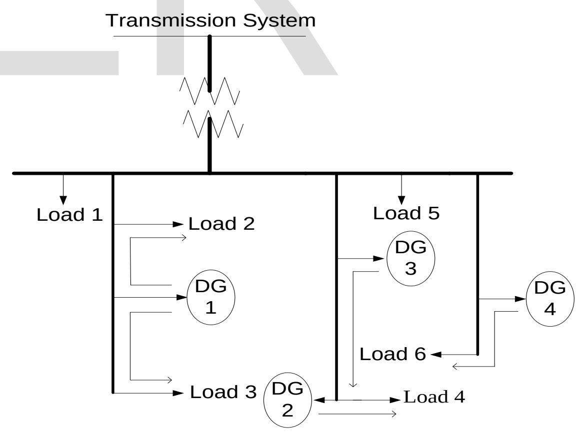

Fig. 1.Distribution system of near future

2 Traditional Over Current relay

Setting of traditional over current relay is gotten off-line and is unchanging, this cannot familiarize to variations working state, topology arrangement, and fault type so cannot make protective relay to acquire the optimum protection result.
The fixed value is set according to evading short circuit current I_{max} on three phase when the system works at maximum operation mode.

$$I_{set} = K_k I_{f\max} \qquad ; \; I_{f\max} = \frac{E}{Z_{S\min} + Z_L}$$

$$I_{set} = \frac{K_k E}{Z_{S\min} + Z_L} \quad (1)$$

E = System equivalent phase voltage of power supply
Z_{Smin} = Impedance of system at maximum apparent power
Z_L = The impedance of protected line
K_K =Coefficient of reliability, K_K = 1. 2 to 1. 3
Action Condition: $I_K \geq I_{Set}$
When fault exists at the location of αZL the fault current is

$$I_f = \frac{K_d E}{Z_S + \alpha Z_L}$$

Z_S = The minimum impedance in system Power supply
α = Fault location coefficient expressed as a percentage, α= 0~1
K_d =Coefficient of fault type, For three phase short circuit, K_d =1 and two phase short circuit, K_d =3/2

2.1 Ptotection Zone For Tradational Over Current Relay

The traditional instantaneous over current relay is set as (1). Supposing the short circuit is found at a point on the transmission line.
The protection range α will be

$$\alpha = \frac{K_d(Z_{S\min} + Z_L) - K_k Z_s}{K_k Z_L} \quad (2)$$

By (2), due to $K_k > 1$, $K_d \leq 1$, $Z_S \geq Z_{Smin}$, Therefore the actual protection range α is always less than the protection scope in maximum operation. When K_d decreases and Z_S increases, the Protection range will decrease.
When the system works at the minimum operation mode and two phase short circuit occurs, Protection scope is minimal. At this point, the short circuit current

$$I_f = \frac{\sqrt{3}}{2} \cdot \frac{E}{Z_{S\max} + \alpha_{\min} Z_L}$$

We can obtain the minimum protection scope

$$\alpha_{\min} = \frac{\sqrt{3}(Z_{S\min} + Z_L) - 2K_k Z_{S\max}}{2Z_L K_k} \quad (3)$$

If the system is going at least apparent power (only one transformer operational) and three phase short circuit occurs the fault current will be

$$I_f = \frac{E}{Z_{S\max} + Z_L}$$

The range of protection

$$\alpha = \frac{Z_L + Z_{S\min} - K_K Z_{S\max}}{Z_L K_K} \quad (4)$$

When the system works in the maximum peration, and occurs three phase short circuit, the protection scope is biggest. At this point, the short circuit current is

$$I_f = \frac{E}{Z_{S\min} + \alpha_{\max} Z_L}$$

Range of of protection

$$\alpha_{\max} = \frac{Z_{S\min} + Z_L - K_S Z_{S\min}}{Z_L K_K}$$

$$\alpha_{\max} = \frac{Z_{S\min}(1 - K_K) + Z_L}{Z_L K_K} \quad (5)$$

If the system operates with at maximum capacity and a two phase, short circuit happens, with respect to variation in short circuit current protection range will be determined as follow

$$\alpha = \frac{\sqrt{3}Z_{S\min} + \sqrt{3}Z_L - 2K_K Z_{S\min}}{2Z_L K_K} \quad (6)$$

3 Adaptive Over Current Relay

The adaptive over current protection is improvement of traditional over current protection, it adopts the measures in real time which could automatically identify the variation of parameters and modify the corresponding protection setting calculation without artificial participation permitting to the real operation state of the power system and fault type. So the protective relay can gain the optimum effective state through out the period. Fig. 2 represents the algorithm of the established adaptive overcurrent protection system.

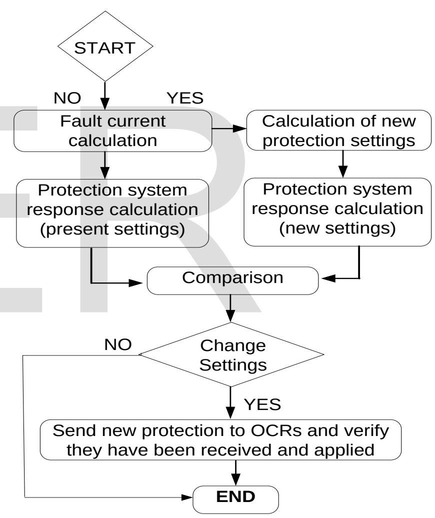

Fig. 1 Flow chart of adaptive function realization

Assume that we can achieve real-time comprehensive impedance of system power supply side and the fault type, the setting value can be set at real, expressed as:

$$I_{set} = \frac{K_k K_d E}{Z_S + Z_L} \quad (7)$$

Where Z_S is the system impedance which will be intended online in existent time. E is the phase potential for the equivalent electrical supply of system which can be calculated online.

3.1 Online determination of System State

To determine the system impedance in actual time is easy way to know system status, if system Positive sequence impedance Z_1 is equal to the negative sequence impedanceZ_2 in a two phase short circuit, the system impedance Z_S can be as:

$$Z_{sys} = Z_1 = Z_2 = \frac{\Delta U}{\Delta I}$$

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$\Delta U, \Delta I$ are fault voltages and fault current components. System corresponding voltage can be obtained online when power system supply impedance Z_{sys} is known, by:

$$E = U_k + I_k Z_{sys}$$

Where U_K and I_K are fault voltage and fault current respectively of the line where protective device is installed.

3.2 Online determination fault type

In power system we can use any of two methods to determine the type of short circuit given below.

1) By Positive and Negative Sequence Currents:
The negative sequence current I_2 should be zero during three phase fault, though negative sequence current I_2 and positive sequence current I_1 will be same during two phase short circuit, Thus, below equation can be used to determine whether a two or three phase short circuit is present, where K < 1

$$|I_2| > K|I_1|$$

2) By Fault Phase Current:
If two phase occurs between B and C,

$$|I_{Ag}| < K_1 |I_{Cg}|$$

If a two phase fault exists between A and B,

$$|I_{Cg}| < K_1 |I_{Bg}|$$

If a two phase fault is between C and A,

$$|I_{Bg}| < K_1 |I_{Ag}|$$

Where, I_{Ag}, I_{Bg} and I_{Cg} are phase currents during fault while, K_1 is constant which is less than 1. If any of these Equationsverified, short circuit occurred will a two phase. Otherwise it will be three phase short circuit fault. This method not only resolves between two phase and three phase faults, but also recognizes the phases which involved in short circuit.

3 PROTECTION ZONE FOR ADAPTIVE OC RELAY

Protection zone is an important measure of instantaneous over current protection, by equation (2) and (7) we can obtain the zone of protection for instantaneous over current protection.

$$\frac{K_d E}{Z_S + \alpha Z_L} = \frac{K_k K_d E}{Z_S + Z_L}$$

$$\alpha' = \frac{Z_S + Z_L - K_k Z_S}{K_k Z_L}$$

$$\alpha' = \frac{Z_L - (K_K - 1) Z_S}{K_K Z_L} \qquad (8)$$

By equation (8) the protection range α is not a constant, it has nothing to do with the fault types, but change along with the variation of system actual impedance, and can meet the requirement of selectivity, the scope of protection is in the best state.

Put $Z_S = Z_{Smax}$ into (3.11), we can get range of protection in the minimum for the operation state,

$$\alpha'_{\min} = \frac{Z_L - (K_K - 1) Z_{S\max}}{K_K Z_L}$$

Put $Z_S = Z_{Smin}$ into (8), we can get range of protection in the maximum for the operation state,

$$\alpha'_{\max} = \frac{Z_L - (K_K - 1) Z_{S\min}}{K_K Z_L}$$

In the conventional instantaneous over current protection, (Under the condition of using electromagnetic type electric current relay, usually take K_k = 1.3, But in the case of using microcomputer in particular, the adaptive instantaneous over current protection Short circuit current and fixed value calculation accuracy is high Can take smaller K_k values, Such as K_k = 1 or 2, K_k = 1.1.

4 Comparison two kinds of protection

Comparison the range of adaptive instantaneous over current protection and conventional instantaneous over current protection, namely compare (3) and (8).

$$\frac{\alpha'}{\alpha} = \frac{Z_L + Z_S - Z_S K_K}{K_d (Z_{S\min} + Z_L) - K_k Z_s}$$

For traditional over current relays, K_d has two different values, for three-phase short-circuit faul K_d=1

$$\frac{\alpha'}{\alpha} = \frac{Z_L + Z_S - Z_S K_K}{(Z_{S\min} + Z_L) - K_k Z_s} > 1$$

When phase-phase short circuit ensues $K_d = \sqrt{3}/2$

$$\frac{\alpha'}{\alpha} = \frac{Z_L + Z_S - Z_S K_K}{\sqrt{3}/2 (Z_{S\min} + Z_L) - K_k Z_s} > \frac{\sqrt{3}}{2}$$

$$K_d (Z_L + Z_{S\min}) \le Z_L + Z_S$$

The threshold current cannot be wide ranging according to mode of the power system and sort of short circuit without adaptive protection. Clearly when the equivalent source impedance is calculated online, the protection zone of adaptive relay will be extended. Therefore range adaptive protection is always longer as compared non adaptive protection range. According to Equation 8, the adaptive instantaneous over current protection range α is independent of the fault type and changes with the impedance and it is always less than 1, which shows that the adaptive instantaneous over current protection can assure the selectivity between upper and lower lines.

4.2 Example analyzing

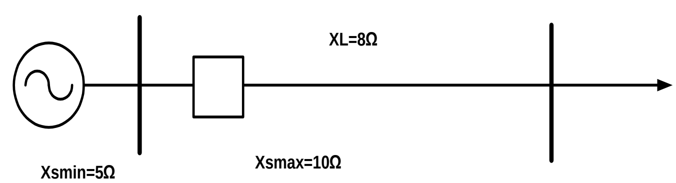

Fig.3 Simple Power system

The comparison of traditional over current protection zone and adaptive over protectoion zone is shown in table.1, which proves that range of adaptive over current protection is larger than the conventional over current protection.

Zone of	Maximum operation	Minimum operation

Protection	state		state	
	3ΦShort circuit	2Φ Short circuit	3ΦShort circuit	2Φ Short circuit
α	0.73	0.50	0.10	<0
α'	0.73	0.73	0.63	0.63

5 Conclusion

We have learned that each power system is unique, not all protection schemes are applicable to all power systems, and one cannot apply a general scheme to a specific power system. Typical relay settings do not apply to all application, with the lack information about real system parameters relay settings achieved would not be reliable for system. Therefore protection systems must respond to changes in the power distribution system's configuration. It is seen from the development trend of relay protection in power system, adaptive protection systems justify the limitations of conventional protection systems.

The adaptive scheme suggested here compromises a practically satisfactory solution to this problem which is independent of number, size and location of DG in the distribution system. The proposed pattern is adaptive to temporary plus permanent variations in supply system and its region of application can be extended to more than one feeder. Adaptive instantaneous over current protection can track the variation of operation mode of system in real-time, recognize the variation of system parameters and modify the setting automatically and will certainly play additional important role in the power system.

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