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Effect of Distributed Generation Based on Synchronous Generator on Fuse Recloser Protection Coordination in Medium Voltage Network

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ABSTRACT
The integration of distributed generation in medium-voltage distribution systems requires rapid evaluation of the protection coordination, especially the integration of synchronous generator-based generators where the contribution effect of short-circuit currents is relatively high. This research makes evaluation software for protection coordination based on fuse saving operation. Short circuit calculations on buses using the Zbus matrix. The increase in short-circuits current due to the installation of distributed generations based on variations in the size and location in the medium-voltage network results in need for redesigning the protection system. After a brief literature review, the methods and simulation results are presented. The low penetration level of 20% (0.406 MVA) has only a minor impact on protection coordination. Fuse replacement at limited locations can restore coordination of protection. The high penetration level of 60% (1.075 MVA) indicates that the protection coordination mechanism is still maintained if the installation is near a substation.

Keywords: *recloser, fuse, distributed generation, synchronous generator.*

1. INTRODUCTION

Various steps have been taken to anticipate the increasing demand for electrical energy supply, both in the context of national electrification and industrial growth. The Small-Scale Power Plant (Distributed Generation) is one of them. Geographical problems and the need to increase the electrification ratio in Indonesia indicate that most distributed generation development will be in rural areas. The characteristics of the network will be related to the SUTM system and the radial network topology. So those network operation problems with the nature of the disturbance will be closely related to the environment or external factors such as; lightning, trees, and animals. Several studies have shown that 70-95% of network disturbances are temporary disturbances, with the duration of the disruption between one-quarter of cycles to several cycles.

The problem of Recloser-Fuse coordination in the Small-Scale Power Generation integration scheme is still actual. Fuse and recloser are traditionally used to reduce interference. Recloser is installed on the main feeder, and the fuse is installed on the lateral. Fuses are inexpensive and reliable protection devices that will fuse within a few cycles due to a high fault current. Therefore fuses are often replaced due to breakage as a result of fault currents. Recloser is performed as a backup to minimize the number of broken fuses. In the case of temporary disturbances, the recloser will clear the disruption, which is the priority of the fuse. This protection scheme is known as a fuse-saving operation.

Answering the problem of developing the integration of Distributed Power Plants in Indonesia and considering several research results showing that non-adaptive solutions are still widely used until 2020. This study does not require on-line measurements to control disturbance [1-6]. Arafa A et al. developed a non-adaptive technique that does not require on-line measurements to prevent disturbances by selectively switch fuse on the new Dispersed Generator integration—considering the finding from their research that the most disturbance is found in the fuse attached to the lateral feeder. Another consideration is that when a disturbance occurs, the feeder will still be connected to the generating unit with a specific location and a certain level of penetration[1]. Elmitwally et al. described the effect of fault current limiters on recloser-fuse coordination due to changes from monopolar (having one direction) to more than one direction resulting in changes in the direction and magnitude of the fault current. This change is due to the contribution of the short-circuit fault current flowing from the generator. This study shows that the magnitude of the fault current is significantly influenced by installing a fault current limiter in the network [2].

Naiem A.F. et al. developed a relay condition adjustment technique to respond to real-time conditions to increase system reliability. The operating system is designed to require little or no operator intervention [3]. Jamali S et al. showed that the transient stability can still be maintained by installing SPAR (Single Pole Auto Recloser) on unit operations integrated with DG. Furthermore, the installation of SPAR can improve supply continuity, given that many distribution network customer loads are one phase. Since most disruptions to the distribution network are single-phase-to-ground and temporary, implementing the SPAR scheme in the distribution network can demonstrate superiority in supply quality. The simulation shows that the transient stability can still be maintained.

Further studies of this subject will be interesting because the installation of SPAR can improve supply continuity, given that many distribution network customer burdens are one phase [4]. Shah P.H. et al. developed an adaptive scheme on the recloser to prevent coordination failure on the recloser [5]. Hussain, B. et al. developed a fuse saving scheme, not with a pole recloser but a recloser on overcurrent protection relays found in substations [6].

In the International Journal of Computers and Electrical Engineering-Elsevier, Alam M., N. in 2019 described the scheme for developing the combination current-time characteristics for overcurrent protection relays specifically for microgrid applications in detail [7]. Zeineldin H.H., et al. created a directional relay using a dual setting using a directional relay on feeder integration protection with Distributed Generation. Two directional relays were developed at the point of interconnection location for the installation of the generating unit. Two relays monitor the fault and determine the direction of the disturbance. The direction of the disturbance monitored by the relay will operate the breaker to isolate the generating unit to minimize the Recloser-Fuse coordination failure [8]. Sa’ed J. A., et al. presented a schematic of the influence of capacity-related integration on the radial network topology. In this paper, the current fault pattern that affects the recloser and fuse functions is explained in detail from the fuse and recloser locations [9]. Abdel-Ghany H. A., et al. develop a system to get an optimal representation integrated with a synchronous generator in the radial network topology [10]. Norshahrani A., M., et al. displays comparative data on several methods in protection mitigation related to developments in several generating units [11]. Pazzini S., et al. made a detailed review of the overcurrent relay settings during integration [12]. Norshahrani, et al. developed the coordination of protection related to network reconfiguration [13].

This research is focused on getting an evaluation model that is applicable and practical. The resulting form is software that can evaluate the coordination of the fuse recloser protection. This research shows the influence of the location and power capacity of the scattered generating unit on the mitigation of the fuse device due to failure of protection coordination in depth. In particular, the study focuses on finding a fuse mitigation method in medium voltage networks when integration with Distributed Generators was carried out.

2. METHODOLOGY

The research process is carried out with the following steps:

1. Create a subprogram of fuse characteristic fitting curve using an approach based on the equation $\log(t) = a. \log(I) + b$
2. Create a subprogram for determining the termination time of the minimal melting fuse and the model for determining the timing of the disconnection of the total clearing fuse on the fault current through the fuse.
3. Create a subprogram for determining the operating timing of the fast (instantaneous) recloser and the model for determining the timing of the operation of the slow recloser
4. Create a subprogram for bus impedance matrix formation and a subprogram for bus impedance matrix that can be adapted by adding generators at specific nodes.
5. Create a short circuit current calculation subprogram using the bus impedance matrix method.
6. Adapt the short circuit calculation subprogram for calculating the maximum and minimum fault currents in the IEEE 34 Node Feeder Test model.
7. Evaluate the location placement and size of the generating unit capacity to integrate Distributed Power Plants.

To obtain the influence relationship between power capacity and generating unit location, the test is made with the variations of the power capacity of the generating unit and the variation in the location of the installation of the generating unit. In this test, the power capacity used is 0.406 MVA (20%) and 1.075 MVA(60%), while the integration point of the generating unit is the node that is on the main feeder (17 test points).

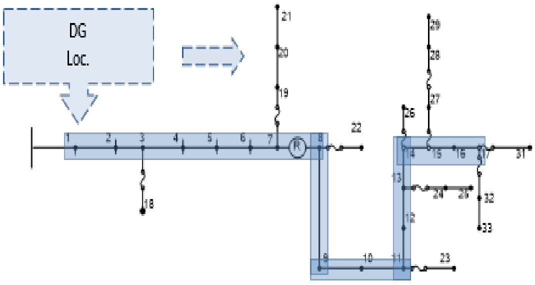

Figure 1 Distributed Generator Location

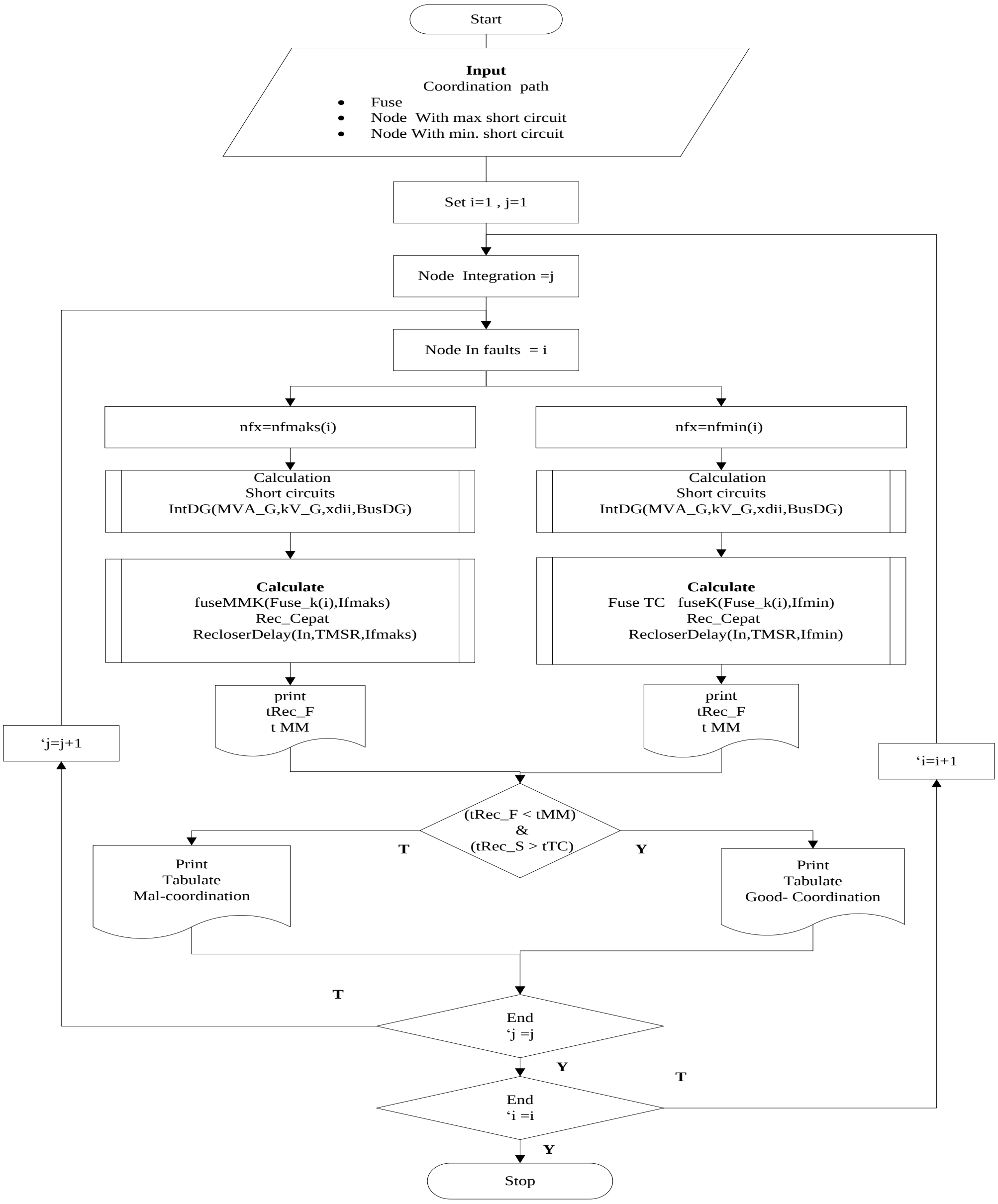

Figure 2 the protection coordination evaluation program flowchart.

3. RESULTS

The protection coordination on integration is 0.406 MVA. Placement of generating units on nodes 10 to 17 on the unit integration of 0.406 MVA results in failure of coordination in the fuse; F.6 and F.9, on the installation of generating units at Node 10 to Node 17 locations. Increasing the Fuse rating by one rating level will normalize the coordination of system protection. The integration of generating units with slight penetration (20%) has a minor impact on protection coordination. Limited fuse replacement is still possible.

On integration 0.6 MVA, fuse F.3 F.6, and F.9 become critical of mal coordination at the installation location at Node 5 to Node 17. In integrating large generating units of 1,075 MVA (60%), the possibility of installation with a small impact on coordination based on ‘fuse saving operation’ is by installing generating units close to substations. Raising the fuse rating by one level on the coordination path experiencing mal-coordination will return to an excellent protective coordination condition. In the test on the integration range between 10% to 60%, 4 Fuses have mal coordinated protection. At 20% integration, fuse F.6 and F.9 experience mal-coordination for unit installation on Nodes 10 to 17. At 30% integration, uses F.3, F.6, and F.9 will mal-coordinate for unit installation on Nodes 5 to 17. On integration from 40% to 60%, fuse F3, F4, F6, and F9 will be mal-coordinated for installation on Node 5 to 17. Table 1 shows the result of the print of calculating the failure of the coordination protection for placement of the generating unit in the IEEE 34 Node Feeder Test.

Table 1. The result calculation of the fuse broken in various distributed generation capacity

No. Fuse of Mal Coordination	The Capacity of Distributed Generation				
	0.406 MVA	0.600 MVA	0.700 MVA	0.900 MVA	1.075 MVA
	20%	30%	40%	50%	60%
	The number of node test				
3		5	5	5	5
3		6	6	6	6
3		7	7	7	7
3		8	8	8	8
3		9	9	9	9
3		10	10	10	10
3		11	11	11	11
3		12	12	12	12
3		13	13	13	13
3		14	14	14	14
3		15	15	15	15
3		16	16	16	16
3		17	17	17	17
4			10	10	10
4			11	11	11
4			12	12	12
4			13	13	13
4			14	14	14
4			15	15	15
4			16	16	16
4			17	17	17
6		5	5	5	5
6		6	6	6	6
6		7	7	7	7
6		8	8	8	8
6		9	9	9	9
6	10	10	10	10	10
6	11	11	11	11	11
6	12	12	12	12	12
6	13	13	13	13	13
6	14	14	14	14	14
6	15	15	15	15	15
6	16	16	16	16	16
6	17	17	17	17	17
9			5	5	5

No. Fuse of Mal Coordination	The Capacity of Distributed Generation				
	0.406 MVA	0.600 MVA	0.700 MVA	0.900 MVA	1.075 MVA
	20%	30%	40%	50%	60%
	The number of node test				
9			6	6	6
9			7	7	7
9		8	8	8	8
9		9	9	9	9
9	10	10	10	10	10
9	11	11	11	11	11
9	12	12	12	12	12
9	13	13	13	13	13
9	14	14	14	14	14
9	15	15	15	15	15
9	16	16	16	16	16
9	17	17	17	17	17

4. CONCLUSION

The penetration level significantly affects the fuse-recloser protection coordination mechanism based on ‘fuse saving operation.’ The penetration level of 20% in the location of generating units has only a small impact on the coordination of protection. Fuse replacement at limited locations can restore coordination of protection. The penetration level of more than 40% indicates that maintaining the protective coordination mechanism requires replacing up to 50% of the number of fuses. At a high penetration level of up to 60%, only installation at Node 3 and Node 4 locations does not impact protection coordination, meaning that all installed Fuses are needed.

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