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Analysis of protection system's risk in distribution networks with DG

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A B S T R A C T

Using Distributed Generation (DG) is an interesting topic that has drawn attention of electrical engineers in recent years. The presence of these generation units in distribution systems, although has many advantages and benefits, has to be applied after performing detailed studies and investigations due to their complexities in operation, control and protection of network. One of the major effects of DGs is their effect on protection operation of distribution networks. In this paper after reviewing this influence, risk analysis of protection system's operation in a test distribution network according to various locations and capacities of DGs has been performed. For this purpose, three indexes for presenting the system's risk has been introduced and calculated in different investigated cases.

1. Introduction

The presence of DGs in distribution networks, like many other technologies, has some disadvantages along with many advantages it can have [2–9]. Among advantages of DGs one can mention improvement in power quality and reliability and reduction of loss, meanwhile using DGs leads to complexity in operation, control and protection of distribution systems [1,2]. Injection of DGs currents to a distribution network results in losing radial configuration and consequently losing the existing coordination among protection devices [2–7]. The extent at which protection coordination is affected depends on the size, type and location of DG, in some cases coordination is lost completely and in other cases the coordination range diminishes [4,5]. Regarding the influence of DGs on protection of distribution systems, so many researches have been performed so far as well as some researches concerning how to tackle the resultant problems of applying DGs [1,8–12].

According to the literature [1–19], some of the problems that raise after connection of DG for the protection system and some solutions have been mentioned. Some of these distinguished difficulties are as follows:

- False tripping of feeders (sympathetic tripping).
- Nuisance tripping of production units.
- Blinding of protection.
- Affecting short circuit levels.
- Unwanted islanding.
- Prohibition of automatic reclosing.
- Unsynchronized reclosing.

Reviewing these problems tends to need exploring the effects of the DG's penetration on protection system of the distribution networks. The impact of distributed generation on distribution networks depends on location, type and size of DGs, and presence of these kinds of energy resources will change the protection coordination range in some cases, and in some other cases it will result in losing it [18].

The promotion of DG is derived not only from its commercial purpose, but also from its power quality improving ability and environmental friendly attribute. Regarding power quality, DG can be applied as backup generation, in addition to its normal operation, when the main supply is interrupted. Without the upstream source, system isolation is formed and obtains electricity supply from the DG located in the connected area. As backup generation, DG is supposed to improve the system reliability if the related concerns are deliberately considered and the solutions are strictly implemented. For example, the isolated area must be able to maintain its own voltage and frequency within the specified standard. Also, the existing protection coordination in the system must not be jeopardized from the installation of DG [19].

The field of risk analysis has assumed increasing importance in recent years given the concern by both engineers and scientists in most technical issues. It is one of the powerful tools for solving engineering problems such as optimization ones [13].

In this paper after reviewing the effect of connecting distributed generation units to distribution network, a new method for risk analysis of protection system's operation is proposed.

The main effects that have been reviewed in this paper are loss of recloser–fuse and fuse–fuse coordination. According to the fact that the main protection devices in distribution networks are fuses and reclosers, loss of fuse–fuse and recloser–fuse coordination has a great impact on the system reliability. So, only these two

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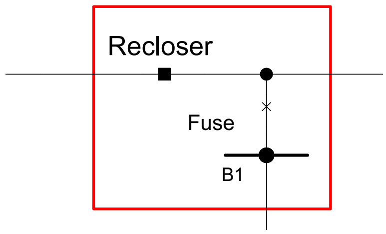

Fig. 1. Recloser–fuse arrangement.

problems have been analyzed and the lack of coordination between the distribution system protection system and the DG grid-interconnection protection has not been analyzed in this paper.

In the suggested method, three indexes for presenting the system's risk are introduced. The indexes have been defined to calculate the effects of DGs on the distribution system's reliability by affecting the protection coordination in terms of interruption duration, interruption frequency and energy not supplied. Then, a test distribution network for risk analysis, in which all kinds of protection miss-coordination among protective devices could be happened because of DGs penetration, is introduced. Finally, suggested indexes are calculated for different cases and various capacities of DGs in order to performing risk analysis.

2. Recloser–fuse miss-coordination problem

Figs. 1 and 2 show traditional recloser–fuse coordination in a distribution system. Fig. 1 shows a fuse in the lateral feeder and a recloser which is located on the main feeder. In order to have a correct operation, the fuse must be coordinated with upstream recloser on the main feeder. The coordination philosophy here is that the fuse should only operate for a permanent fault on the load feeder. For a temporary fault, recloser should disconnect the circuit with fast operation and give the fault a chance to clear. Only if the fault is permanent, the fuse should be allowed to open. In this way, the load feeder does not get disconnected for every temporary fault. Recloser also provides back up to fuse through slow mode. Since temporary faults constitute 70–80% of faults occurring in distribution system, this arrangement improves reliability while decreasing the maintenance cost. Fig. 2 shows the recloser–fuse coordinated graph for all fault currents within I_{fmin} and I_{fmax}. This is called the coordination range. Therefore, as long as the fault current values for faults on lateral feeder are within the coordination range, the recloser–fuse coordination is considered to be acceptable. It can be seen from Fig. 2 that fast characteristic of the recloser lies below the MM characteristics of fuse between I_{fmin} and I_{fmax}. Therefore, in coordination range the recloser operates in less time than the time sufficient to damage the fuse.

If the fault persists after the recloser closes following the second fast operation, then the fault has to be a permanent one and hence fuse must operate to clear the fault. As shown in Fig. 2, the TC curve of the fuse is below the slow curve of recloser in coordination range. Therefore, for a permanent fault, fuse will open before recloser operates in the slow mode. If the fuse fails to operate, recloser will back it up by operating in the slow mode and finally locking out [5].

After connection of DG, maximum and minimum fault currents for a fault on the load feeder will change and for any fault on load feeder, fuse will see more current than the recloser. In addition, as conventional protection, a temporary fault, occurring mostly at lateral feeder, should be discriminated by the fast operation of recloser. However, this conventional scheme may not be held when DG is connected at the end of the feeder. It is possible that this temporary fault is cleared by the lateral fuse, and be changed to a permanent fault. These undesirable operations of protective devices called "Fuse Blowing" and certainly decrease the system reliability.

In order to clarify the consequence of injected current, depending on placement of DG toward the recloser, four different cases are depicted in Fig. 3 and tabulated in Table 1.

In case 1, fault current seen by the fuse is summation of both fault currents from the substation and the DG. It indicates that system problem will occur whenever both DG source and fault position are located behind the recloser. This is the case of fuse blowing above mentioned. With this situation, it is possible that the miss-coordination of recloser and fuse will happen [14].

In case 2, DG and fault location are respectively after and before the recloser. In this case, reverse current flows through the recloser

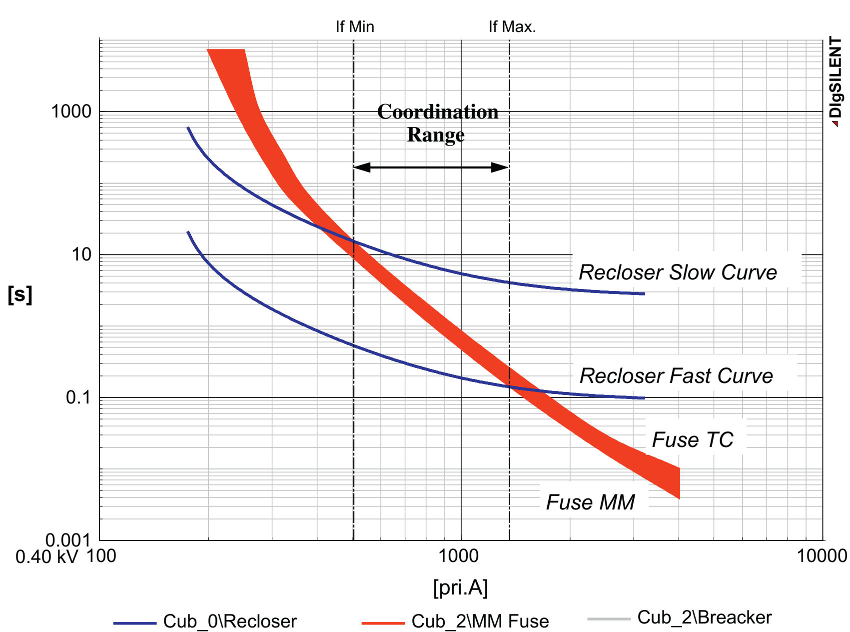

Fig. 2. Recloser–fuse coordination range.