Maintaining Fuse in the Presence of Distributed Generation Sources in the Distribution Network to Improve Protection System

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***Abstract*—The need to reduce greenhouse gas emissions and the high price of fossil fuels have made renewable resources attractive in energy-based economies around the world. Renewable energy sources will make up a significant part of the modern energy system in the future because they have promising potential. Many countries are already working to increase their capacity for renewable energy. Renewable resources are placed on distribution feeders or near consumers to provide power in power systems. The use of these resources may have negative effects on the distribution network, which should be considered in their placement. In this study, based on the current control of distributed production sources using the current-voltage diagram of the sources during the fault, a method of coordinating protection devices is presented. The effect of the presence of filling sources at different points on the flow during the flood has been compared. The simulation results are obtained using ETAP software. Coordination and regulation of protection devices have problems in some cases when scattered resources enter the network, which is recovered by using the proposed method of protection coordination.**

Keywords— Renewable energy sources; Power system protection; Distribution network; Distributed resource generation; Resource impact.

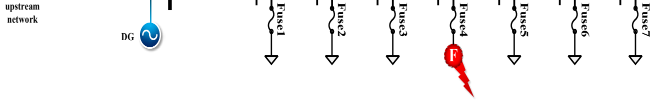
I. INTRODUCTION

Nowadays, climate change is at the forefront of scientific and political discussions around the globe. Although climate change has occurred since the beginning of time, the speed with which it has happened in recent years is cause for concern and may be one of the greatest threats humanities now faces. Carbon dioxide emissions have been rising at a faster rate in recent years [1,2]. Renewable technologies are widely regarded as clean energy sources because they reduce environmental impacts and secondary waste while meeting current and future economic and social demands [3,4]. Switching to renewable energy sources, which are increasingly competitive with traditional ones, can help greatly with energy conservation and slowing global warming (from fossil fuel-based sources) [5,6]. The design and selection of appropriate protection strategies are critical to the operation and control of energy grids. It supports improving power dependability, reducing risk to power infrastructure, and protecting operational staff. Protection principles are established in energy systems where traditional synchronous machines are employed as the primary fault-feeding source. When new fault-feeding sources are added to the network, their protection strategies are reevaluated and updated [7,8].

Another issue caused using renewable energy sources in the energy grid is intermittent infeed. For low-penetration input from a renewable power source, the protection schemes designed during the planning stage may function reliably. The widespread use of renewable resources, on the other hand, causes distribution feeders over current relays to trip frequently, which can affect transmission system distance relays. However, the electrical distance between the producer and the consumer is reduced by using distributed production sources, and also by improving the voltage profile, reactive power and reducing problems between distribution and transmission [9,10]. Among the other advantages of using scattered production sources, we can mention the reduction of electrical losses and the prevention of waste of thermal energy produced in generators [11,12]. Due to decentralization, distributed production sources can also increase the reliability and power quality of the system. By entering the distribution and super-distribution systems, scattered production sources affect the network structure, and one of their most important effects is the change in the protection system. Disconnecting distributed generation sources as soon as a short circuit occurs is one of the primary proposed methods. Therefore, before the protection function of the feeders, the factor of change in the short circuit current and loss of protection coordination is removed from the circuit, and the protection plan can have its proper function as before. In this case, protections such as fast reclosers curve function cannot be implemented. Also, going out of resources removes the benefits of installing them from the system, and the problem of resynchronizing them should also be considered [13,14].

Using current limiters of distributed generation sources during short circuit is another protection method [15,16]. The high cost, design and installation of fault current limiters is one of the disadvantages of this method and therefore it is not suitable for short-circuit current control [17]. Preventive methods based on which, calculations of protective equipment settings, maximum penetration coefficient of scattered production sources are considered are mentioned in some references [18,19]. Limiting the penetration rate of these sources is one of the disadvantages of this method. The advanced protection plan based on automation and telecommunication channels is one of the other methods proposed in the articles [20], which has many advantages, but due to the high cost and the need for a lot of infrastructure, it cannot be implemented in many cases.

Another method is to use a new structure for the protection system [21]. In this method, a new reclosers is used at the beginning of the branches where the scattered source is installed, and sometimes distance protection is also used. As it is known, due to the high costs and installation of additional equipment, this method cannot be implemented. In this paper, the aim of modifying the existing protection settings is to restore the coordination of the protection plan with the least change by entering the scattered sources with high penetration coefficient. In the second section, the radial distribution network under study is mentioned. The proposed control strategy is described in the third section. In the fourth section, the simulation results are presented along with the results analysis. Finally, the conclusion of the paper is stated in the fifth section.



One-line diagram of the studied distribution network in the ETAP environment

II. Radial distribution network

A distribution network with a radial structure is considered for the study according to Fig. 1. In this network, the current flows from one side and through the power post upstream to the network loads in the side branches. The protection system is of the common construction type, and the fuse protection scheme is implemented. A reclosers is used at the beginning of the main feeder and a fuse is used at the beginning of each side branch. The process of connecting and disconnecting the reclosers is done several times to keep the fuse safe in the event of transient errors, because when the fuse is functioning, it has caused the fuse to burn and melt, and the element needs to be replaced. This problem has been time-consuming, and it has caused the increase in the period of blackout of subscribers and network loads, and also increases the costs of the power system. Reducing the time margin between the reclosers and the corresponding fuse 4, due to the presence of the PV source, depending on the amount of production of this source, can have changes.

When the penetration coefficient of this source in the network increases, the contribution of injected current in fault conditions by the PV source will also increase. This increase will further strengthen the connection current, and as a result, it will reduce the operating times of the two protective devices and thus reduce the coordination margin between them. In the worst case, the current passing through the reclosers and fuse 4 increases. In this situation, it can be seen that not only the margin of coordination between the two protection devices has decreased from its minimum value, but also based on the curve, the fuse has operated earlier than the reclosers and has caused a protection mismatch.

The inverter of distributed production sources is one of their protection devices. Due to the direct flow of the output of these sources, it is inevitable to use an inverter in their output to connect to the network. Therefore, for fault and short circuit, this inverter must be protected, which is done by the inverter itself and by limiting the permanent short circuit current. This limited limit of the short-circuit current in the inverter of distributed generation sources exists by a factor called the K factor in the internal settings of the source inverter, which is usually considered between 200 and 300% of the steady-state current. Based on the proposed method, the adopted settings should be done on inverter-based distributed generation sources.

III. Suggested Method

In photovoltaic systems, to protect the internal circuits of the inverter, a sudden increase in the output current is prevented. These sudden currents occur in the conditions of voltage drop, such as the condition of failure in the network. Dispersed production sources, especially sources based on renewable energies, are used with the aim of obtaining maximum power from the power supply source.

In the conditions of voltage drop from the nominal value according to the characteristics of the photovoltaic system, the production current increases to keep the output power of the photovoltaic system constant. In severe voltage drop caused by a connection in the network, the increase in source current leads to damage to the inverter and internal circuits and is limited at a certain level. Therefore, in this condition, it changes from the working mode of constant power to the working mode of constant current, which is called the working mode of fault crossing (FRT).

IV. Simulation Results

ETAP software is used for simulation in this section. Fault occurrence conditions and protection coordination checks in the presence of distributed generation resources are shown to evaluate the proposed method. The studied system, a sample distribution network, has a radial structure, with voltage levels of 20 and 0.4 kV, and network loads are located in the lateral branches. Each side branch is modeled with a microgrid, where the 20 kV busbar assembly, 20-0.4 kV transformer, 0.4 kV busbar and finally the connected load are located (Fig. 2). The short circuit level of the network is 450 MVA and the length of each part of the feeder is 2 Km.

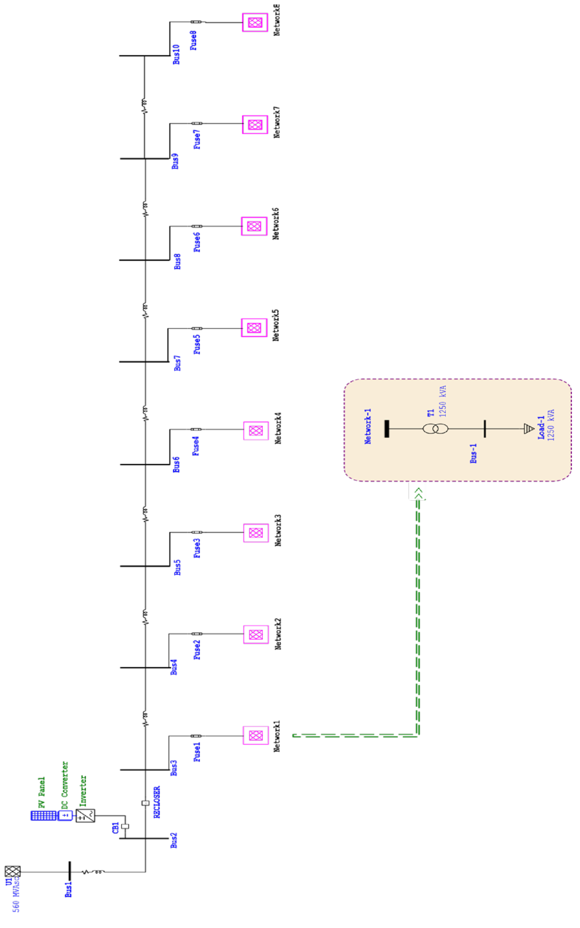


Fig. 1. One-line diagram of the studied distribution network in the ETAP environment

In the common protection scheme on the feeder, which is the coordinated fuse protection scheme, the reclosers is placed at the beginning of the feeder, and the fuses are installed at the beginning of each side branch. According to this design, for every short circuit that occurs in the protection zone of the fuses, the reclosers is responsible for quickly clearing the fault, which is caused by the burning of the fuses due to transient connections, is prevented in the network. If the error occurred is stable, after the reclosers has been disconnected and connected several times and finally locked, the said error will be cleared by burning the fuse.

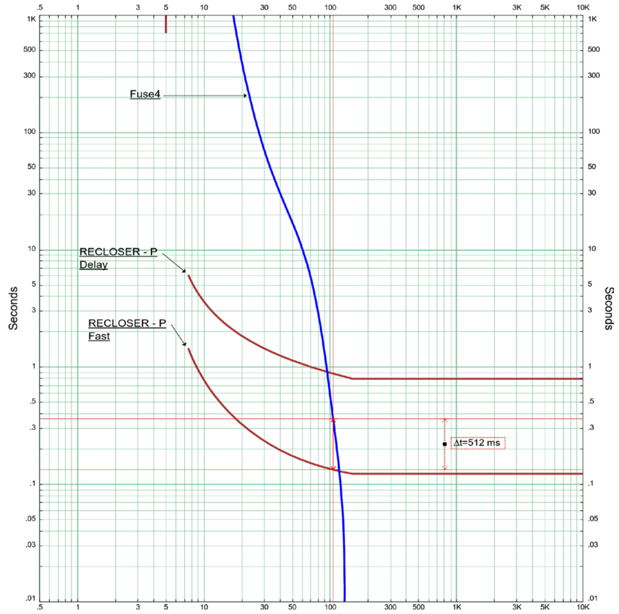


Fig. 2. One-line diagram of the studied distribution network in the ETAP environment

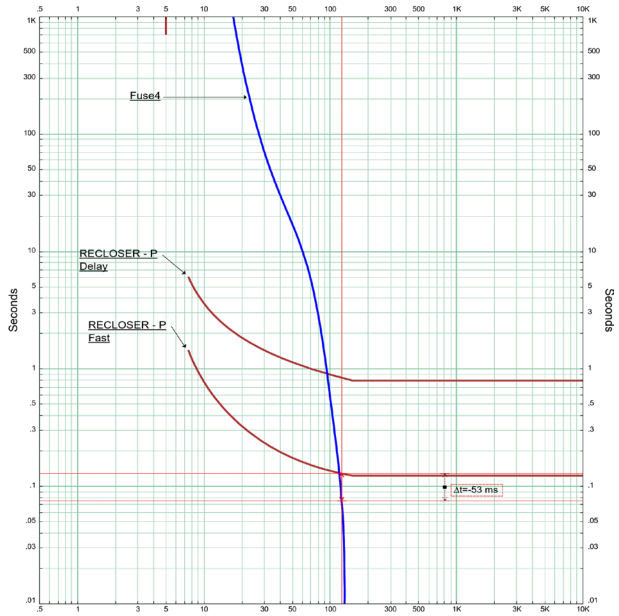


Fig. 3. The presence of the PV source in the highest penetration coefficient based on the initial design

Based on the curve set on the reclosers, the operating time should be less than 75% of the fuse operating time. When the PV is not present in the network, due to the fault created in the Fuse4 protection area, the fault current passing through the network is equal to 982 amps. The operation time of the reclosers according to its predefined protection curve is 136 milliseconds. After the reclosers has operated twice on its fast curve, the fuse has blown at 648 milliseconds due to the remaining fault, breaking the circuit. It can be seen that the coordination is well maintained, because the time of 136 ms is less than the 75% melting time of the fuse (648 ms), 487 ms. In this situation, the protection characteristic curve of reclosers and fuse 4 of the network under test is as shown in Fig. 3. In the event of an error in the area protected by fuse 4, the operation of two protective devices is shown. For the penetration factor of 25% of the photovoltaic source, the fault current passing through the feeder was equal to 1054 amperes, for which the operating time of the reclosers and fuse is equal to 134 and 365 milliseconds, respectively.

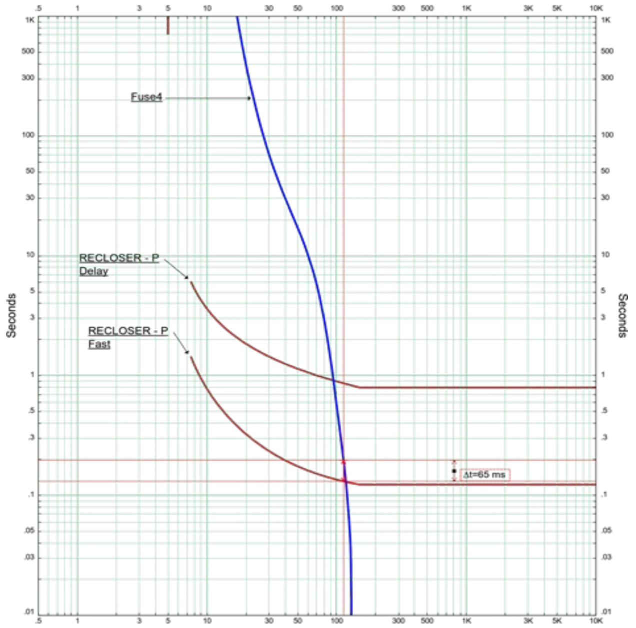


Fig. 4. The presence of the PV source in the highest penetration coefficient based on the new proposed control method

After applying the proposed method on controlling the output current of the PV source, in the event of an error occurring in accordance with the voltage of the connection point of that source to the grid, the error current passing through the protection equipment is controlled and causes coordination between them.

Table 1. operation times of fuse and recloser in the presence of scattered production source after applying the proposed method

PV Penetration (%)	Δt (ms)	$t_{Recloser}$ (ms)	t_{fuse4} (ms)	$I_{Recloser}$ (Amp)	I_{fuse4} (Amp)
100	16.75	130	196	1130	1130
75	61.5	131	257	1096	1096
50	125.75	132	344	1059	1059
25	217.5	134	469	1021	1021
0	350.75	135	648	982	982

The effect of the proposed method on the operation times of the fuse and reclosers in the presence of a distributed generation source is shown in Table I. As can be seen, after applying the new control strategy on the photovoltaic system, even in the high penetration coefficients of the presence of scattered production sources, the coordination between the two protection devices, reclosers and fuse, based on the fuse protection plan, has been well maintaining the worst condition of the presence of PV sources, the margin of coordination between the reclosers and the fuse can be seen in Fig. 4. At the highest penetration coefficient, the protection characteristics of the two devices are presented in Fig. 5 and the good effect of the proposed method can be seen.

V. Conclusion

The protection system in the electrical distribution network is one of the most important parts of the network. The presence of scattered production resources causes various problems such as changing network protection settings. In this paper, current control using a distributed source inverter is used. The design and coordination of fuse-reclosers protection scheme in a 20 kV distribution network is presented. The protection coordination of scattered production resources and the problems of increasing the penetration rate have been investigated. ETAP software is used for simulation.

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