Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-Objective Method

by Ramadoni Syahputra

International Review of Electrical Engineering (I.R.E.E.), Vol. 9, N. 3
ISSN 1827-6660 May – June 2014

Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-objective Method

Ramadoni Syahputra[1], Imam Robandi[2], Mochamad Ashari[2]

Abstract – *This paper proposes a reconfiguration methodology that aims for achieving the minimum active power loss of radial distribution networks with integration of distributed energy resources (DER) in order to improve the distribution system performance. The problems of power system operations and planning schemes will be arising due to the presence of DER to the distribution systems, such losses will rise and the increase of the voltage at which there are many DER. One of the popular efforts to improve the performance of the distribution system is network reconfiguration. In this study, reconfiguration method proposed is based on an extended fuzzy multi-objective approach. Multi-objective function are considered for minimization of the active power loss, deviation of bus voltage, and load balancing among the feeders, while subject to a radial network structure in which all loads must be energized. In this case, all objectives may be simultaneously weighted. The implementation of the extended fuzzy multi-objective for reconfiguration of distribution network with integration of DER on IEEE 77-bus distribution network and Yogyakarta 60-bus distribution network are described. The simulation results show that a 1.80% of efficiency improvement is achieved for IEEE 77-bus network, and a 0.11% of Yogyakarta 60-bus network efficiency improvement is achieved by the method.*

Keywords: *Fuzzy Logic, Multi-objective, Distribution Networks, Efficiency, Distributed Energy Resources.*

Nomenclature

P_{loss}	Acive 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.
V_i	Voltage magnitude at bus i.
N_k	Total number of branches in the loop including sectionalyzing-branch and tie-branch when i-th tie-switch is closed.
$P_{loss,i}$	Total active power loss of the system when i-th branch in the loop is opened.
$P_{loss,B}$	Total active power loss before reconfiguration.
α_i	Minimization factor of power loss.
$\mu(\alpha_i)$	Membership value for power loss.
β_i	Maximization factor of bus voltage deviation.
$\mu(\beta_i)$	Membership value for bus voltage deviation.
N_B	Total number of bus of the system.
V_s	Voltage of the substation, in p.u.
$V_{i,j}$	Voltage of node corresponding to the opening of the i-th branch in the loop, in p.u.
$\|I_{i,m}\|$	Electric current magnitude of branch-m when the i-th branch in the loop is opened.
$I_{c,m}$	Line capacity of branch-m.
χ_i	Maximization factor of branch current loading index.
$\mu(\chi_i)$	Membership value for current loading index.
LBI	Load balancing index, represents the degree of loading among feeders.
$IF_{i,j}$	Electric current of feeder corresponding to the opening of the i-th branch in the loop.
$IFF_{i,max}$	Maximum of all the currents corresponding to the opening of the i-th branch in the loop = $\max(IF_{i,j})$, for $j = 1, 2, 3, \ldots, N_F$.
δ_i	Maximization factor of load balancing index.
$\mu(\delta_i)$	Membership value for load balancing index.
$D_{k,i}$	Fuzzy decision for overal satisfaction.
OS_k	Fuzzy decision for optimal solution.

I. Introduction

Most of power distribution systems operate in radial structure. The distribution systems have sectionalizing switches that remain normally closed and tie switches that remain normally open in order to configure distribution

DOI: http://dx.doi.org/10.15866/iree.v9i3.956
Manuscript received February 2014, revised May 2014, accepted June 2014

networks. Reconfiguration of the network is built through switching operation of the switches. In modern electrical power distribution systems, the multi-objective network reconfiguration problem has assumed significant importance. The multi-objectives are considered for minimizing the active power loss, load balancing among the feeders, and improving voltage profile, while subject to a radial network structure in which all loads must be energized. Moreover, the great demands of renewable energy resources with respect to energy reserve and environmental issues make the new small generator technologies such as solar photovoltaics, wind farms, micro hydro, and other resources more and more popular. The technologies that have capacity of less than 10 MW commonly powered by renewable energy sources that are connected to transmission or distribution systems is called distributed energy resources (DER) [1]. It is also known as Distributed Generation or Distributed Resources. The number and size of DER connected to distribution systems is rapidly increasing. The advantages of integration of DER in power distribution network are typically for grid reinforcement, reducing power losses and on-peak operating costs, improving voltage profiles and load factors and thus deferring or eliminating system upgrades, which is the dominant effect distribution system in rural networks [2-7]. Increasing in levels of DER will need to change planning and design of distribution networks to harness approaches that use information and communication technology to actively manage the network [8-9].

Many researches in literature have been studied for minimization of active power loss via reconfiguration of distribution networks. These study efforts can be broadly classified into two categories: conventional approaches [3, 10-15] and artificial intelligent (AI) based approaches [4-7, 16-25]. The conventional approaches include classical and heuristic optimization algorithms. The first effort of distribution network reconfiguration with aim for loss reduction was proposed by Merlin and Back [10]. They have used a conventional technique which considering a branch and bound to determine the minimum loss configuration. After that, many conventional method that aim to reduce the active power loss of distribution network. Chen and Cho [11] have proposed the energy loss reduction using critical switches operation, while Borozan *et al.* [12-13] have considered the application aspects of optimal distribution network reconfiguration. An optimization method to determine the network configuration with minimum energy losses for a given period has proposed by Taleski and Rajicic [14]. Lin and Chin [15] have proposed a network reconfiguration technique using voltage, ohmic, and decision indexes to determine the switching operation. For most of conventional approaches, these techniques do not necessarily guarantee global optimization.

The effort of distribution network reconfiguration based on AI has proposed by Zhou et al. [16]. They have used two algorithms for optimization of distribution network configuration in order to service restoration and load balancing. In their study, combination of heuristic rules and fuzzy logics in optimization purposes for efficiency and robust performance is used. The use of genetic algorithm (GA) for distribution network reconfiguration technique in order to minimize the active power loss has proposed by Nara *et al.* [17], while Enacheanu *et al.* [18] has proposed the GA based on the matroid theory and graph theory. Mendoza *et al.* [19] have proposed a new methodology using GA with the help of fundamental loops for reconfiguration of distribution networks. Jeon *et al.* [20] and Augugliaro *et al.* [21] have proposed simulated annealing algorithms in large scale distribution system for active power loss reduction purpose.

Rao *et al.* [22] have proposed the use of harmony search algorithm (HSA) for optimal large-scale distribution network reconfiguration. The algorithm is a method which is conceptualized using the musical process of harmony searching in perfect state. Farahani *et al.* [23] have proposed network reconfiguration network based on a simple branch exchange method of single loop. In the method, loops selection sequence affects the optimal configuration and the network loss. Also, discrete GA is used to optimize the location and size of capacitors. The algorithm is tested on an IEEE 77-bus distribution system, as used in our study. The applications of fuzzy multi-objective method for optimal distribution network configuration have presented by Das [24], Filipiak and Stepien [25], Niknam *et al.* [26], and Syahputra *et al.* [27]. In the method, there are several objectives include active power loss, load balancing among the feeders, deviation of bus voltage, and branch current constraint violation for simultaneously modeled and proceed. Criteria for selecting a membership function for each objective are not provided in their works. Also, weights of each objective are not considered.

In our study, the formulations of the distribution network reconfiguration problem as a multi-objectives problem subject to electric and operational constraints are performed. The objectives considered are: minimization of the active power loss, minimization of the deviation of nodes voltage, minimization of the branch current constraint violation, and load balancing among various feeders.

The above objectives are transformed into fuzzy sets using different type of fuzzy membership functions. Radially of the distribution network must remain after reconfiguration in which all loads must be simultaneously energized. The main advantage of this study is to propose a novel network reconfiguration method based on the fuzzy multi-objective algorithm with DER in which all objectives may be simultaneously weighted. The weights of all objectives are dependent on the priority of optimization. Weighting of objective functions is an important issue in a multi-objective optimization [28-29]. The objective of minimization of active power loss is the main important in our work.

Therefore, the proposed method can provide another useful algorithm for the optimization of distribution network configuration with DER integration.

II. Power Distribution Network with Integration of DER

In this study, two types of DER are modeled to connect to distribution network, solar photovoltaics and wind farms, respectively. The operation of the DER is considered to be at steady state. Therefore, the DER from solar photovoltaics is modeled as injected only active power, while DER from wind farms is modeled as injected both active and reactive power, P_i and Q_i, respectively.

In the first study, the 20-kV radial distribution system has examined. The system has one substation, two feeders, and 77-bus as shown in Fig.1. The switches of the distribution system consist of 114 sectionalizing switches and 10 tie switches. Tie switches of this system are open in normal conditions. Fig.1 shows the initial configuration of distribution network without DER integration. Load and branch data of the IEEE 77-bus distribution network can be found in [23].

In order to analyze the impact of DER integration to distribution network, we have installed as many as 14 DERs on buses 5, 7, 14, 22, 28, 34, 36, 41, 46, 54, 59, 68, 70 and 74, respectively, as shown in TABLE I. The DER models that have used in our study consist of both solar photovoltaics and wind farms. DER solar photovoltaics with unity power factor and wind farms with power factor from 0.8 to 0.9 (lagging) are assumed.

In the second study, the proposed extended fuzzy multi-objective method is implemented in real power distribution system. In this case, a 20-kV electric power distribution system of the Provincial Electricity Authority of Yogyakarta, Indonesia, is selected to illustrate the performance of the method.

TABLE I
DER LOCATION AND CAPACITY ON IEEE 77-BUS DISTRIBUTION SYSTEM

Bus Number	DER Capacity (kW)	Power Factor
5	150	0.8
7	100	0.9
14	100	0.9
22	100	1
28	150	0.9
34	50	0.8
36	100	0.9
41	150	0.8
46	100	0.9
54	200	0.9
59	100	1
68	200	0.9
70	50	0.8
74	100	0.9

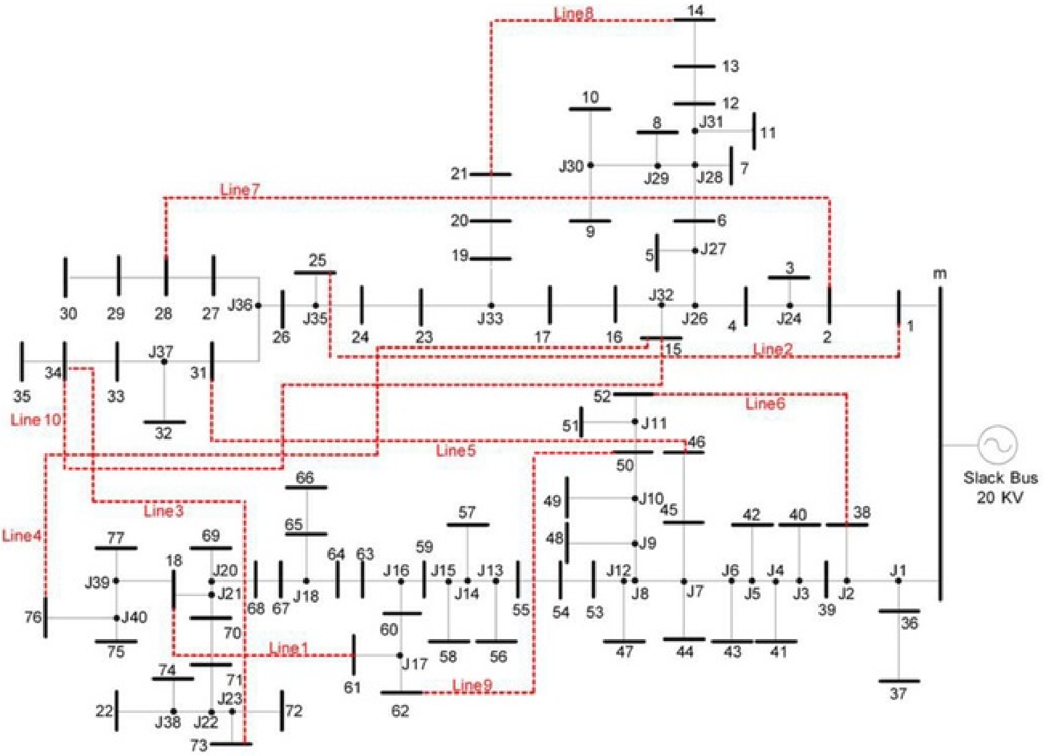

Fig.1. IEEE 77-bus distribution network [23]

Yogyakarta is one of the provinces in Indonesia which is located in Java islands. Fig. 2 describes the practical one-line diagram of the system. The system has 13 feeders that are powered by two 60 MVA power transformers, but the study has focused on feeder 6, 7, and 11, respectively. The selection of the three feeders is because the most complex of all existing feeders. All three feeders have 60 bus and 56 load points. Load and branch data of the network can be seen in Appendix. The total capacity of all feeders of the test system is 26547 kW.

In order to analyze the impact of DER integration to distribution network, we have installed as many as 14 DERs on buses 5, 8, 12, 15, 16, 28, 33, 36, 37, 43, 46, 52, 55 and 59, respectively, as shown in TABLE II.

TABLE II
DER LOCATION AND CAPACITY ON YOGYAKARTA 60-BUS DISTRIBUTION SYSTEM

Bus Number	DER Capacity (kW)	Power Factor
5	150	0.8
8	100	1
12	100	0.9
15	100	0.8
16	150	1
28	100	1
33	100	1
36	150	0.8
37	100	0.9
43	200	0.9
46	100	0.8
52	200	0.8
55	100	1
59	100	1

The DER models that have used in our study consist of both solar photovoltaics and wind farms. DER solar photovoltaics with unity power factor and wind farms with power factor from 0.8 to 0.9 (lagging) are assumed.

III. Extended Fuzzy Multi-objective Method

III.1. Problem Formulation

Network reconfiguration is a very important function of automated distribution systems to reduce power losses, to improve bus voltage profile, to balance load, and to improve system security. Loads can be transferred from feeder to feeder by changing the states of sectionalizing switches and tie switches. In this paper, network reconfiguration for active power loss minimization can be formulated as follows:

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

where P_{loss} is active power loss; P_i and Q_i are the active and reactive powers flowing out of bus, respectively; n_b is the number of branch, and R_i and V_i are the resistance and voltage magnitude at bus i, respectively. The optimization also took into consideration the subject to the following: voltage magnitude constraint, current magnitude constraint, power source limit constraint, and radial network constraint.

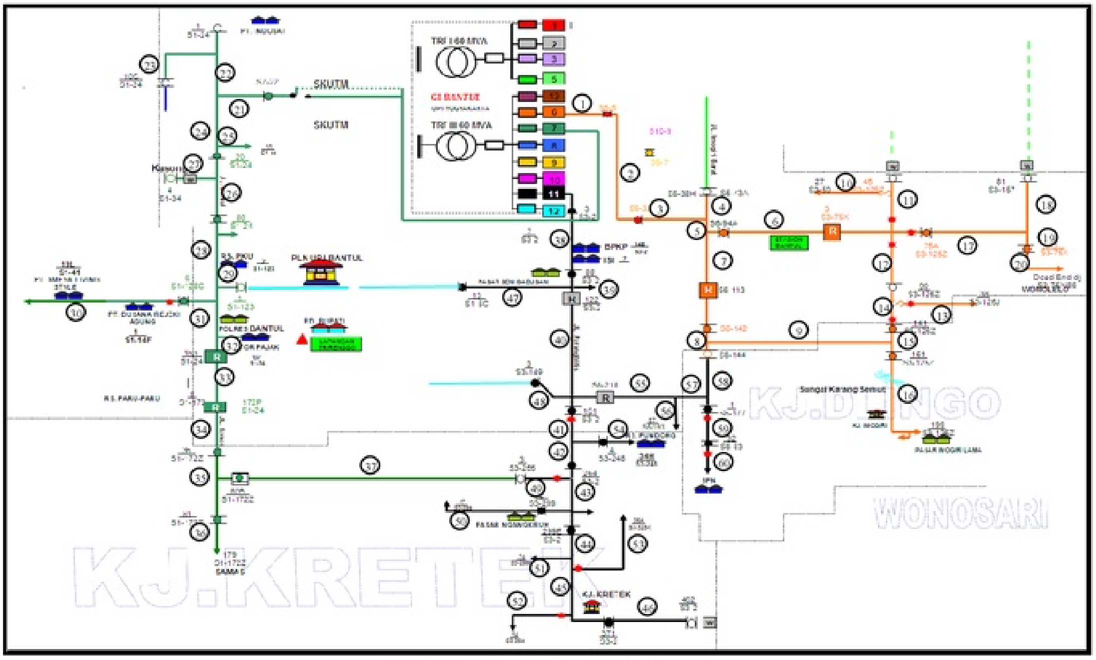

Fig. 2. Yogyakarta 60-bus distribution system

Manuscript received February 2014, revised May 2014, accepted June 2014

The proposed algorithm transforms the multi-objectives of the reconfiguration problem into a single objective optimization problem using fuzzy set theory. In the fuzzy domain, each objective is associated with a membership function. The membership function indicates the degree of satisfaction of the objective. The fuzzy membership functions of [24-26] have not considered the weight factor for each objective. The four objectives which are constructed in fuzzy membership function include: active power loss reduction, maximum bus voltage deviation, maximum branch current loading index, and load balancing among the feeders.

III.2. Fuzzy Membership Function for Power Loss

The main purpose of optimization of distribution network configuration is reducing the active power loss. Therefore, the first assignment of constructing the fuzzy membership function is how to reduce the active power loss of the distribution system. The ratio of total active power loss after and before reconfiguration may be defined as

$$\alpha_i = \frac{P_{loss,i}}{P_{loss,B}}, \quad for \ i = 1,2,3,...,N_k \tag{2}$$

where, N_k is the total number of branches in the loop including sectionalyzing-branch and tie-branch when i-th tie-switch is closed; $P_{loss,i}$ is the total active power loss of the system when i-th branch in the loop is opened; and $P_{loss,B}$ is the total active power loss before reconfiguration. It can be indicated that if α_i is high, active power loss reduction is low and, hence, a lower membership value is assigned and if α_i is low, the active power loss reduction is high and a higher membership value is assigned. The fuzzy membership function of the objective is assigned to be trapezoidal fuzzy as shown in Fig. 3. It has been assumed that α_{min} = 0.5, α_{max} = 1.0, and the weight factor for the membership function is 0.3.

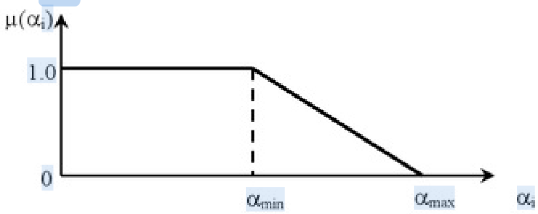

Fig. 3. Membership function for power loss

The membership value of $\mu(\alpha_i)$ can be written as

$$\mu(\alpha_i) = \begin{cases} \dfrac{(\alpha_{max} - \alpha_i)}{(\alpha_{max} - \alpha_{min})}, & for \ \alpha_{min} < \alpha_i < \alpha_{max} \\ 1, & for \ \alpha_i \le \alpha_{min} \\ 0, & for \ \alpha_i \le \alpha_{max} \end{cases} \tag{3}$$

III.3. Fuzzy Membership Function for Bus Voltage

The purpose of constructing this membership function is that the deviation of bus voltage should be less. The maximization factor of bus voltage may be defined as

$$\beta_i = \max |V_{i,j} - V_s|, \quad for \ i = 1,2,3,...,N_k \ \ and \ \ j = 1,2,3,...,N_B. \tag{4}$$

where, N_B is total number of bus of the system; V_s is voltage of the substation, in p.u; and $V_{i,j}$ is voltage of node corresponding to the opening of the i-th branch in the loop, in p.u. The membership function of the objective is also assigned to be trapezoidal fuzzy as shown in Fig. 4. It has been assumed that β_{min} = 0.05, β_{max} = 0.1, and the weight factor for the membership function is 0.225.

In fuzzy environment of the research, if the maximum voltage deviation is less, then a higher membership value is assigned and if deviation is more, then a lower membership value is assigned. Fig. 4 shows the membership function for maximum node voltage deviation. From Fig. 4, the membership value of $\mu(\beta_i)$ can be written as

$$\mu(\beta_i) = \begin{cases} \dfrac{(\beta_{max} - \beta_i)}{(\beta_{max} - \beta_{min})}, & for \ \beta_{min} < \beta_i < \beta_{max} \\ 1, & for \ \beta_i \le \beta_{min} \\ 0, & for \ \beta_i \le \beta_{max} \end{cases} \tag{5}$$

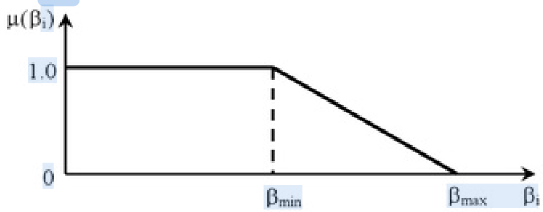

Fig. 4. Membership function for voltage deviation

III.4. Fuzzy Membership Function for Branch Current Loading Index

The basic purpose for constructing this membership function is to minimize the branch current constraint violation. The branch current loading index may be defined as

$$Branch\ current\ loading\ index = \frac{|I_{i,m}|}{I_{c,m}}, \quad for \ i = 1,2,3,...,N_k, \ \ and \ \ m = 1,2,3,...,N_B - 1. \tag{6}$$

where, $|I_{i,m}|$ is electric current magnitude of branch-m when the i-th branch in the loop is opened; $I_{c,m}$ is line capacity of branch-m.

Manuscript received February 2014, revised May 2014, accepted June 2014

The maximization factor of branch current loading index may be defined as

$$\chi_i = \max\left[\frac{I_{i,m}}{I_{c,m}}\right], \quad (7)$$
$$for\ \ i = 1,2,3,...,N_k,\ \ and\ \ m = 1,2,3,...,N_B - 1.$$

The trapezoidal fuzzy membership function of the objective is shown in Fig. 5. When the value of branch current index exceeds unity, a lower membership value is assigned and as long as it is less than or equal to unity, the maximum membership value is assigned. It has been assumed that χ_{min} = 1.0, χ_{max} = 1.15, and the weight factor for the membership function is 0.2. From Fig. 5, the membership value of $\mu(\chi_i)$ can be written as

$$\mu(\chi_i) = \begin{cases} \dfrac{(\chi_{\max} - \chi_i)}{(\chi_{\max} - \chi_{\min})}, & for\ \chi_{\min} < \chi_i < \chi_{\max} \\ 1, & for\ \chi_i \le \chi_{\min} \\ 0, & for\ \chi_i \le \chi_{\max} \end{cases} \quad (8)$$

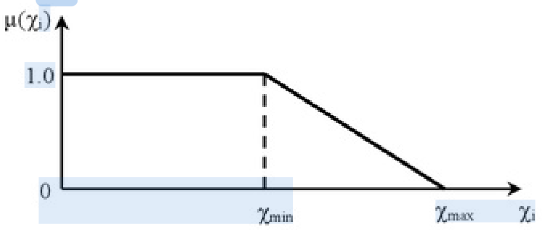

Fig. 5. Membership function for current loading index

III.5. Membership Function for Feeder Load Balancing

Load balancing is one of the main objectives of distribution network reconfiguration. Load balancing index (LBI) represents the degree of loading among feeders. This index measures how much a branch can be loaded without exceeding the rated capacity of the branch. An effort to increase the margin of heavily loaded feeders is to transfer part of their loads to lightly loaded feeders of distribution system.

The load balancing index may be defined as

$$LBI_{i,j} = \frac{(IFF_{i,\max} - IF_{i,j})}{IFF_{i,\max}}, \quad (9)$$
$$for\ \ i = 1,2,3,...,N_k,\ \ and\ \ j = 1,2,3,...,N_F.$$

where, $IF_{i,j}$ is electric current of feeder corresponding to the opening of the i-th branch in the loop; $IFF_{i,max}$ is the maximum of all the currents corresponding to the opening of the i-th branch in the loop = max($IF_{i,j}$), for j = 1, 2, 3, …, N_F.

The maximization factor of load balancing index may be defined as

$$\delta_i = \max(LBI_{i,j}), \quad (10)$$
$$for\ \ i = 1,2,3,...,N_k,\ \ and\ \ j = 1,2,3,...,N_F.$$

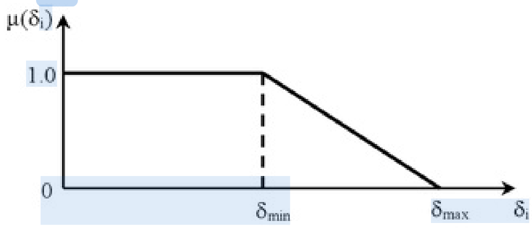

Fig. 6. Membership function for the load balancing index

Fig. 6 shows the membership function for load balancing index. From Fig. 6, the membership value of $\mu(\delta_i)$ can be written as

$$\mu(\delta_i) = \begin{cases} \dfrac{(\delta_{\max} - \delta_i)}{(\delta_{\max} - \delta_{\min})}, & for\ \delta_{\min} < \delta_i < \delta_{\max} \\ 1, & for\ \delta_i \le \delta_{\min} \\ 0, & for\ \delta_i \le \delta_{\max} \end{cases} \quad (11)$$

It has been assumed that δ_{min} = 0.10, δ_{max} = 0.50, and the weight factor for the membership function is 0.275.

III.6. Fuzzy Multi-objective Algorithm

Fuzzy multi-objective method in this study has been extended by adding a weighting factor to each objective function.

The addition of this weighting is an extension of the method presented in reference [24]. Giving weight factors are important in multi-objective optimization, but it has not been used in the distribution network reconfiguration.

The weighting of the objective function is for power losses by 0.3, for the objective function of the bus voltage by 0.225, for the current branch loading index by 0.2, and for load balancing by 0275. The proposed extended fuzzy multi-objective algorithm for the optimization of distribution network configuration in this study is shown in Fig. 7.

IV. Test Results

In order to demonstrate the effectiveness of the proposed method, it is applied to two test electrical distribution systems, i.e. IEEE distribution system of 77-bus with DER integration and Yogyakarta Indonesia distribution system of 60-bus with DER integration.

The optimization of distribution network configuration with considering DER using extended fuzzy multi-objective method was implemented in Matlab software, and the simulations were performed on an Intel® core(TM) i5-3337U CPU@1.80 GHz, 4 GB RAM.

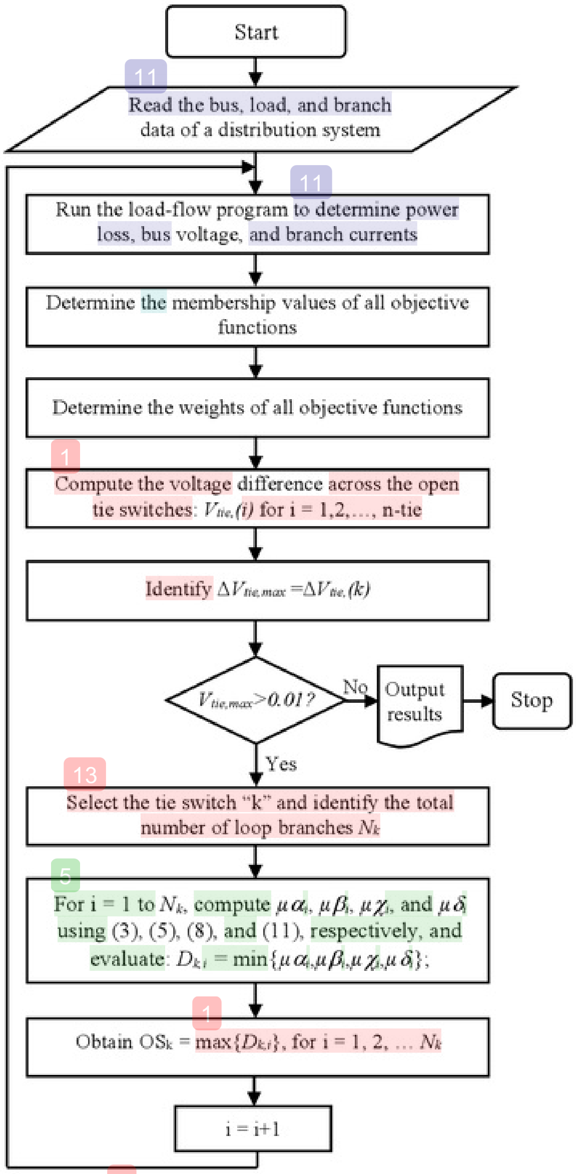

Fig. 7. An extended fuzzy multi-objective algorithm for network reconfiguration

IV.1. IEEE Distribution System of 77-Bus with DER Integration

In the first study, the IEEE distribution system of 77-bus has examined, as shown in Fig.1. For base case, before reconfiguration the network, the total active power loss of the network under study is 229.64 kW. The active power loss dispersed of each bus of distribution network for the base case has shown in Fig. 8. In this state, the minimum voltage is 0.914 p.u magnitude that occurred on bus 76.

From the result of our case study, it can be seen from the 77-bus test system that integration of DER has the effects of reduction the active power loss over feeders in this particular case. Load flow simulation results show that the total active power loss of the system with DER integration is 179.87 kW, or, in other words that the efficiency of distribution network is 94.63%, as shown in TABLE III. For voltage profile evaluation has resulted that the minimum voltage is 0.934 p.u in bus 76.

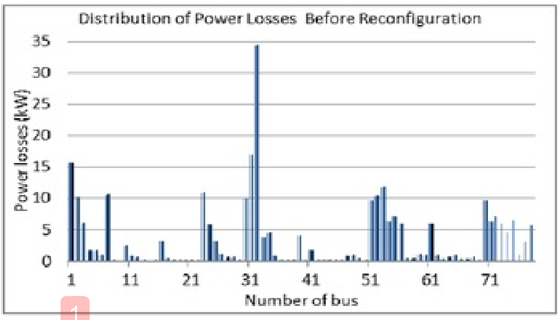

Fig. 8. Distribution of power loss before reconfiguration for IEEE 77-bus test system

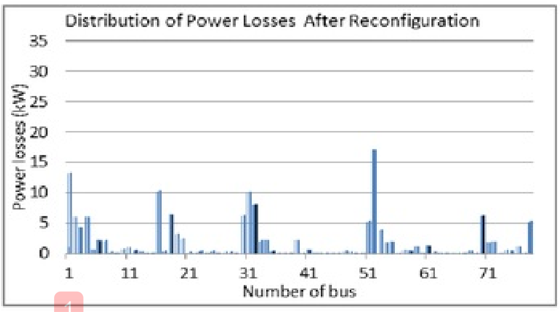

Fig. 9. Distribution of power loss after reconfiguration for IEEE 77-bus test system

After experimenting the extended fuzzy multi-objective technique for reconfiguration purpose, the total active power loss is 165.07 kW, or the other words, the efficiency of distribution network under study is 95.05%, as shown in TABLE II.

The power loss dispersed of each bus of distribution network with DER integration after reconfiguration has shown in Fig. 9. From the results of our study which has shown in Fig. 8 and Fig. 9, it is observed that the losses in almost every bus is reduced, except at 4, 6, 16, 17, 18, 19, 20, and 53, where the losses are increased because of shifting of loads onto these feeders. The minimum voltage is 0.949 p.u magnitude that occurred on the bus 76.

TABLE III
THE SIMULATION RESULTS OF IEEE 77-BUS DISTRIBUTION NETWORK

Test Case	Parameters of Analysis				
	Active Power Loss (kW)	Efficiency of Distribution Network (%)	Minimum Voltage (p.u.)	Tie Switches to be Closed	Sectionalizing Switches to be Open
Distribution network without DER before reconfiguration	229.64	93.25	0.914 (V_{76})	NA	NA
Distribution network with DER before reconfiguration	179.87	94.63	0.934 (V_{76})	NA	NA
Distribution network with DER after reconfiguration	165.07	95.05	0.949 (V_{76})	Line3, Line4, Line6, and Line7	J9, J16, J21, and J33

Voltage profile for each bus of IEEE 77-bus test system has shown in Fig. 10. As can be seen in Fig. 10 and TABLE III that the minimum voltage magnitude before reconfiguration is 0.914 p.u which occurred on bus 76, while the minimum voltage magnitude after reconfiguration is 0.949 p.u which occured on the same bus. Impact of DER installations in several locations of IEEE 77-bus test system is an increase in the magnitude of the bus voltage significantly. The maximum voltage after reconfiguration is 0.999 p.u magnitude which occurred on bus 36, as shown in Fig. 10.

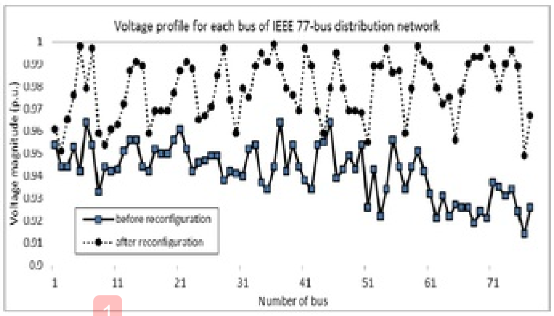

Fig. 10. Voltage profile for each bus of IEEE 77-bus test system

From the result of the IEEE 77-bus radial distribution network test system that DER has the effects of loss reduction improvement and increasing in voltage magnitude over feeders, and the topological structures of optimum network in base case are different from those with DER integration. Based on the 77-bus radial distribution system with DER integration, the proposed method in this paper has significant loss reduction in order to improve the performance of electrical distribution system with considering the DER integration.

IV.2. Yogyakarta Distribution System of 60-Bus with DER Integration

In the second study, the proposed method is tested on a real-life 60-bus Yogyakarta power distribution system. In this case, a 20-kV electric power distribution system of the Provincial Electricity Authority of Yogyakarta, Indonesia, is selected to illustrate the performance of the method, as shown in Fig. 2. The system has 13 feeders that are powered by two 60 MVA power transformers.

For base case, before reconfiguration the network, the total active power loss of this system is 656.20 kW, or, in other words that the efficiency of distribution network is 97.53%, as shown in TABLE IV. The loss dispersed of each bus of distribution network for the base case has shown in Fig. 10. In this state, the minimum voltage that occurred on bus 50 is 0.907 p.u magnitude.

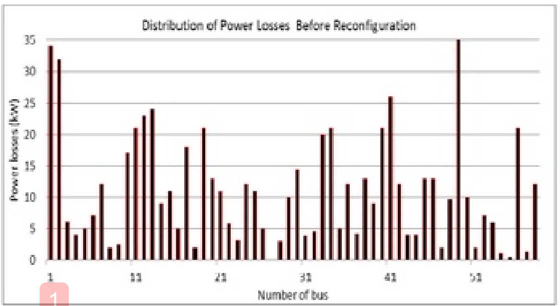

Fig. 11. Distribution of power loss before reconfiguration for Yogyakarta 60-bus test system

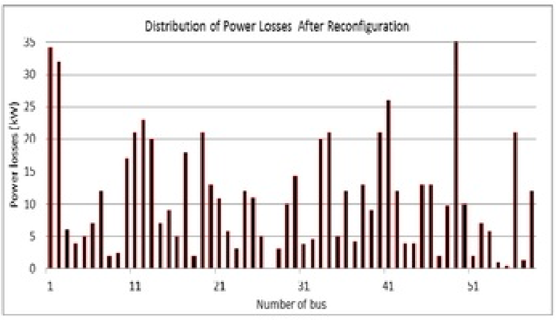

Fig. 12. Distribution of power loss after reconfiguration for Yogyakarta 60-bus test system

From the result of our real-life case study, it can be seen from the Yogyakarta 60-bus test system that integration the DER has the effects of loss reduction improvement over feeders in this particular case.

By using load flow simulation, it is resulted that the total active power loss of the system with DER integration is 649.82 kW, or, in other words that the efficiency of distribution network is 97.55%, as shown in TABLE IV. For voltage profile evaluation has resulted that the minimum voltage that occurred on bus 20 is 0.929 p.u magnitude.

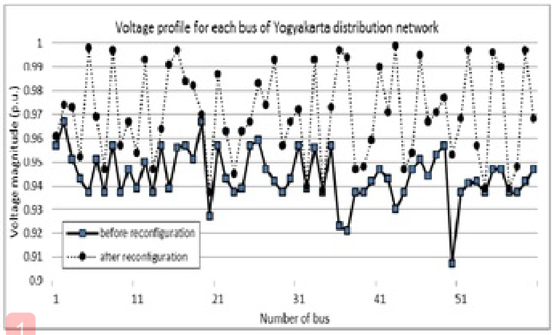

Fig. 13. Voltage profile for each bus of Yogyakarta 60-bus test system

TABLE IV
THE SIMULATION RESULTS OF YOGYAKARTA 60-BUS DISTRIBUTION NETWORK

Test Case	Parameters of Analysis				
	Active Power Loss (kW)	Efficiency of Distribution Network (%)	Minimum Voltage (p.u.)	Tie Switches to be Closed	Sectionalizing Switches to be Open
Distribution network without DER before reconfiguration	656.20	97.53	0.907 (V_{50})	NA	NA
Distribution network with DER before reconfiguration	649.82	97.55	0.929 (V_{20})	NA	NA
Distribution network with DER after reconfiguration	631.07	97.64	0.937 (V_{20})	3/S3-265 and 90/S3-125Z	80B/S1-172Z and 141/S3-125Z

After experimenting with extended fuzzy multi-objective technique for reconfiguration purpose, optimization result of Yogyakarta distribution network configuration that the best configuration is achieved by connecting both tie switch of 3/S3-265 and 90/S3-125z for on position, while both sectionalizing switch of 80B/S1-172Z and 141/S3-125z for off position. The total active power loss in this case is 631.07 kW, or the other words, the efficiency of distribution network under study is 97.64%, as shown in TABLE IV.

The power loss dispersed of each bus of distribution network with DER integration after reconfiguration has shown in Fig. 11. From the results of our study which has shown in Fig. 10 and Fig. 11, it is observed that the losses in almost every bus is reduced, except at 3, 7, 11, 16, 17, 23, 34, 40, 43 and 55, where the losses are increased because of shifting of loads onto these feeders.

Voltage profile for each bus of Yogyakarta 60-bus test system has shown in Fig. 13. As can be seen in Fig. 13 and TABLE IV that the minimum voltage magnitude before reconfiguration is 0.907 p.u which occurred on bus 50, while the minimum voltage after reconfiguration is 0.937 p.u which occurred on the bus 20. The impact of DER installation in several location of Yogyakarta 60-bus test system is increasing on bus voltage magnitude significantly. The maximum voltage after reconfiguration is 0.999 p.u magnitude that occurred on bus 43, as shown in Fig. 13.

From the result of our case study of Yogyakarta distribution system, it can be seen from the 60-bus radial distribution network test system that DER has the effects of loss reduction improvement over feeders in this particular case, and the topological structures of optimum network in base case are different from those with DER integration. Based on the Yogyakarta 60-bus radial distribution system with DER integration, the proposed extended fuzzy multi-objective method in this paper has significant loss reduction in order to improve the performance of electrical distribution system with considering the DER integration. As shown in TABLE IV, by using the proposed method, not only efficiency of distribution network are more increased but also minimum voltages at bus of the network are increased compared to the network before reconfiguration.

V. Conclusion

In this paper, an efficient method for optimization of distribution networks configuration including DER integration in order to improve the performance of the networks has been presented. The effectiveness of the method has been demonstrated by an IEEE 77-bus distribution network test system and Yogyakarta 60-bus test system. The excellence of the proposed method is the capabilities of reducing the active power loss and increasing the voltage magnitude of each bus of distribution network in order to improve the performance of the network. The simulation result show that for IEEE 77-bus test system, a 1.80% of distribution network efficiency improvement is achieved by the method. And, the simulation result for Yogyakarta 60-bus test system show that a 0.11% of distribution network efficiency improvement is achieved by the extended fuzzy multi-objective method.

Appendix

TABLE A
LOAD AND BRANCH DATA OF YOGYAKARTA 60-BUS DISTRIBUTION SYSTEM

Bus Number	Active Power (kW)	Reactive Power (kVAr)	Resistance of Line (Ω)	Reactance of Line (Ω)
1	270.0	194.9	0.03360	0.12845
2	630.0	454.8	0.18144	0.69363
3	90.0	65.0	0.04032	0.15414
4	279.0	201.4	0.05376	0.20552
5	1368.0	987.6	0.37632	1.43864
6	328.5	237.2	0.10080	0.38535
7	495.0	357.4	0.11424	0.43673
8	382.5	276.1	0.20832	0.79639
9	225.0	162.4	0.17472	0.66794
10	427.5	308.6	0.12096	0.46242
11	585.0	422.3	0.20160	0.77070
12	652.5	471.1	0.10080	0.38535

13	1125.0	812.2	0.28224	1.07898
14	571.5	412.6	0.34272	1.31019
15	0	0.0	0.06720	0.25690
16	1732.5	1250.8	0.32256	1.23312
17	495.0	357.4	0.16800	0.64225
18	450.0	324.9	0.18144	0.69363
19	1012.5	731.0	0.06720	0.25690
20	1057.5	763.5	0.52416	2.00382
21	247.5	178.7	0.16128	0.61656
22	697.5	503.6	0.06720	0.25690
23	180.0	130.0	0.02016	0.07707
24	292.5	211.2	0.06720	0.25690
25	495.0	357.4	0.13440	0.51380
26	2236.5	1614.6	0.45696	1.74692
27	225.0	162.4	0.02688	0.10276
28	2596.5	1874.5	0.23520	0.89915
29	3262.5	2355.4	0.09408	0.35966
30	3028.5	2186.4	0.44352	1.69554
31	90.0	65.0	0.06048	0.23121
32	180.0	130.0	0.17472	0.66794
33	405.0	292.4	0.16800	0.64225
34	1507.5	1088.3	0.30240	1.15605
35	427.5	308.6	0.30240	1.15605
36	1422.0	1026.6	0.66528	2.54331
37	0	0.0	0.01344	0.05138
38	3145.5	2270.9	0.59136	2.26072
39	1404.0	1013.6	0.22848	0.87346
40	630.0	454.8	0.18144	0.69363
41	1215.0	877.2	0.66528	2.54331
42	0	0.0	0.04704	0.17983
43	450.0	324.9	0.29568	1.13036
44	337.5	243.7	0.12096	0.46242
45	67.5	48.7	0.07392	0.28259
46	855.0	617.3	0.65856	2.51762
47	144.0	104.0	0.10752	0.41104
48	0	0.0	0.02016	0.07707
49	1125.0	812.2	0.02016	0.07707
50	549.0	396.3	0.31584	1.20743
51	787.5	568.5	0.16128	0.61656
52	315.0	227.4	0.36288	1.38726
53	1035.0	747.2	0.47712	1.82399
54	1386.0	1000.6	0.28224	1.07898
55	157.5	113.7	0.16800	0.64225
56	787.5	568.5	0.38304	1.46433
57	135.0	97.5	0.10752	0.41104
58	261.0	188.4	0.22176	0.84777
59	1291.5	932.4	0.55776	2.13227
60	1444.5	1042.9	0.21504	0.82208

Acknowledgements

The authors gratefully acknowledge the contributions of the Directorate General of Higher Education (DIKTI), Ministry of Education and Culture, Republic of Indonesia, for funding this research.

References

[1] A.M. Borbely and J.F. Kreider, *Distributed Generation: The Power Paradigm for the New Millennium* (CRC Press, Washington D.C., 2001).

[2] 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.

[3] M. E. Baran and F. F. Wu, Network Reconfiguration in Distribution Systems for Loss Reduction and Load Balancing, *IEEE Trans. on Power System, vol. 4, no. 3*, 1989, pp. 1401–07.

[4] E. Carpaneto, G. Chicco, and A. Prunotto, Reliability of reconfigurable distribution systems including distributed generation, *9th International Conference on Probabilistic Methods Applied to Power Systems KTH*, June 11-15, 2006, Stockholm, Sweden.

[5] 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.

[6] N.K. Aryani, M. Syai'in, A. Soeprijanto, I.M.Y. Negara, Optimal Placement and Sizing of Distributed Generation for Minimize Losses in Unbalance Radial Distribution Systems using Quantum Genetic Algorithm, *International Review of Electrical Engineering (IREE), vol. 9, no. 1, 2014*, pp. 157-164.

[7] 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.

[8] 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 Transactions on Power Delivery, Vol. 24, No. 1*, January 2009, pp. 268-276.

[9] A. Swarnkar, N. Gupta, and K.R. Niazi, Reconfiguration of radial distribution systems with fuzzy multi-objective approach using adaptive particle swarm optimization, *Power and Energy Society General Meeting, 2010 IEEE*, 25-29 July 2010, Minneapolis, US.

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

[11] C. S. Chen and M. Y. Cho, Energy Loss Reduction by Critical Switches, *IEEE Transactions on Power Delivery, vol. 8, no. 3*, 1993, pp. 1246–1253.

[12] V. Borozan, D. Rajicic, and R. Ackovski, Improved Method for Loss Minimization in Distribution Networks, *IEEE Transactions on Power System, vol. 10, no. 3*, 1995, pp. 1420–1425.

[13] V. Borozan and N. Rajakovic, Application Assessments of Distribution Network Minimum Loss Reconfiguration, *IEEE Trans. on Power Delivery, Vol. 12,No. 4*, 1997, pp. 1786–1792.

[14] R. Taleski and D. Rajicic, Distribution Network Reconfiguration for Energy Loss Reduction, *IEEE Transactions on Power System, vol. 12, no. 1*, 1997, pp. 398–406.

[15] W. M. Lin and H. C. Chin, A New Approach for Distribution Feeder Reconfiguration for Loss Reduction and Service Restoration, *IEEE Transactions on Power Delivery, vol. 13, no. 3*, 1998, pp. 870–875.

[16] Q. Zhou, D. Shirmohammadi, and W. H. E. Liu, Distribution Feeder Reconfiguration for Service Restoration and Load Balancing, *IEEE Transactions on Power System, vol. 12, no. 2*, 1997, pp. 724–729.

[17] K. Nara, A. Shiose, M. Kitagawa, and T. Ishihara, Implementation Of Genetic Algorithm for Distribution System Loss Minimum Reconfiguration, *IEEE Transactions on Power Delivery, vol. 7, no. 3*, 1992, pp. 1044–1051.

[18] 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.

[19] 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.

[20] 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.

[21] 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.

[22] 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 Transactions on Power Systems, Vol. 26, No. 3*, 2011, pp. 1080-1088.

[23] 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.*

[24] 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.

[25] S.Filipiak, J.Stępień, Application of the Co-Evolutionary Algorithm with Memory at the Population Level for Optimisation of the Operation of Real Electric Power Distribution Networks, International Review of Electrical Engineering (IREE), vol. 9, no. 2, 2014. pp. 373-381.
[26] T. Niknam, M.R. Narimani, and R.A. Abarghooee, A Multi-objective Fuzzy Adaptive PSO Algorithm for Location of Automatic Voltage Regulators in Radial Distribution Networks, *International Journal of Control, Automation, and Systems, vol. 10, no. 4*, 2012, pp. 772-777.
[27] R. Syahputra, I. Robandi, and M. Ashari, Reconfiguration of Distribution Network with DG Using Fuzzy Multi-objective Method, *International Conference on Innovation, Management and Technology Research (ICIMTR)*, May 21-22, 2012, Melacca, Malaysia.
[28] D. Zaharie, D. Lungeanu, and S. Holban, Feature Ranking Based on Weights Estimated by Multiobjective Optimization, *IADIS European Conference Data Mining*, 2007.
[29] G.D. Yalcin and N. Erginel, Determining Weights in Multi-Objective Linear Programming under Fuzziness, *Proceedings of the World Congress on Engineering Vol. II WCE, July 6-8, 2011*, London, U.K.

Authors' information

[1] Department of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta 55183 Indonesia.

[2] Department of Electrical Engineering, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya 60111 Indonesia.

E-mails: ramadons@ymail.com
robandi@ee.its.ac.id
ashari@ee.its.ac.id

Ramadoni Syahputra received B.Sc. degree from Institut Teknologi Medan and M.Eng. degree from Department of Electrical Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia in 2002. He is currently a Ph.D candidate at the Department of Electrical Engineering, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

His research interests are in computational of power system, artificial intelligence in power system, power system control, the application of fuzzy logic in power system, distributed generation, and renewable energy.

Imam Robandi received the Ph.D. degree form Tottori University, Japan. He is currently a Professor in the Department of Electrical Engineering, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

His research interests are in power system operation, power electronics, power system control, artificial intelligence in power system control, power quality, distributed generation, micro grid simulation, power system automation, and renewable energy.

Mochamad Ashari received the M.Eng. and Ph.D. degrees form Curtin University, Australia, in 1997 and 2001, respectively. He is currently a Professor in the Department of Electrical Engineering, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

His research interests are in power system operation, power electronics, artificial intelligence in power system, power system control, optimization of power system, distributed generation, micro grid simulation, power quality, and renewable energy.

Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-Objective Method

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-Objective Method

ORIGINALITY REPORT

71%	40%	69%	19%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Syahputra, Ramadoni, Imam Robandi, and Mochamad Ashari. "Optimal distribution network reconfiguration with penetration of distributed energy resources", 2014 The 1st International Conference on Information Technology Computer and Electrical Engineering, 2014. Publication	28%
2	icitacee.undip.ac.id Internet Source	16%
3	Syahputra, Ramadoni, Imam Robandi, and Mochamad Ashari. "Reconfiguration of distribution network with DG using fuzzy multi-objective method", 2012 International Conference on Innovation Management and Technology Research, 2012. Publication	6%
4	Syahputra, Ramadoni, Imam Robandi, and Mochamad Ashari. "Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using	5%

Extended Particle Swarm Optimization Algorithm", International Review of Electrical Engineering (IREE), 2015.
Publication

5	iiste.org Internet Source	2%
6	Submitted to Queen's University of Belfast Student Paper	2%
7	Soedibyo, , Mochamad Ashari, and Ramadoni Syahputra. "Power loss reduction strategy of distribution network with distributed generator integration", 2014 The 1st International Conference on Information Technology Computer and Electrical Engineering, 2014. Publication	2%
8	www.iaeng.org Internet Source	1%
9	Wu, Yuan-Kang, Ching-Yin Lee, Le-Chang Liu, and Shao-Hong Tsai. "Study of Reconfiguration for the Distribution System With Distributed Generators", IEEE Transactions on Power Delivery, 2010. Publication	1%
10	Syahputra, Ramadoni; Robandi, Imam and Ashari, Mochamad. "PSO Based Multi-objective Optimization for Reconfiguration of Radial Distribution Network", International	1%

Journal of Applied Engineering Research, 2015.
Publication

11	N. Rugthaicharoencheep. "Optimal feeder reconfiguration with distributed generators in distribution system by fuzzy multiobjective and Tabu search", 2009 International Conference on Sustainable Power Generation and Supply, 04/2009 Publication	1%
12	Banerjee, S., C. K. Chanda, and D. Das. "Reconfiguration of Distribution Networks based on Fuzzy Multiobjective Approach by Considering Loads of Different Types", Journal of The Institution of Engineers (India) Series B, 2013. Publication	1%
13	Savier, J.S.. "Loss allocation to consumers before and after reconfiguration of radial distribution networks", International Journal of Electrical Power and Energy Systems, 201103 Publication	1%
14	Brusco, Giovanni, Alessandro Burgio, Daniele Menniti, Anna Pinnarelli, and Nicola Sorrentino. "About the Effectiveness, the Electric Demand Profile Impact and the Imbalance Reduction of an Optimal Sized CHP Generator for an Agro-Industrial	1%

Microgrid Using Real Data", International Review of Electrical Engineering (IREE), 2015.
Publication

15	Swarnkar, Anil, Nikhil Gupta, and K R Niazi. "Reconfiguration of radial distribution systems with fuzzy multi-objective approach using adaptive particle swarm optimization", IEEE PES General Meeting, 2010. Publication	1%
16	D. Das. "A Fuzzy Multiobjective Approach for Network Reconfiguration of Distribution Systems", IEEE Transactions on Power Delivery, 1/2006 Publication	<1%
17	airccse.org Internet Source	<1%
18	lib.tkk.fi Internet Source	<1%
19	"Feeder reconfiguration for loss reduction", Power Distribution Automation, 2016. Publication	<1%
20	Reddy, M. Damodar. "A Hybrid Method of Optimal Capacitor Placement for The Reconfigured Network", International Journal of Applied Engineering Research/09734562, 20081101 Publication	<1%

21 Das, D.. "Reconfiguration of distribution system using fuzzy multi-objective approach", International Journal of Electrical Power and Energy Systems, 200606 <1%

Publication

---

22 Submitted to VIT University <1%

Student Paper

---

23 Zou Bi-chang. "Distribution network reconfiguration based on the minimum comprehensive cost with distributed generations", 2011 IEEE Power Engineering and Automation Conference, 09/2011 <1%

Publication

---

24 www.edi-info.ir <1%

Internet Source

---

25 docslide.us <1%

Internet Source

---

26 Sun, Liang Wang, Bing. "Robust optimisation approach for vehicle routing problems with uncertainty.(Research Article)(Report", Mathematical Problems in Engineering, Annual 2015 Issue <1%

Publication

---

27 Küfeoğlu, Sinan, Samuel Prittinen, and Matti Lehtonen. "A Summary of the Recent Extreme Weather Events and Their Impacts on Electricity", International Review of Electrical Engineering (IREE), 2014. <1%

Publication

28 www.praiseworthyprize.com
Internet Source
<1%

29 doria.fi
Internet Source
<1%

30 www.downloadebooks.ir
Internet Source
<1%

31 M. Sydulu. "A Heuristic-Expert based Approach for Reconfiguration of Distribution Systems", 2007 IEEE Power Engineering Society General Meeting, 06/2007
Publication
<1%

32 Zoko Ble, Frank, Matti Lehtonen, Ari Sihvola, and Charles Kim. "Power Arcing Source Location Using First Peak of Arrivalof RF-Signal", International Review of Electrical Engineering (IREE), 2014.
Publication
<1%

33 tii.ieee-ies.org
Internet Source
<1%

34 elife.elifesciences.org
Internet Source
<1%

35 Ghasemi, S., and J. Moshtagh. "A novel codification and modified heuristic approaches for optimal reconfiguration of distribution networks considering losses cost and cost benefit from voltage profile
<1%

improvement", Applied Soft Computing, 2014.
Publication