Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm

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Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm

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Abstract – *This paper proposes the performance improvement of radial distribution network with distributed generation (DG) integration using extended particle swarm optimization (PSO) algorithm. High-performance distribution network is a network that has a low power loss, better voltage profile, and loading balance among feeders. The effort to improve the performance of the distribution network is network configuration optimization. The optimization has become an important issue with the presence of DG in distribution networks. In this study, network configuration optimization is based on an extended PSO algorithm. The methodology has been tested in two models of IEEE radial distribution networks. The results showed that the optimal configuration of the distribution network is able to reduce power loss and to improve the voltage profile of the network significantly.*

Keywords*: Radial distribution, network reconfiguration, network performance, particle swarm optimization, distributed generation.*

Nomenclature

Q_{DG}	Reactive power of DG.
P_{loss}	Cost function of active power loss.
P_i	Active power flowing out of bus *i*.
Q_i	Reactive power flowing out of bus *i*.
n_b	Number of branch.
R_i	Resistance at bus *i-th*.
V_i	Voltage magnitude at bus *i-th*.
$V_{i,min}$	Lower voltage magnitude limits at bus *i-th*.
$V_{i,max}$	Upper voltage magnitude limits at bus *i-th*.
$I_{i,min}$	Lower current magnitude limits at bus *i-th*.
$I_{i,max}$	Upper current magnitude limits at bus *i-th*.
X_i	Position of the *i-th* individual of swarm.
V_i	Velocity of the *i-th* individual of swarm.
$V_i^{(t+1)}$	Modified velocity of particle.
$X_i^{(t+1)}$	Latest position of particle.
$Pbest_i$	Particle best experience of *i-th*.
$Gbest_i$	Best global position for swarm search *i-th*.
t	Number of iterations.
$rand_1(o)$	A random number between 0 and 1.
$Rand_2(o)$	A random number between 0 and 1.
N	Number of the swarm.
ω_{max}	Maximum inertia weight.
ω_{min}	Minimum inertia weight.
t_{max}	Maximum number of iterations.

I. Introduction

The uncertainty system load of a different feeder is highly variables, therefore the operation and control of power distribution systems become more complex, especially in areas that have a high load density. In this state the power loss in a distributed network will not minimum for a fixed network configuration for all cases of varying loads. Therefore, it is necessary to increase system performance through the distribution network reconfiguration. Distribution network reconfiguration is achieved by using sectionalizing switches that remain normally closed and tie switches that remain normally open. The main purpose of the reconfiguration is to minimize active power losses in order to improve distribution system performance [1]–[3]. Basically, the network is reconfigured to reduce the real power losses and to balance the load of each feeder. However, because of the dynamic nature of the load, the total load is more than the capacity of the generation system that makes eliminating the load on the feeder is not possible and hence the system voltage profile will not be upgraded to the required level. In order to meet the required level of load demand would require the DG unit is integrated in the distribution network. Until now, network reconfiguration and placement of DG in distribution networks are considered independent. However, in the proposed method, network reconfiguration and installation of DG handled simultaneously to increase the

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minimization of losses and voltage profile.

Merlin and Back [4] first proposed network reconfiguration problem to obtain the minimal active power losses using conventional technique. In the last two decades, the applications of artificial intelligence in optimization purposes have been significantly increased [5]–[7]. The use of artificial intelligence based techniques for optimization of network configuration has become something of interest for many researchers, as can be seen in [8]–[19]. In [8], the use of genetic algorithm (GA) for distribution network reconfiguration technique to minimize the active power loss has been proposed. In [9] and [10], they have presented simulated annealing techniques in large scale distribution system for active power loss reduction purpose. In [11], they have proposed a new GA based methodology with the fundamental loops for network reconfiguration. Another variant of the GA for distribution network reconfiguration has been proposed in [12]. They have developed a GA method based on the matroid and graph theories. In [13], the use of ant colony optimization method for placement of sectionalizing switches in distribution networks has been presented. In [14], network reconfiguration based on a simple branch exchange technique of single loop has been proposed. In the technique, loops selection sequence affects the optimal configuration and the network power loss. In [15], harmony search algorithm was used to reconfigure large-scale distribution network in order to minimize active power losses. The technique is conceptualized using the musical process of harmony searching in perfect state. In [16]–[18], the use of fuzzy multi-objective technique for optimal network reconfiguration has been presented. The technique of particle swarm optimization (PSO) for distribution network reconfiguration purpose has been presented in [19]. In their work, there are several objectives, i.e., active power loss, load balancing among the feeders, deviation of bus voltage, and branch current constraint violation. Criteria for selecting a membership function for each objective are not provided.

The use of renewable energy sources as an alternative power generation has become popular in recent years. The power generation generally is having a capacity of up to 10 MW and located in several places that are connected to the grid distribution system, often called distributed generation (DG) [20]–[22]. The advantages of DG integration in distribution system are reducing power losses, improving voltage profiles and load factors, eliminating system upgrades and reducing environmental impacts [23]–[24]. Integration of DG in distribution system has become an interesting challenge for researchers to find the most appropriate method in the planning and operation of distribution system [25]–[28].

In this work, an extended PSO algorithm is proposed to perform distribution network reconfiguration problem in the presence of DG for reducing the active power loss, improving voltage profile, and balancing the load among the feeders. Radially of the network post-reconfiguration must remain in which all loads must be simultaneously supplied. Also, effect of DG type and voltage profile of the network is investigated. All objective functions are simultaneously weighted. Weighting of objective functions is a new issue in a multi-objective optimization [17]–[18]. The effort is done in order to improve the distribution system performance.

II. DG Integration in Distribution Network

Most of the electricity generated at the power plant, and is transmitted via high voltage or extra high voltage transmission lines supply to the distribution network before going to the consumer in a traditional power system. In a recent development, because the shrinking of economic scale, technological innovation, and environmental issues, the DG units derived from renewable energy sources has penetrated the system in a number of significant power and capacity. In addition, the small-scale capacity as DG provide some advantages like some uncertainty in economic planning and development is reduced. A further advantage is the DG project comes with less risk than the conventional centralized power plants. DG can provide better quality of power to the distribution network and improve the voltage profile at the end of the distribution feeder and reduce congestion and power losses in the network, because they can directly supply power to local demand. DG improve reliability by increasing the supply of electricity in certain areas, reducing power delivery and power losses through the distribution network, and delay the need for upgrading the distribution network by utilizing local resources that comes from renewable energy sources.

However, the DG could create some problems such as the addition of reactive power on the network, the problem of protection, power conditioning, power quality, and electricity tariffs. Some DG technologies, e.g. wind turbines, using asynchronous generator (induction generator) which consumes reactive power from the grid. This leads to a deficit of reactive power either locally or globally, and, consequently, leads to poor voltage profile which will cause a voltage collapse. Moreover, DG creates protection systems in the distribution network is more complicated in terms of selectivity and coordination. The reasons for the power flow in the distribution network with DG units are no longer unidirectional and error rate change. In addition, several DG technologies, such as PV and fuel cells, do not have a back spin to respond to rapid changes in the balance of electrical power.

There are four types of DGs based on their technology and their terminal characteristics [29].

Type I: DG injects active power (P) only, e.g., photovoltaic.

Type II: DG injects reactive power (Q) only, e.g., synchronous compensators.

Type III: DG injects active power but absorbs reactive power, e.g., asynchronous generator. The reactive power absorbed by an asynchronous generator is given by QDG=(0.5+0.04P2).

Type IV: DG injects both active and reactive power, e.g., synchronous generators.

In our study, the two types of DG units are employed in radial distribution network, i.e. solar photovoltaics and wind farms. DG of solar photovoltaics injects active power while the DG of wind farms which are using asynchronous generator injects both active and reactive powers.

III. Particle Swarm Optimization

II.1 Problem Formulation

The aim of network reconfiguration is to minimize active power losses and to improve voltage quality. The constraints of network reconfiguration problem are load flow equations, upper and lower limits of bus voltages, and upper and lower limits of line currents. Network reconfiguration for active power loss minimization can be formulated as follows:

$$\min P_{loss} = \sum_{i=1}^{N_k} R_i \frac{(P_i^2 + Q_i^2)}{V_i^2} \tag{1}$$

Subject to:

$$F(x) = 0 \tag{2}$$

$$V_{i,\min} \le V_i \le V_{i,\max} \tag{3}$$

$$I_{i,\min} \le I_i \le I_{i,\max} \tag{4}$$

where P_{loss} is a cost function of active power loss; N_k is the number of branch; R_i is resistance at bus *i-th*; P_i and Q_i are active and reactive powers flowing out of bus, respectively; V_i is voltage magnitude at bus *i-th*; $V_{i,min}$ and $V_{i,min}$ are lower and upper voltage limits at bus i-th, respectively; I_i is current magnitude at bus *i-th*; and $I_{i,min}$ and $I_{i,min}$ are lower and upper current limits at bus *i-th*, respectively;

II.2 Extended Particle Swarm Optimization

Particle swarm optimization (PSO) algorithm was first published by Eberhart and Kennedy [30]. The algorithm was inspired by a flock of birds movement in searching of food. The movement model can be used as a powerful optimizer. In one n-dimensional search space, let us assume that the position of the *i-th* individual is $X_i = (x_{i1}, \ldots, x_{id}, \ldots, x_{in})$ and the speed of the *i-th* individual is $V_i = (v_{i1}, \ldots, v_{id}, \ldots, v_{in})$. The particle best experience *i-th* is recorded and represented by $Pbest_i = (pbest_{i1}, \ldots, pbest_{id}, \ldots, pbest_{in})$. The best global position for swarm search is $Gbest_i = (gbest_1, \ldots, gbest_d, \ldots, gbest_n)$. The modified velocity of each particle is calculated based on the personal initial velocity, the distance from the personal best position, and the distance from the global best position, as shown in the following equation:

$$V_i^{(t+1)} = \omega \cdot V_i^{(t)} + c_1 \cdot rand_1(\circ) \cdot (Pbest_i - X_i^{(t)}) + c_2 \cdot rand_2(\circ) \cdot (Gbest_i - X_i^{(t)}) \tag{5}$$

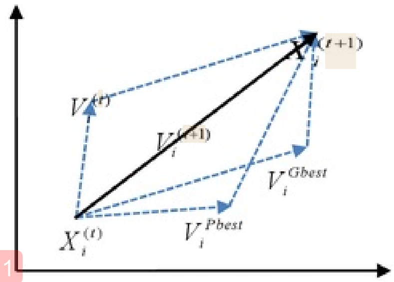

Fig. 1. The concept of optimization using PSO.

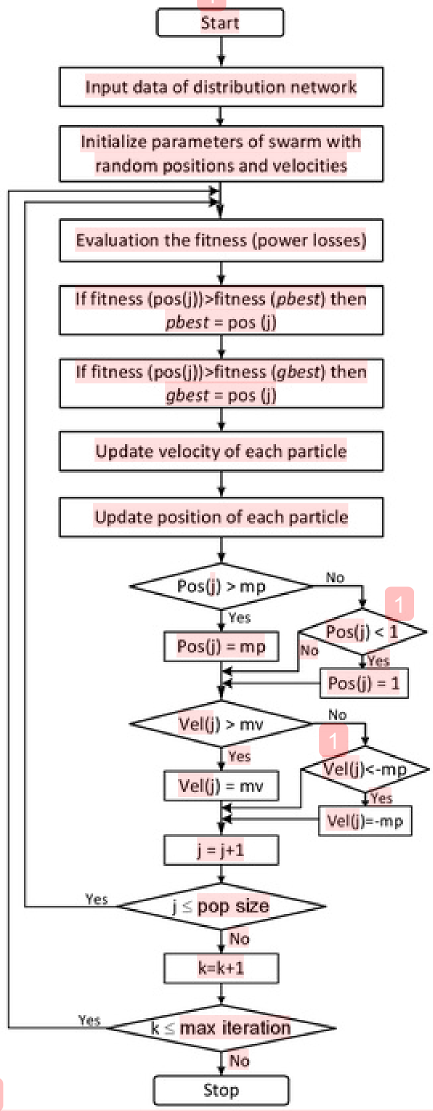

Fig. 2. The flow chart of extended PSO algorithm.

Equation (5) determines the velocity vector of the *i-th* particle. Therefore, the latest position of the particle can be determined by using the equation:

$$X_i^{(t+1)} = X_i^{(t)} + V_i^{(t+1)} \quad (6)$$

where i = 1, 2, ..., N is the index of each particle; t is the number of iterations; $rand_1(\circ)$ and $rand_2(\circ)$ are a random number between 0 and 1; and N is the number of the swarm.

Inertia weights ω can be determined by the equation:

$$\omega^{(t+1)} = \omega^{\max} - \frac{\omega^{\max} - \omega^{\min}}{t_{\max}} \times t \quad (7)$$

where ω_{max} is the maximum inertia weight; ω_{min} is the minimum inertia weight; t_{max} is the maximum number of iterations; and t is the actual number of iterations. The value of inertia weight decrease linearly from 0.9 to 0.4.

The improved PSO algorithm is shown in Fig. 2, and described as follows [31]:

1. Input distribution network data and initialize parameters.
2. Run the load flow program to measure the fitness (active power loss) of each particle (*pbest*) and store it with the best value of fitness (*gbest*).
3. Update velocity and position of particle using (5) and (6).
4. Perform violation of particle position:
   If particle position pos(j)>mp, then pos(j)=mp.
   Else if particle position pos(j)<mp, then pos(j)=1.
5. Perform violation of particle velocity:
   If particle velocity vel(j)>mv, then vel(j)=mv.
   Else if particle velocity vel(j)<-mv, then pos(j)= -mv.
6. Decrease the inertia weight (ω) linearly from 0.9 to 0.4.
7. Repeat steps 2-6 until a criteria is obtained.

IV. Simulation Results

In this research, two test electrical distribution systems, i.e., a 33-bus IEEE radial distribution network test system and a 71-bus IEEE radial distribution system, are examined. The two test systems have been integrated DG in assumption. Reconfiguration of distribution network with DG integration using improved PSO method has been implemented in Matlab software. Based on the DG technology, two types of DG which are connected to distribution network in our work, i.e., solar photovoltaics and wind farms, are modeled. Operation of DG is assumed to be in steady state condition. Hence, DG of solar photovoltaics injects active power while the DG of wind farms injects both active and reactive powers.

III.1 Test System of 33-Bus IEEE Distribution Network

In this section, the configuration optimization of the 33 bus IEEE model distribution network using PSO algorithm is described. Configuration optimization is implemented on the 33 bus, 12.66 kV radial distribution network in two conditions, i.e. without DG integration and with DG integration. The radial distribution system consists of one main and three lateral feeders. This system has 33 buses and 32 sections, as shown in Fig. 3. The distribution network has 32 sectionalizing switches and 5 tie switches. Sectionalizing switches are switches that are in closed position under normal conditions, while the tie switches are switches that are in open position under normal conditions. Data load and 33-bus IEEE radial distribution network can be seen in [32]. The total load of the system is 3715 kW and the base of the system is V=12.66 kV and S=10 MVA. The PSO parameters that have been used to 33-bus distribution system are consists of population size of 20 and maximum iteration of 1000. The minimum and maximum voltages are set at 0.90 and 1.00 p.u., respectively. In original configuration, the distribution system of the 33-bus IEEE model has been set at five tie switches, i.e. switches of 33, 34, 35, 36 and 37, respectively, as can be seen in Fig. 3.

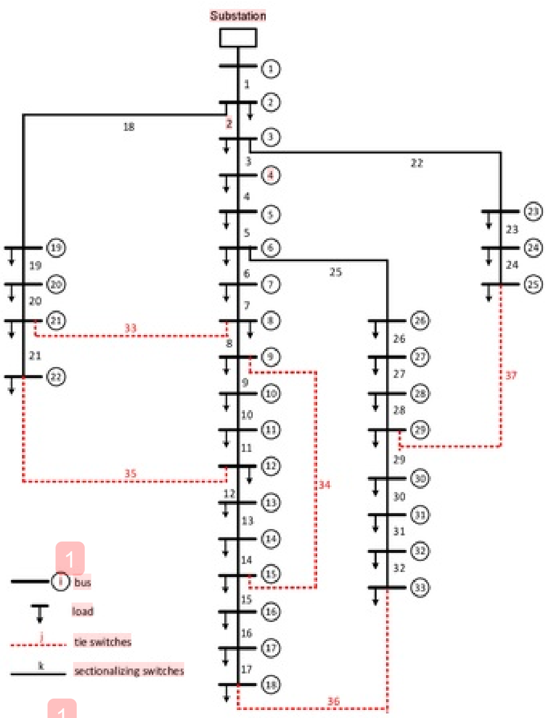

Fig. 3. Original configuration of 33-bus IEEE radial distribution network [32].

Table 1. DG Location and Capacity of 33-Bus Test System

Name	Bus Number	Active Power (MW)	Power Factor	Reactive Power (MVAr)
DG1	18	1.92	0.9	0.93
DG2	22	1.75	1	0
DG3	33	1.68	0.9	0.81
Total		5.35	-	1.74

In order to analyze the impact of DG integration to distribution network, we have installed as many as three DGs on buses of 18, 22, and 33, with the capacity of 1.92

MW, 1.75 MW, and 1.68 MW, respectively, as shown in Table 1. Location and capacity of the three DGs are the most optimal as stated in [33]. The DG models that have used in our study consist of both solar photovoltaics and wind farms. We have assumed that power factor of all DG solar photovoltaics are unity, while wind farms are 0.9 lagging. Integration of the three DGs on 33-bus IEEE radial distribution network is shown in Fig. 4. Then, the optimization of configuration of the network model with DG integration using PSO algorithm is performed. The results of the optimization are shown in Fig. 5, Fig. 6, Fig. 7, Fig. 8, and Table 2.

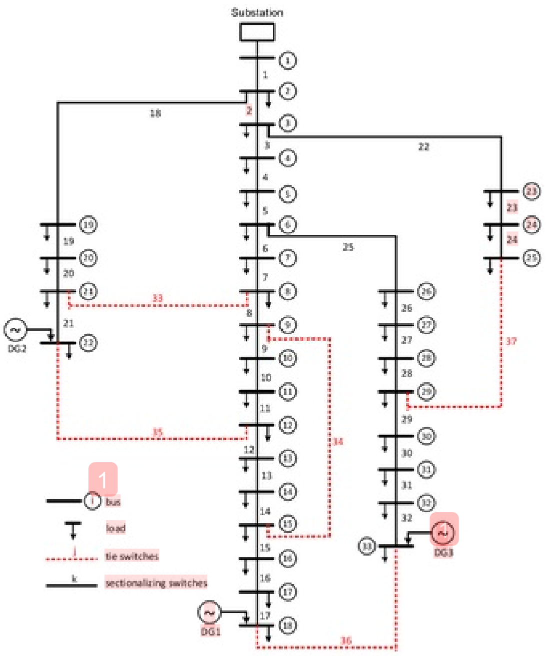

Fig. 4. Integration of three DGs on 33-bus IEEE radial distribution network.

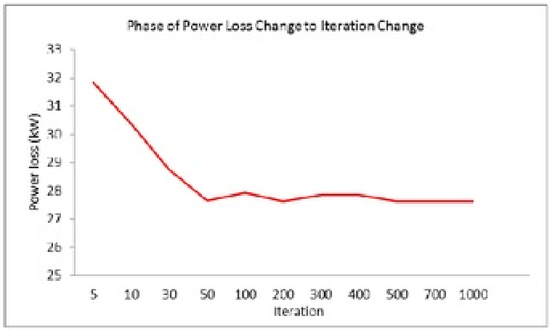

Fig. 5. Phase of power loss to iteration during optimization of 33-bus IEEE radial distribution network with integration of three DGs.

Fig. 5 shows phase of power loss change to iteration change during optimization of 33-bus IEEE radial distribution network with integration of three DGs. Variations in the number of iterations is applied to see the performance of PSO algorithm in optimization of distribution network configuration. Using the variation of the number of iterations, it is expected to be obtained information that the lowest number of iterations to get the best configuration and the lowest computation time. Optimization results show that there are 9 phases of power losses due to changes in iteration numbers, i.e. 5, 10, 30, 50, 100, 200, 300, 400 and 500, respectively, as illustrated in Fig. 5. Optimal configuration is obtained on the iteration number of 500, i.e. phase change in the ninth, in computing time of 396.96 seconds. In this configuration, positions of tie switches are 8, 19, 27, 34 and 36, respectively. In the next iteration, it has been resulted in the same configuration. This study has been carried out up to 1000 iterations optimization test, and the optimal results are still in the same position of tie switches. This optimal configuration produces a power loss of 27.63 kW, or the other words, power loss reduction is 86.37% compared to the power loss of 202.68 kW in the original configuration. The optimal configuration of the 33 bus IEEE distribution network model is shown in Fig. 6. It is shown that the configuration of the distribution network optimization results using extended PSO algorithm remains in the radial topology.

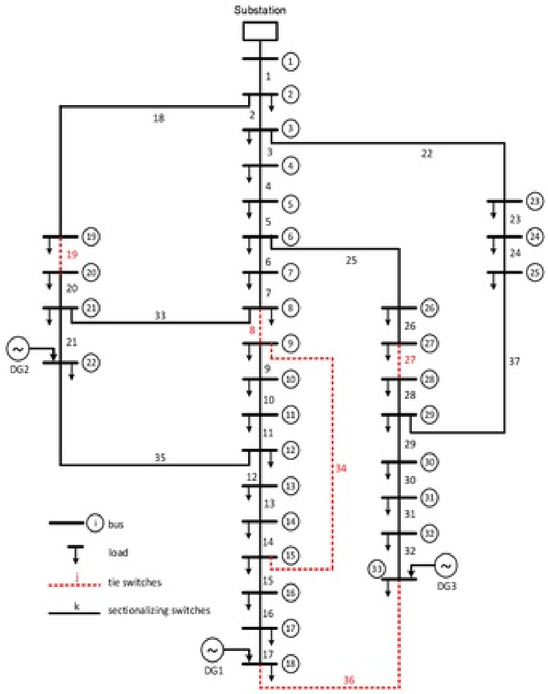

Fig. 6. The optimal configuration of 33-bus IEEE radial distribution network with integration of three DGs.

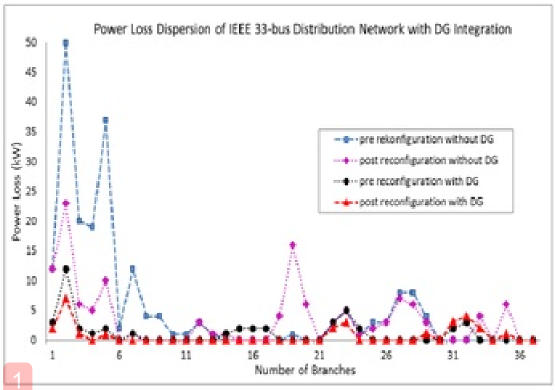

Fig. 7. Power loss dispersion of 33-bus distribution test system.

Fig. 7 shows a graph of the power loss dispersion of 33-bus IEEE distribution test system in conditions of pre-reconfiguration without DG, post-reconfiguration without DG, pre-reconfiguration with DG, and post-reconfiguration with DG. It can be seen in the Figure that the magnitude of the active power losses on each branches is reduced by reconfiguration. For example, the branch 2, on the condition of pre-reconfiguration without DG has 50 kW active power losses, but after reconfiguration decreased to 24 kW. The decrease is due to be reconfigured after the current flowing in the conductor 2 is smaller than the pre-reconfiguration of the network. Overall reduction in power loss of the distribution network without the integration of DG post-reconfiguration is 36.21%, which is decreased from 202.68 kW at pre-reconfiguration condition becomes 129.29 kW at post-reconfiguration condition, as shown in Table 2. The optimal configuration is obtained by making the status of tie switches 33, 35, and 36 to be closed, while the sectionalizing switches 6, 10, and 32 are open.

Integration of DG on the buses 18, 22, and 33 with the capacity of 1.92 MW, 1.75 MW and 1.68 MW, respectively, has a significant effect in the reduction of active power loss of 33 bus distribution network, as shown in Fig. 7 and Table 2. For example, the branch 2 in conditions of pre and post-reconfiguration of network without DG have active power losses are 50 kW and 24 kW, respectively, but after integration of DG, it has been plummeted to 12.5 kW. The decrease is due to the integration of DG on the buses 18, 22, and 33 accounted for active and reactive power in large enough so that the effect in increasing the overall magnitude of the bus voltage, thus the current flowing in the conductor of distribution network to be reduced. Total power loss of distribution network decreased from 202.68 kW to 43.53 kW. Furthermore, the optimal network configuration further reduces power loss becomes 27.63 kW. The optimal configuration is obtained by making the status of tie switches 33, 35, and 37 be closed, while the status of the sectionalizing switches 8, 19, and 27 to be open.

Comparison of the distribution network voltage profile of 33-bus IEEE model in conditions of pre-reconfiguration without DG, post-reconfiguration without DG, pre-reconfiguration with DG, and post-reconfiguration with DG, is shown in Fig. 8. In the examination of network configuration optimization without DG has resulted voltage profile improvement in almost all buses, except on buses 1, 20, 21, and 22. In the first bus, voltage magnitudes remain in an ideal value, 1 p.u., corresponding to a maximum of restraint in this optimization. On the buses 20, 21, and 22, there was a slight decrease in the magnitude of the voltage as a consequence of changes in the status of the current reconfiguration switches. As shown in the results of reconfiguration in Fig. 8, it can be seen that the buses 20, 21, and 22 are connected to more buses, so resulting in a slight voltage drop. In overall, the voltage profile of post-reconfiguration is better than pre reconfiguration. The lowest voltage magnitude of pre-reconfiguration is 0.911 p.u. on bus 18, while the lowest voltage magnitude of post-reconfiguration is 0.946 p.u. on the same bus, as shown in Figure 8 and Table 2.

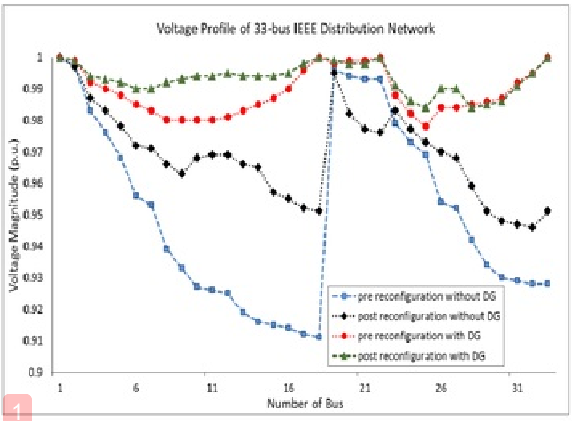

Fig. 8. Voltage profile of 33-bus radial distribution test system.

Integration of three DGs in 33-bus IEEE distribution network model has a significant effect on bus voltage profile improvement compared to the network without DG integration in the same configuration. As seen in Fig. 8, the entire bus voltage magnitude increase except bus 1 which has reached 1 p.u. Overall significantly improved voltage profile can be seen from the increasing in magnitude of the lowest voltage. In condition without DG integration, the lowest voltage is 0.911 p.u. on bus 18, while in condition with DG integration is 0.978 p.u. in bus 25 for the same network configuration, as shown in Fig. 8 and Table 2. This increase occurred due to the integration of DG on the buses 18, 22, and 33 accounted for active and reactive power is large enough so that the effect increasing the overall magnitude of the bus voltage. In particular, it can be observed on the bus 18. The voltage magnitude on the bus is the lowest voltage in 33 bus IEEE distribution network on the initial conditions, i.e. 0.911 p.u. Integration of DG1 with a capacity of 1.92 MW on bus 18 is able to increase the magnitude of the voltage to 1 p.u. Likewise with integration of DG3 with a capacity of 1.68 MW on bus 33 is able to raise the voltage magnitude from 0.928 to 1 p.u.

Table 2. The Simulation Results of 33-Bus Radial Distribution Network

Test Case of Distribution Network	Parameters of Analysis						
	Active Power Loss (kW)	Percentage of Loss Reduction (%)	Efficiency of Distribution Network (%)	Minimum Voltage (p.u.)	Maximum Voltage (p.u.)	Tie Switches to be Closed	Sectionalizing Switches to be Open
Without DG integration pre-reconfiguration	202.68	NA	94.82	0.911 (V_{18})	1.00 (V_1)	NA	NA
Without DG integration post-reconfiguration	129.29	36.21	96.64	0.946 (V_{18})	1.00 (V_1)	33 35 36	6 10 32
With DG integration pre-reconfiguration	43.35	78.61	98.85	0.978 (V_{25})	1.00 (V_1)	NA	NA
With DG integration post-reconfiguration	27.63	86.37	99.26	0.984 (V_{25})	1.00 (V_1)	33 35 37	8 19 27

Furthermore, the distribution network voltage profile being improved further with the optimal configuration. The results showed that the optimal configuration is able to improve the quality of the voltage distribution system that can be seen from the increasing magnitude of the lowest voltage of 0.978 pu on bus 25 to 0.984 pu on the same bus. Increasing the voltage profile also occurs in almost all buses except on buses that voltage magnitude of 1 p.u. has been reached, as shown in Figure 8. Increasing the voltage profile and reducing the power losses make an important contribution to improving the efficiency of the distribution network. As shown in Table 2 that the efficiency of the distribution network without DG increased from 94.82% to 96.64% after optimal reconfiguration. Integration of three DGs in the original configuration is able to improve the efficiency becomes 98.85%. Optimal reconfiguration in the distribution network with DG integration is managed to maximize the efficiency becomes 99.26%.

III.2 Test System of 71-Bus IEEE Distribution Network

In this part, the configuration optimization of the 71 bus IEEE distribution network using PSO algorithm is described. Configuration optimization is implemented on the 71 bus, 11 kV radial distribution network in two conditions, i.e. without DG integration and with DG integration. The radial distribution system consists of one main and three lateral feeders. This system has 71 buses and 68 sections, as shown in Fig. 9. The distribution network has 70 sectionalizing switches and 11 tie switches. Sectionalizing switches are switches that are in closed position under normal conditions, while the tie switches are switches that are in open position under normal conditions. Data load and 71-bus IEEE radial distribution network can be seen in [1],[28]. The total load of the system is 4468 kW and the base of the system is V=11 kV and S=10 MVA. The PSO parameters that have been used to 70-bus distribution system are consists of population size of 30 and maximum iteration of 1000. The minimum and maximum voltages are set at 0.90 and 1.00 p.u., respectively. In original configuration, the distribution system of the 70-bus IEEE model has been set at five tie switches, i.e. switches of 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, and 79, respectively, as can be seen in Fig. 9.

Table 3. DG Location and Capacity of 71-Bus Test System

Name	Bus Number	Active Power (MW)	Power Factor	Reactive Power (MVAr)
DG1	16	0.300	0.9	0.145
DG2	29	0.200	1	0
DG3	35	0.100	1	0
DG4	63	0.400	0.9	0.194
Total		1.000	-	0.339

In order to analyze the impact of DG integration to distribution network, we have installed as many as four DGs on buses of 16, 29, 35 and 63, with the capacity of 0.3 MW, 0.2 MW, 0.1 MW and 0.4 MW, respectively, as shown in Table 3. Location and capacity of the three DGs are the most optimal as stated in [1],[34]. The DG models that have used in our study consist of both solar photovoltaics and wind farms. We have assumed that power factor of all DG solar photovoltaics are unity, while wind farms are 0.9 lagging. Integration of the four DGs on 71-bus IEEE radial distribution network is shown in Fig. 9. Then, the optimization of configuration of the network model with DG integration using PSO algorithm is performed. The results of the optimization are shown in Fig. 10, Fig. 11, Fig. 12, Fig. 13, and Table 4.

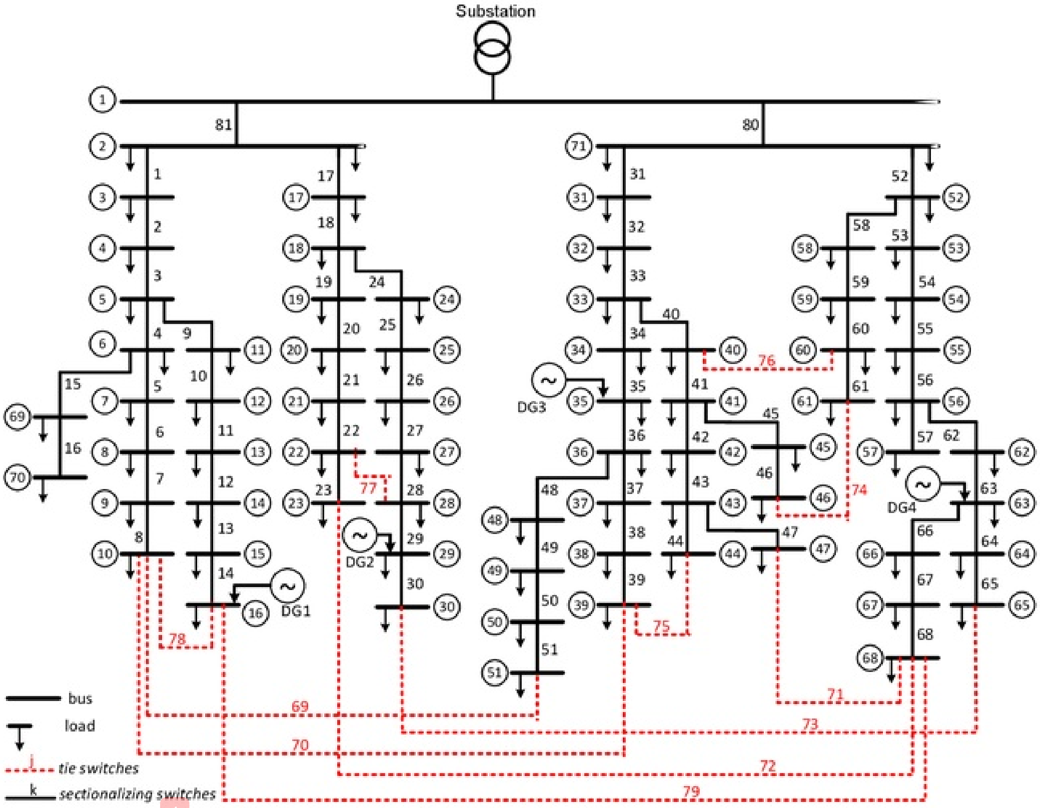

Fig. 9. Original configuration of 71-bus IEEE distribution network with DG [1],[28].

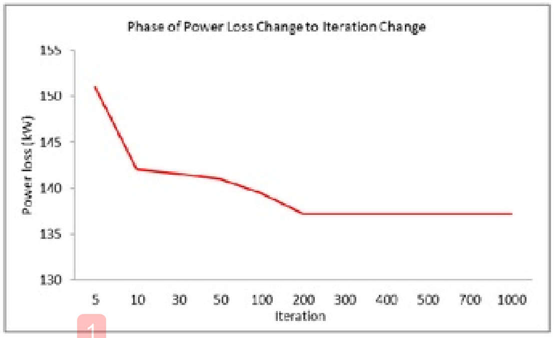

Fig. 10. Phase of power loss to iteration during optimization of 71-bus IEEE radial distribution network with integration of four DGs.

Fig. 10 shows phase of power loss change to iteration change during optimization of 71-bus IEEE radial distribution network with integration of four DGs. Variations in the number of iterations is applied to see the performance of PSO algorithm in optimization of distribution network configuration. Using the variation of the number of iterations, it is expected to be obtained information that the lowest number of iterations to get the best configuration and the lowest computation time. Optimization results show that there are 6 phases of power losses due to changes in iteration numbers, i.e. 5, 10, 30, 50, 100 and 200, respectively, as illustrated in Fig. 10. Optimal configuration is obtained on the iteration number of 200, i.e. phase change in the sixth, in computing time of 232.87 seconds. In this configuration, positions of tie switches are 5, 20, 42, 49, 60, 68, 70, 71, 73, 76 and 79, respectively. In the next iteration, it has been resulted in the same configuration. This study has been carried out up to 1000 iterations optimization test, and the optimal results are still in the same position of the tie switches. This optimal configuration produces a power loss of 137.23 kW, or the other words, power loss reduction is 39.68% compared to the power loss of 227.51 kW in original configuration. The optimal configuration of the 71 bus IEEE distribution network model is shown in Fig. 11. It is shown that the configuration of the distribution network optimization results using extended PSO algorithm remains in the radial topology.

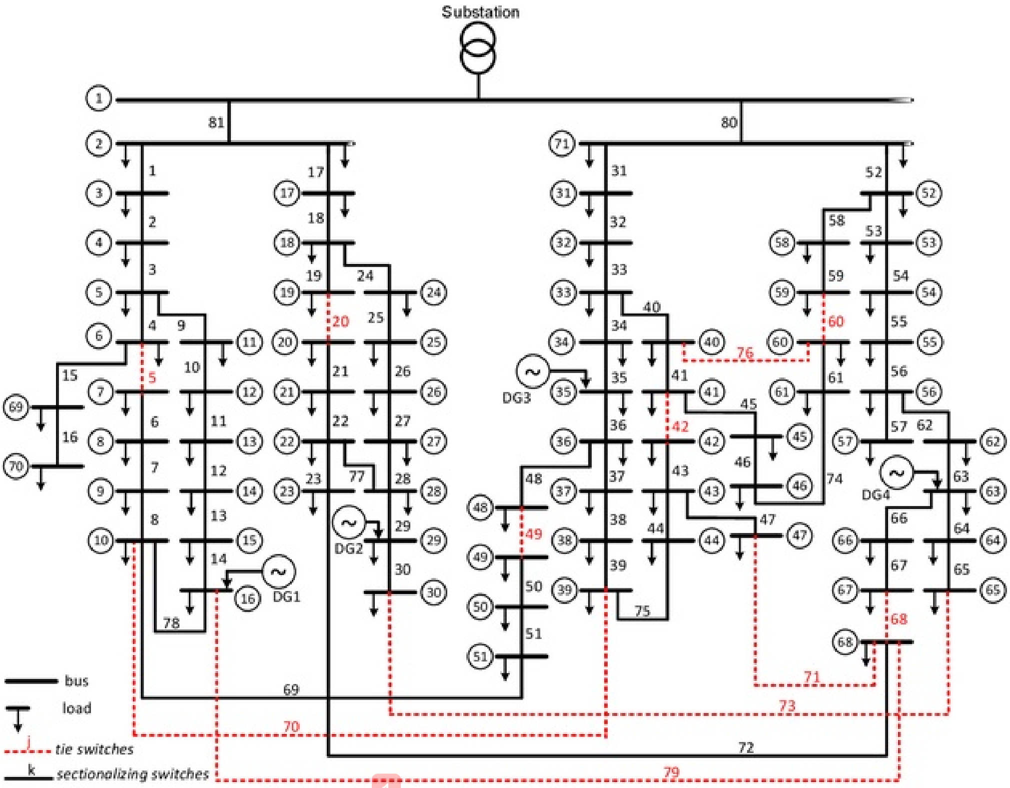

Fig. 11. The optimal configuration of 71-bus IEEE radial distribution network with integration of four DGs.

Table 4. The Simulation Results of 71-Bus Radial Distribution Network

Test Case of Distribution Network	Parameters of Analysis						
	Active Power Loss (kW)	Percentage of Loss Reduction (%)	Efficiency of Distribution Network (%)	Minimum Voltage (p.u.)	Maximum Voltage (p.u.)	Tie Switches to be Closed	Sectionalizing Switches to be Open
Without DG integration pre-reconfiguration	227.51	NA	95.15	0.900 (V_{68})	1.00 (V_1)	NA	NA
Without DG integration post-reconfiguration	204.69	10.03	95.62	0.916 (V_{68})	1.00 (V_1)	69 72 74 75 77 78	8 22 42 48 60 68
With DG integration pre-reconfiguration	156.21	31.34	96.62	0.933 (V_{47})	1.00 (V_1)	NA	NA
With DG integration post-reconfiguration	137.23	39.68	97.02	0.947 (V_{49})	1.00 (V_1)	69 72 74 75 77 78	5 20 42 49 60 68

Fig. 11 shows a graph of the power loss dispersion of 71-bus IEEE distribution test system in conditions of pre-reconfiguration without DG, post-reconfiguration without DG, pre-reconfiguration with DG, and post-reconfiguration with DG. It can be seen in the Figure that the magnitude of the active power losses on each

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branches is reduced by reconfiguration. For example, the branch 7, on the condition of pre-reconfiguration without DG has 12 kW active power losses, but after reconfiguration decreased to 10 kW. The decrease is due to be reconfigured after the current flowing in the conductor 7 is smaller than the pre-reconfiguration of the network. Overall reduction in power loss of the distribution network without the integration of DG post-reconfiguration is 10.03%, which is decreased from 227.51 kW at pre-reconfiguration condition becomes 204.69 kW at post-reconfiguration condition, as shown in Table 4. The optimal configuration is obtained by making the status of tie switches 69, 72, 74, 75, 77 and 78 to be closed, while the sectionalizing switches 5, 20, 42, 49, 60 and 68 are open.

Integration of DG on the buses 16, 29, 35 and 63 with the capacity of 0.3 MW, 0.2 MW, 0.1 MW and 0.4 MW, respectively, has a significant effect in the reduction of active power loss of 71 bus distribution network, as shown in Fig. 12 and Table 4.

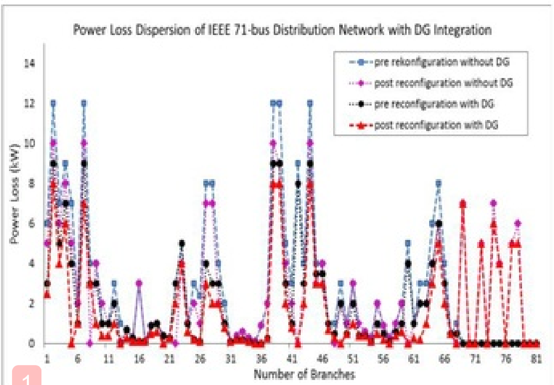

Fig. 12. Power loss dispersion of 71-bus distribution system.

For example, the branch 7 in conditions of pre and post-reconfiguration of network without DG have active power losses are 12 kW and 10 kW, respectively, but after integration of DG, it has been decreased to 9 kW. The decrease is due to the integration of DG on the buses 16, 29, 35 and 63 accounted for active and reactive power in large enough so that the effect in increasing the overall magnitude of the bus voltage, thus the current flowing in the conductor of distribution network to be reduced. Total power loss of distribution network decreased from 227.51 kW to 156.21 kW. Furthermore, the optimal network configuration further reduces power loss becomes 137.23 kW. The optimal configuration is obtained by making the status of tie switches 69, 72, 74, 75, 77 and 78 to be closed, while the sectionalizing switches 8, 22, 42, 48, 60 and 68 to be open.

Comparison of the distribution network voltage profile of 71-bus IEEE model in conditions of pre-reconfiguration without DG, post-reconfiguration without DG, pre-reconfiguration with DG, and post-reconfiguration with DG, is shown in Fig. 13. In the examination of network configuration optimization without DG has resulted voltage profile improvement in almost all buses, except on buses 1, 2, 17, 52 and 71. In these buses, voltage magnitudes remain in an ideal value, 1 p.u., corresponding to a maximum of restraint in this optimization. On the buses 47 and 48, there were a slight decrease in the magnitude of the voltage as a consequence of changes in the status of the current reconfiguration switches. As shown in the results of reconfiguration in Fig. 11, it can be seen that the buses 47 and 48 are connected to more buses, so resulting in a slight voltage drop.

In overall, the voltage profile of post-reconfiguration is better than pre reconfiguration. The lowest voltage magnitude of pre-reconfiguration of network without DG is 0.900 p.u. on bus 68, while the lowest voltage magnitude of post-reconfiguration is 0.916 p.u. on the same bus, as shown in Figure 13 and Table 4.

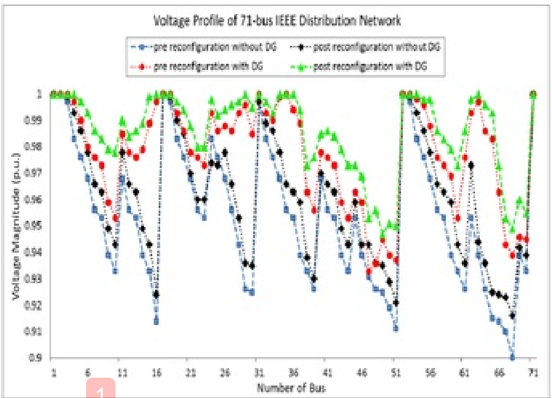

Fig. 13. Voltage profile of 71-bus radial distribution system.

Integration of four DGs in 71-bus IEEE distribution network model has a significant effect on bus voltage profile improvement compared to the network without DG integration in the same configuration. As seen in Fig. 13, the entire bus voltage magnitude increase except buses 1, 2, 17, 52 and 71, which has reached 1 p.u. In overall, significantly improved voltage profile can be seen from the increasing in magnitude of the lowest voltage. In condition without DG integration, the lowest voltage is 0.900 p.u. on bus 68, while in condition with DG integration is 0.933 p.u. in bus 47 for the same network configuration, as shown in Fig. 13 and Table 4. This increase occurred due to the integration of DG on the buses 16, 29, 35 and 63 accounted for active and reactive power is large enough so that the effect increasing the overall magnitude of the bus voltage. In particular, it can be observed on the bus 68. The voltage magnitude on the bus is the lowest voltage in 71 bus IEEE distribution network on the initial conditions, i.e. 0.900 p.u. Integration of DG4 with a capacity of 0.4 MW on bus 63 is able to increase the magnitude of the voltage to 0.939 p.u. Likewise with integration of DG3 with a capacity of 0.1 MW on bus 35 is able to raise the voltage magnitude from 0.956 to 1 p.u.

Furthermore, the distribution network voltage profile being improved further with the optimal configuration. The results showed that the optimal configuration is able to improve the quality of the voltage distribution system that can be seen from the increasing magnitude of the lowest voltage of 0.933 pu on bus 47 to 0.953 pu on the same bus. Increasing the voltage profile also occurs in almost all buses except on buses that voltage magnitude of 1 p.u. has been reached, as shown in Figure 13.

Increasing the voltage profile and reducing the power losses make an important contribution to improving the efficiency of the distribution network. As shown in Table 4 that the efficiency of the distribution network without DG increased from 95.15% to 95.62% after optimal reconfiguration. Integration of four DGs in the original configuration is able to improve the efficiency becomes 96.62%. Optimal reconfiguration in the distribution network with DG integration is managed to maximize the efficiency becomes 97.02%.

V. Conclusion

The research proposed a methodology for optimal reconfiguration of radial distribution network with integration of DG using extended PSO algorithm. The algorithm is able to find the optimal reconfiguration to improve the performance of the distribution network under test. In this work, the extended PSO algorithm was tested on a 33-bus IEEE distribution network and a 71-bus IEEE distribution network. Based on the numerical results, it was shown that the algorithm is effective in enhancing efficiency of the two test distribution systems. Efficiencies of the 33-bus IEEE network in the pre reconfiguration without DG, post reconfiguration without DG, pre reconfiguration with DG, and post reconfiguration with DG are 94.82%, 96.66%, 98.85% and 99.26%, respectively. For a 71-bus IEEE network, in the pre reconfiguration without DG, post reconfiguration without DG, pre reconfiguration with DG, and post reconfiguration with DG are 95.15%, 95.62%, 96.62% and 97.02%, respectively. For voltage profile of the network, integration of DG in the two test networks has resulted in improved voltage quality. The quality is to be improved further by reconfiguring the networks.

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References

[1] Ramadoni Syahputra, I. Robandi, and M. Ashari, Reconfiguration of Distribution Network with DG Using Fuzzy Multi-objective Method, *Int. Conference on Innovation, Management and Technology Research (ICIMTR)*, May 21-22, 2012, Melacca, Malaysia.

[2] Ramadoni Syahputra, I. Robandi, and M. Ashari, Distribution Network Efficiency Improvement Based on Fuzzy Multi-objective Method. *IPTEK Journal of Proceedings Series*. 2014; 1(1): 224-229.

[3] Ramadoni Syahputra, Distributed Generation: State of the Arts dalam Penyediaan Energi Listrik. *LP3M UMY*, Yogyakarta, 2012.

[4] A. Merlin and H. Back, "Search for a minimal-loss operating spanning tree configuration in an urban power distribution system", *Proc. 5th PSCC Conference*, 1975, pp.1–18, Cambridge, U.K.

[5] H.A. Nugroho, N. Faisal, Indah Soesanti, L. Choridah, Identification of malignant masses on digital mammogram images based on texture feature and correlation based feature selection, *International Conference on Information Technology and Electrical Engineering (ICITEE)*, Yogyakarta, 2014.

[6] R.N. Rohmah, A. Susanto, Indah Soesanti, M. Tjokronagoro, Computer Aided Diagnosis for lung tuberculosis identification based on thoracic X-ray, *International Conference on Information Technology and Electrical Engineering (ICITEE)*, Yogyakarta, 2013.

[7] H. Afrisal, M. Faris, P. Utomo, Indah Soesanti, F. Andri, Portable smart sorting and grading machine for fruits using computer vision, *International Conference on Computer, Control, Informatics and Its Applications, IC3INA* 2013.

[8] K. Nara, A. Shiose, M. Kitagawa, and T. Ishihara, Implementation Of Genetic Algorithm for Distribution System Loss Minimum Reconfiguration, *IEEE Trans on PWRD, 7(3)* 1992, pp.1044–1051.

[9] A. Augugliaro, L. Dusonchet, M. Ippolito, and E. R. Sanseverino, Minimum Losses Reconfiguration of MV Distribution Networks Through Local Control of Tie-Switches, *IEEE Transactions on Power Delivery, vol. 18, no. 3*, 2003, pp. 762–771.

[10] Y. J. Jeon, J. C. Kim, J. O. Kim, J. R. Shin, and K. Y. Lee, An Efficient Simulated Annealing Algorithm for Network Reconfiguration in Large-Scale Distribution Systems, *IEEE Trans. on Power Delivery, vol. 17, no. 4*, 2002, pp. 1070–1078.

[11] J. Mendoza, R. Lopez, D. Morales, E. Lopez, P. Dessante, and R. Moraga, Minimal loss reconfiguration using genetic algorithms with restricted population and addressed operators, *IEEE Trans. on Power Systems*, vol. 21, no. 2, 2006, pp. 948–954.

[12] B. Enacheanu, B. Raison, R. Caire, O. Devaux, W. Bienia, and N. HadjSaid, Radial Network Reconfiguration Using Genetic Algorithm Based on the Matroid Theory, *IEEE Transactions on Power Systems, Vol. 23, No. 1*, 2008, pp. 186-195.

[13] H. Falaghi, M.R. Haghifam, and C. Singh, Ant Colony Optimization-Based Method for Placement of Sectionalizing Switches in Distribution Networks Using a Fuzzy Multiobjective Approach, *IEEE Trans on Power Delivery, Vol. 24, No. 1*, 2009, pp. 268-276.

[14] V. Farahani, B. Vahidi, and H.A. Abyaneh, Reconfiguration and Capacitor Placement Simultaneously for Energy Loss Reduction Based on an Improved Reconfiguration Method, *IEEE Trans. on Power Systems, Vol. 27, No. 22, 2012, pp. 587-595.*

[15] R.S. Rao, S.V.L. Narasimham, M.R. Raju, and A.S. Rao, Optimal Network Reconfiguration of Large-Scale Distribution System Using Harmony Search Algorithm, *IEEE Trans on PS, 26(3)*, 2011.

[16] Ramadoni Syahputra, "Fuzzy Multi-Objective Approach for the Improvement of Distribution Network Efficiency by Considering DG", *IJCSIT, Vol. 4, No. 2, pp. 57-68*, April 2012.

[17] Ramadoni Syahputra, I. Robandi, and M. Ashari, Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-objective Method, *International Review of Electrical Engineering (IREE), vol.9, no.3, 2014.*

[18] Ramadoni Syahputra, I. Robandi, and M. Ashari, "Optimal Distribution Network Reconfiguration with Penetration of Distributed Energy Resources", *in Proceeding of ICITACEE 2014*, Semarang, Indonesia, 2014.

[19] T. Niknam, H.Z. Meymand, and H.D. Mojarrad, A practical multi-objective PSO algorithm for optimal operation management of distribution network with regard to fuel cell power plants, *Renewable Energy (ELSEVIER), Vol. 36*, 2011, pp. 1529-1544.

[20] Ramadoni Syahputra, I. Robandi, and M. Ashari, "Performance Analysis of Wind Turbine as a Distributed Generation Unit in Distribution System", *International Journal of Computer Science & Information Technology (IJCSIT) Vol 6, No 3, pp. 39-56*, June 2014.

[21] Ramadoni Syahputra, I. Robandi, M. Ashari, Modeling and Simulation of Wind Energy Conversion System in Distributed Generation Units, *3rd International Seminar on Applied Technology, Science and Arts (APTECS)*, 2011, pp. 290-296.

[22] Mochamad Ashari, S. Anam, and Surojo, "A Wide Range Fuzzy Based Maximum Power Point Tracker for Improving the Efficiency and Sizing of PV Systems", *Jurnal of Electrical Engineering (JEE), Vol. 11, No. 2*, 2011.

[23] Mochamad Ashari and C.V. Nayar, "Optimum Operation Strategy and Economic Analysis of a PV-Battery-mains Hybrid Uninterruptible Power Supply", Journal of Renewable Energy, ELSEVIER, Vol. 22, January 2001.

[24] Mochamad Ashari and C.V. Nayar, "A Grid-interactive Photovoltaic Uninterruptible Power Supply System Using Battery Storage and a Backup Diesel Generator", *IEEE Transactions on Energy Conversion*, Vol. 15, No. 3, 2000.

[25] Imam Robandi, "Desain sistem tenaga modern: optimisasi, logika fuzzy, algoritma genetika", Andi Publisher, Yogyakarta, 2006.

[26] Imam Robandi, "Modern Power System Control", Andi Publisher, Yogyakarta, 2009.

[27] R.J. Millar, E. Saarijärvi, M. Lehtonen, M. Hyvärinen, J. Niskanen, P. Hämäläinen, Electricity Distribution Network Planning Algorithm Based on Efficient Initial and Radial-to-Full Network Conversion, *International Review of Electrical Engineering (IREE), vol. 8, no. 3, 2013*, pp. 1076-1090.

[28] G. Brusco, A. Burgio, D. Menniti, A. Pinnarelli, N. Sorrentino, Optimal Sizing of DGs for a CHP-Based Agro-Industrial Microgrid with a Priority Criteria Operational Strategy, *International Review of Electrical Engineering (IREE), vol. 9, no. 2, 2014*. pp. 351-362.

[29] N.C. Hien, N. Mithulananthan, and R. C. Bansal, "Location and Sizing of Distributed Generation Units for Loadabilty Enhancement in Primary Feeder", *IEEE System journal, Vol. 7, No. 4, Dec. 2013*, pp. 797-806.

[30] J. Kennedy and R. C. Eberhart, "Particle swarm optimization," in *Proc IEEE Int Conf Neural Networks*, Dec 1995, vol. 4, pp. 1942–48.

[31] A.Y. Abdelaziz, S.F. Mekhamer, F.M. Mohammed, M.A.L. Badr, "A Modified Particle Swarm Technique for Distribution Systems Reconfiguration", *the Online Journal on Electronics and Electrical Engineering (OJEEE)*. Vol. 1, No. 2, 2009.

[32] N. Rugthaicharoencheep, S. Nedphograw, ; W. Wanaratwijit, "Distribution system operation for power loss minimization and improved voltage profile with distributed generation and capacitor placements", *Intl Conf Electric Utility DRPT, July 2011*, Shandong.

[33] V. Calderaro, A. Piccolo, dan P. Siano, "Maximizing DG penetration in distribution networks by means of GA based reconfiguration", *International Conference on Future Power Systems*, Amsterdam, 18 Nov. 2005.

[34] D. Das, A Fuzzy Multi-Objective Approach for Network Reconfiguration of Distribution Systems, *IEEE Transactions on Power Delivery, vol. 21, no. 1*, 2006, pp. 202–209.

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