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Optimal Reconfiguration using Firefly Algorithm for Integrated Electrical Distribution Network with Distributed Generation, Case Study: 20 kV Tarahan Substation, Province of Bandar Lampung, Indonesia

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Abstract: The unbalanced load distribution in the electrical distribution network caused crucial power losses. This condition occurs in one of the electrical distribution networks, 20 kV Tarahan Substation, Province of Bandar Lampung, Indonesia. This condition can be maintained using optimal reconfiguration with the integration of Distributed Generation (DG) based on Renewable Energy (RE). This study demonstrates the optimal reconfiguration of the 20 kV Tarahan Substation with the integration of the Photovoltaic (PV) and Battery Energy Storage System (BESS). The reconfiguration process is optimized by using the Firefly Algorithm (FA). This process is conducted in the 24-hour simulation with various load profiles. The optimal reconfiguration is investigated in two scenarios based on without and with DG integration. The optimal configuration with more balanced load distribution conducted by FA reduces the power losses by up to 31.39% and 32.38% in without and with DG integration, respectively. Besides that, the DG integration improves the lowest voltage bus in the electrical distribution network from 0.95 p.u to 0.97 p.u.

Keywords: Electrical Distribution Network, Firefly Algorithm, Optimal Reconfiguration, Renewable Energy.

1 Introduction

ELECTRICAL distribution network is the most important part of electrical power downstream for consumers [1]. During the distribution process, electrical power losses can occur. These power losses become higher and more crucial due to the unbalanced load distribution in the electrical distribution network. This condition occurs in one of the important substations in Tarahan Substation, Province of Bandar Lampung, Indonesia. This substation consists of a 20 kV electrical distribution network with a radial configuration consisting of 2 generation resources and 6 feeders to supply 203 load buses with 208 tie-switches [2]. Along with the electrical consumer growth, the load distribution in this network becomes unbalanced. As mentioned before, this condition can lead to huge power losses and voltage profile reduction [3]. This problem needs to be investigated quickly before the situation becomes worse.

One of the viable options for fixing the unbalanced load distribution is doing an optimal reconfiguration in the electrical distribution network [4]. The reconfiguration of the electrical distribution network is the rearrangement of the distribution topology by changing the open or closed status of the tie switches on the feeders [5]. The optimal reconfiguration approach is divided into static and dynamic reconfigurations. A static reconfiguration focuses on a specific load and generation power at a time. Dynamic reconfiguration has a wider consideration, such as load and generation power profiles changing in specific time intervals [6]. Moreover, the integration of Distributed Generation (DG) based on Renewable Energy (RE) is also required

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in this reconfiguration case due to improving the voltage profile. The site in Tarahan Substation has a huge solar energy potential. The Solar Global Horizontal Irradiation (Solar GHI) in this location has reached 1,713.8 kWh/m^2/year with a total solar power output potential of 1,391 GWh/year [7]. Thus, the Photovoltaic (PV) system is considered as a viable option. Battery Energy Storage System is also needed to maintain the continuity of power supply [8], [9]. This complexity needs the proper dynamic reconfiguration to be implemented. The dynamic reconfiguration of the electrical distribution network can be done manually using the Civanlar method [10]. However, the complexity of the modern electricity system makes this method not viable anymore. Thus, the researchers develop various Artificial Intelligence (AI)-based methods to help the reconfiguration process for electrical distribution networks.

One of the popular AI-based methods is metaheuristic algorithm-based which has many advantages, such as eliminating complex calculations and reducing long mathematical calculation time with tiny error results in large-scale power system cases. Various metaheuristic algorithms are presented to perform the reconfiguration of electrical test systems [11]. In [12], the Coyote Algorithm is implemented to find the optimal network reconfiguration with DG placement in a test system consisting of 69-node and 119-node. In another example, the dynamic reconfiguration of IEEE-33 bus and IEEE-118 bus electrical systems has been done using the Slime Mold Algorithm [13]. Other algorithms, such as Sparrow Search Algorithm [14], Artificial Ecosystem Optimization [15], and Artificial Hummingbird Algorithm [16], are also reported in optimal reconfiguration. However, most of the paper has only been validated in electrical standard test systems [17]–[19]. The papers that investigated real cases are still limited. In [20], the dynamic reconfiguration of the Lagoa Electrical System with DG based on RE is reported in Sao Miguel Island, Azores. In [21], the optimal reconfiguration is performed in the 20 kV electrical distribution system in Bali, Indonesia. The most popular algorithm for electrical distribution network reconfiguration is the Firefly Algorithm (FA) [22]–[24]. Due to the FA investigation for real case systems is still limited, further implementation of FA in real electrical distribution networks is needed.

From the literature, it has been necessary to investigate the metaheuristic algorithms to solve real electrical distribution network reconfiguration cases in more complex consideration. With this motivation, the contribution of this paper is stated in the following:

1) This paper demonstrates the optimal reconfiguration for the integrated electrical distribution network with DG based on RE. The investigated system is based on a real electricity system, 20 kV Tarahan Substation that is integrated with PV and BESS. The proposed method aims to improve the load distribution in the electrical distribution network and the lowest voltage bus performance.
2) This paper presents the implementation of dynamic reconfiguration by using FA. This process is conducted in the 24-hour simulation with various load profiles.

The organization of this paper is presented as follows: In Section II, the models for Tarahan Substation and DG based on RE are described. In Section III, the problem formulation and the optimal reconfiguration by using FA are presented with detailed flowcharts and steps. In Section IV, the results have been discussed in the comparison with two scenarios based on without and with DG integration. In the rest, Section V highlights the main findings in this paper.

2 Model for Investigated Power System

In this section, the detailed model for the electrical distribution network is given. Moreover, the PV and BESS are modeled as DG [8], [9]. Besides that, various load profiles have also been forecasted.

2.1 Model for Tarahan Substation

The Tarahan Substation is located in Province of Bandar Lampung, Indonesia. This substation has a radial topology of 20 kV distribution network. The existing model for the Tarahan Substation is shown in Fig. 1. This system has 6 feeders, named Gelombang, Laut, Samudera, Buih, Surut, and Pasang. This system has 2 power sources, named Tarahan#1 and Tarahan#2. The Gelombang Feeder has 3 load buses, The Laut Feeder has 77 load buses, The Samudera Feeder has 2 load buses, The Buih Feeder has 48 load buses, The Surut Feeder has 28 load buses and The Pasang Feeder has 43 load buses. In the current condition, the tie-switches S202, S203 S204, S205, S206, S207 and S208 are opened. The DG consists of PV and BESS is placed at Bus 203.

2.2 Model for DG

The PV and BESS are modeled with a simple model for DG. Thus, the DG is modeled based on the mathematical equation of each component represented by the power generation behavior. The PV generates power electricity dependent on the Solar GHI. PV output can be calculated by Eq. (1) [25].

$$P_{PV} = M\left(P_{STC} \times \frac{G_{ING}}{G_{STC}} + \left(1 + k(T_c - T_r)\right)\right) \tag{1}$$

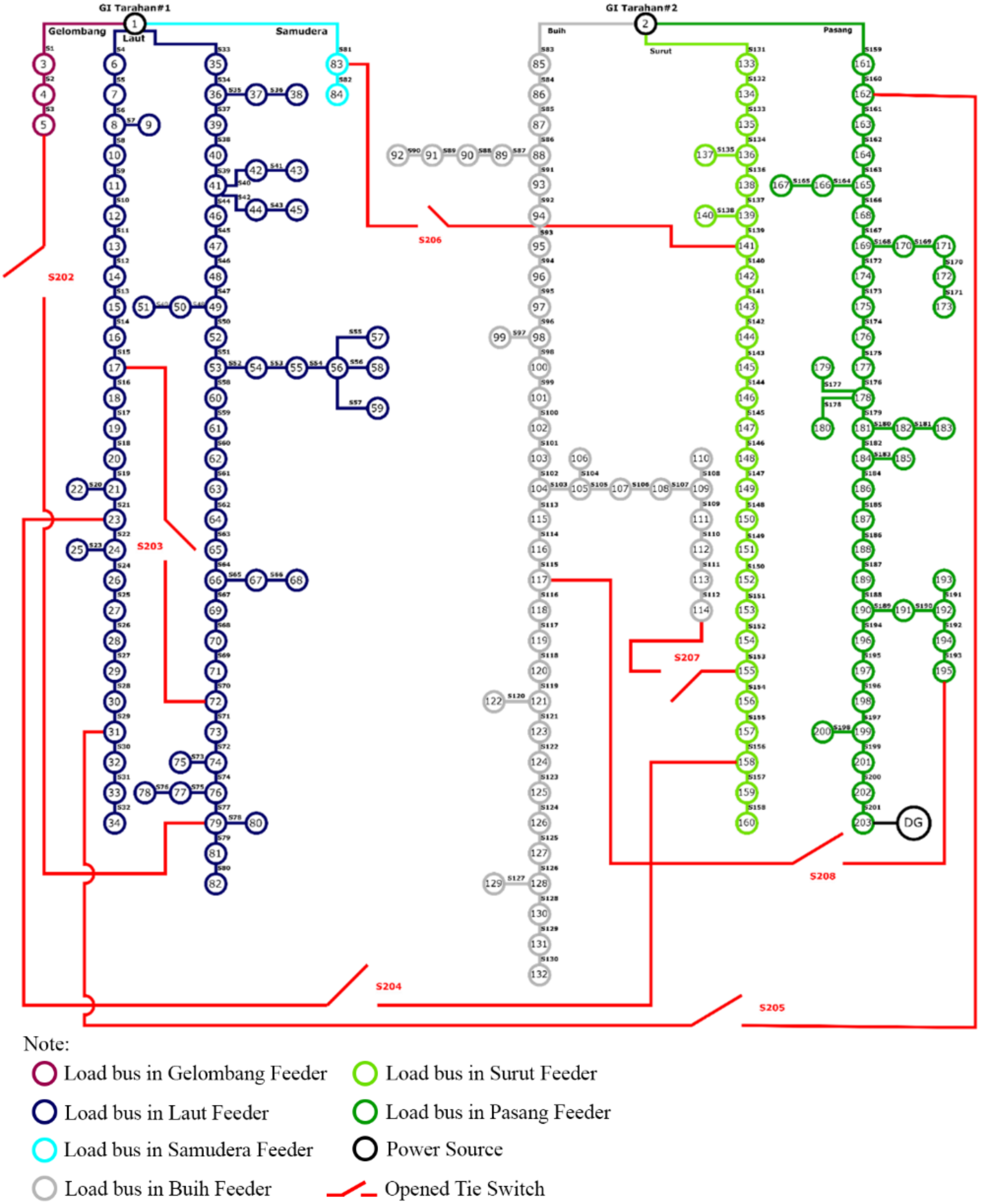


Fig. 1 Single line diagram of Tarahan Substation.

This study assumed to use the 1 MWp PV that connected to the Tarahan Substation. The PV generation profile was used the secondary data from the Department of Electrical Engineering of Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. It is used to forecast the PV power output in Tarahan by comparing the Solar GHI as shown in Fig. 2.

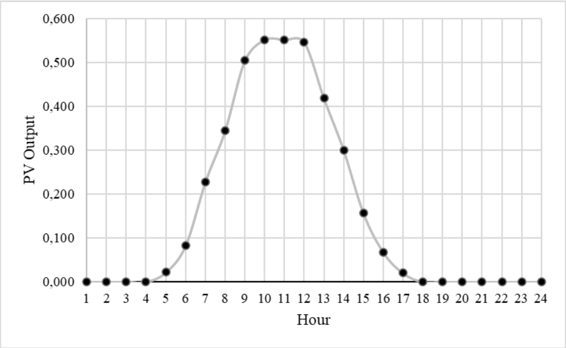


Fig. 2 Forecasted PV power output in Tarahan.

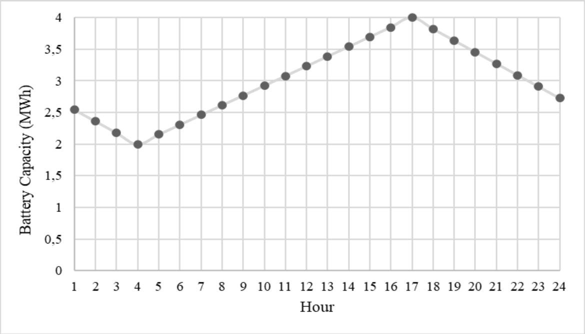


Fig. 3 Forecasted SOC for BESS profile.

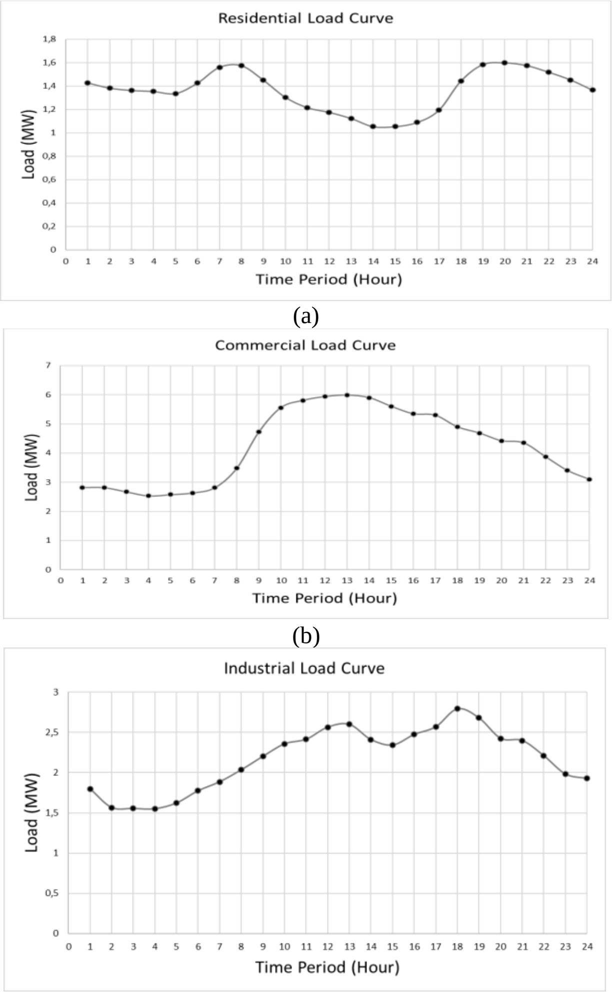
Table 1 Battery specification.

Parameter	Value
Capacity	4 MWh
Minimum SOC	50 %
Maximum SOC	100 %
Charging Energy	0.1538 MW/hour
Discharging Energy	0.1818 MW/hour

PV system requires BESS to ensure the continuity of the power supply. The mathematical model for BESS is dependent on the State of Charge (SOC) equation as shown in Eq. (2) [26]

$$SOC_{t+i} = SOC_t + \sum_{t}^{t+i} (P_{battery\,+} - P_{battery\,-}) \qquad (2)$$

The DG was placed on Bus 203 with the lowest average voltage value. The DG is expected to increase the voltage. In this study, the PV is modeled with a negative load due to represented as a generator supplying the electrical power to the system [27]. The BESS is modeled into two types of loads, a positive and negative load. A positive load represents the charging condition due to it is like an electrical load that consumes electrical power, while the negative load represents the discharging condition due to it is like a generator supplying the electrical power to the system. The forecast of the SOC of the BESS is given in Fig. 3. The battery is run in charging conditions from the 5th hour until the 17th hour and in discharging conditions from the 18th hour until the 4th hour. The BESS specification is detailed in Table 1.



(a)

(b)

(c)

Fig. 4 Load profile references: a) Residential; b) Commercial; and c) Industrial.

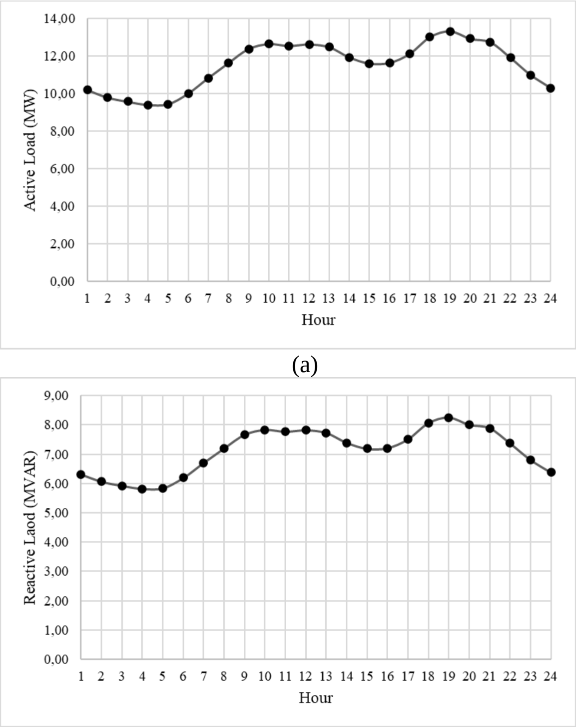
2.3 Model for DG

The optimal reconfiguration is conducted by using a dynamic reconfiguration approach within a 24-hour load simulation. The load data obtained from the previous study that modeled per bus according to each bus characteristics dependent on three load profiles, there are residential, commercial, and industrial as shown in Fig. 4 [2]. The load profile in Tarahan is forecasted using Eq. (3) and illustrated as shown in Fig. 5 [28].

$$P_{load\ real\ i} = \frac{P_{load\ curve\ i}}{P_{peak\ curve}} \text{ x } P_{peak\ real} \qquad (3)$$

3 Methodology

In this section, the detailed processes for optimal reconfiguration of the 20 kV Tarahan Substation with DG integration are explained. A problem formulation and FA implementation for optimizing the reconfiguration is also presented with a flowchart and brief description.



(a)

(b)

Fig. 5 Forecasted 24-hour load profiles in Tarahan Substation: a) Active loads; and b) Reactive loads.

Table 2 Optimization parameters for FA.

Parameter	Value
n	50
iter$_m$	200
dim	7
α	1
β_0	1
γ	1

3.1 Problem Formulation

The optimal reconfiguration aims to minimize the electrical power losses in the system. the objective function (F) based on the electrical power losses function (P_{loss}) is given in Eq. (4) and Eq. (5) [29].

$$F = \min P_{loss} \tag{4}$$

$$P_{loss} = \sum_{K=1}^{K} |I_K|^2 \text{ x } R_K \tag{5}$$

This study considers the power balance, the radiality of the system, and the voltage of each bus as optimization problem constraints. The power balance of the system is dependent on the principle of the equilibrium point that the supply of power must be equal to its demand as shown in Eq. (6) [25].

$$\sum\nolimits_i P_{gen} + \sum\nolimits_k P_{DG} + P_{baterry} = P_{load} + P_{loss} \tag{6}$$

The electrical distribution network configuration should be kept in radial topology after the optimal reconfiguration. The closed tie-switches are represented with 0 and opened tie-switches are represented with 1 according to Eq. (7).

$$\sum_{K=1}^{K} S_K = 1 \tag{7}$$

The voltage of each bus must satisfy the voltage standard. Each bus should have a voltage value as given in Eq. (8) [30].

$$0.9 \leq Vbus_i \leq \ 1.05 \tag{8}$$

3.2 Optimal Reconfiguration Using FA

The FA is one of the popular nature-inspired metaheuristic algorithms. This algorithm is widely used to make decisions inspired by flashing patterns and the behavior of fireflies in nature. This algorithm has used the concept that the attractiveness of a firefly is proportional to a firefly's brightness but decreases as distance increases. Thus, the less bright firefly will move toward the bright firefly [31]. The FA has three general rules in the following [32]:

1) All fireflies are unisex, so each firefly is attracted to other fireflies regardless of their gender.
2) The attractiveness is proportional to the brightness. The less bright fireflies will move to fireflies with brighter brightness and reduced brightness as the distance increases. If there is no brightest firefly around, the firefly will move randomly.
3) The brightness of the firefly is determined by the place of the objective function of the firefly.

The optimal reconfiguration processes are described in Fig. 6. The first step is a review of the integrated electrical distribution network with RE and current trends in dynamic reconfiguration with metaheuristic algorithms. The next step is data preparation. The 24-hour load data is loaded as given in Fig. 5. Besides that, DG parameters are set. After that, the parameters for FA are also defined as given in Table 2.

The next step is determining the initial conditions with tie-switches that opened are S202, S203, S204, S205, S206, S207, and S208. Then, this algorithm generates 50 random fireflies with each population having seven tie-switches opened according to Eq. (9).

$$\text{x} = \begin{vmatrix} S_{1,1} & \dots & S_{7,1} \\ . & . & . \\ S_{1,50} & \dots & S_{dim,n} \end{vmatrix} \tag{9}$$

The light intensity of the fireflies represents the electrical power losses as given in Eq. (10) and Eq. (11) [33]. This study aims to minimize electrical power losses, thus the best fitness value represented by *Light_{best}* indicates the optimal solution that gives minimum electrical power losses.

$$[Light_n \ = Ploss_n] \tag{10}$$

$$Light_{best} = min(Ploss) \tag{11}$$

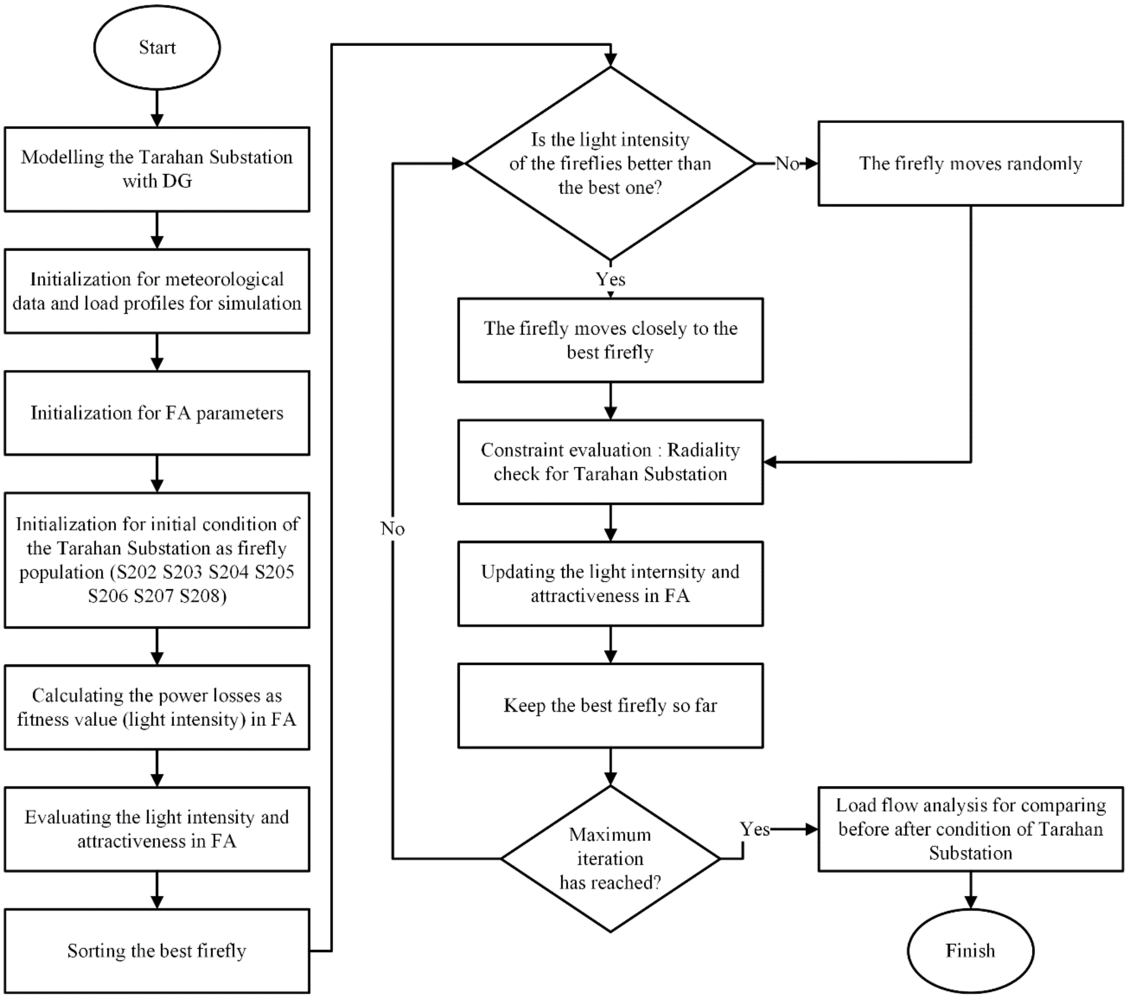


Fig. 6 Flowchart of reconfiguration using FA.

With n is several populations of fireflies. The $Light_{best}$ represents the firefly with the lowest fitness value.

The power loss calculation using the MATPOWER program that is already installed in MATLAB. By running the "*runpf*" code, the MATPOWER will analyze the power flow using the Newton-Raphson method corresponding to Eq. (4) and Eq. (5).

The distances between two fireflies are given in Eq. (12) [32]. The movement of fireflies in a population can be expressed in Eq. (13) [33]. If the light intensity value of the firefly is brighter than the others, the firefly moves randomly according to Eq. (14) [30]. The parameters are defined in Eq. (15) [33]. The movement bounds of the fireflies are given in Table 3. The bounds contain possible tie-switches that are opened or closed in each firefly.

$$r_{ij} = \left\| x_i - x_j \right\| \tag{12}$$

$$x_{i,k} = x_{i,k} + \beta_0 e^{-\gamma r^2}\left(x_{j,k} - x_{i,k}\right) + \alpha(rand - 0.5) \tag{13}$$

$$x_{i,k} = x_{i,k} + \alpha(rand - 0.5) \tag{14}$$

$$\beta(r) = \beta_0 e^{-\gamma r^2} \tag{15}$$

Table 3 Tie-switches bounds

Bounds	Tie-Switches
1	S1, S2, S3, S71, S72, S74, S77, S202
2	S4, S5, S6, S8, S9, S10, S11, S12, S13, S14, S15, S33, S34, S37, S38, S39, S44, S45, S46, S47, S50, S51, S58, S59, S60, S61, S62, S63, S64, S67, S68, S69, S70, S203
3	S16, S17, S18, S19, S21, S154, S155, S156, S204
4	S22, S24, S25, S26, S27, S28, S29, S159, S160, S205
5	S81, S131, S132, S133, S134, S136, S137, S139, S206
6	S103, S105, S106, S107, S109, S110, S111, S112, S140, S141, S142, S143, S144, S145, S146, S147, S148, S149, S150, S151, S152, S153, S207
7	S113, S114, S115, S161, S162, S163, S166, S167, S172, S173, S174, S175, S176, S179, S182, S184, S185, S186, S187, S188, S189, S190, S192, S193, S208

In this study, the light intensity represents the value of the electrical power losses. The firefly with the minimum power loss value means the lowest light intensity. The next step is to determine and save the best firefly. The fireflies move to the best firefly and the best firefly moves randomly. The movement of the firefly is ruled by the seven bounds in Table 3. Each bound will be selected with one tie-switch to be opened. After that, the radiality of the distribution network is evaluated by Eq. (7). Then, the light intensity and attractiveness are updated. This process is terminated until the maximum number of iterations.

4 Simulation Result and Discussion

This study aims to find the optimal reconfiguration of the 20 kV Tarahan Substation with PV and BESS. The optimal reconfiguration is achieved with the minimum power losses by using FA. The simulation is conducted on two scenarios. In the first scenario, the system is reconfigured without DG integration. In the second scenario, the reconfiguration is performed with DG integration.

4.1 Scenario I: Reconfiguration without DG

The comparison between before and after reconfiguration without DG integration is presented in Table 4. Before reconfiguration, the opened tie-switches are S202, S203, S204, S205, S206, S207, and S208. The electrical power losses of this configuration are 3,843.80 kW and 6,821.12 kVAR. After reconfiguration, the opened tie-switches are S18, S67, S77, S139, S188, S205, and S207. The electrical power losses of the reconfigured network are 2605.97 kW and 4619.45 kVAR. The comparison profiles before and after the reconfiguration process are shown in Table 4 and Fig. 7. The power losses are significantly decreased due to the balancing in the number of load busses in feeders as shown in Table 5.

In this scenario, the optimal reconfiguration reduces 32.20% and 32.28% of the active power losses and reactive power losses, respectively. Besides the reduced power losses, the lowest voltage on the distribution network is also increased after reconfiguration. From the average of 24-hour voltage per bus, the lowest bus voltage value before reconfiguration is 0.95 p.u on Bus 203. After reconfiguration, the lowest voltage is increased to 0.97 p.u on Bus 189.

4.2 Scenario II: Reconfiguration with DG

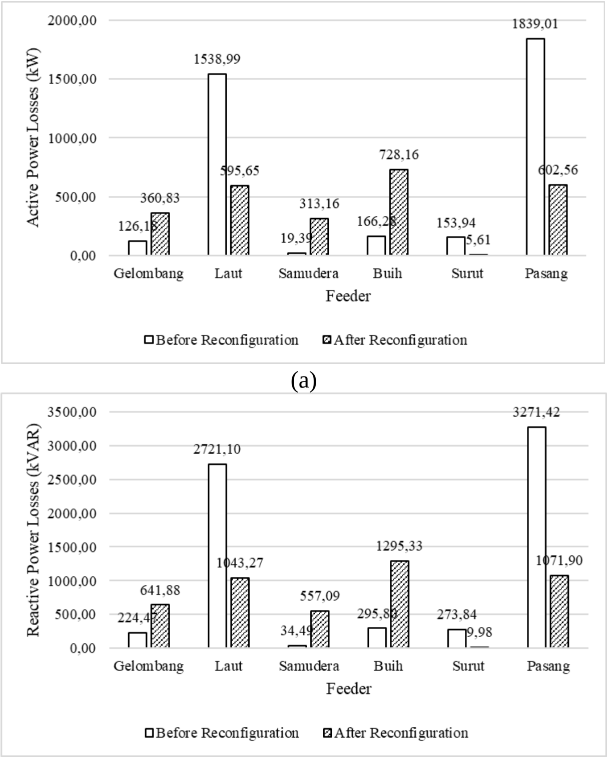
The single line diagram for the electrical distribution network in Tarahan with DG is shown in Fig. 8. The detailed comparison between before and after reconfiguration with DG is given in Table 6 and Fig. 9. Before reconfiguration, the opened tie-switches are S202, S203, S204, S205, S206, S207, and S208. The electrical power losses of this configuration are 3,664.56 kW and 6,502.27 kVAR. The opened tie-switches are shown by the red dotted line. After dynamic reconfiguration, the opened tie-switches are S18, S67, S77, S139, S187, S205 and S207.

Table 4 Comparison before and after reconfiguration without DG integration

Parameter	Before	After
Opened Tie-switch	S202 S203 S204 S205 S206 S207 S208	S18 S67 S77 S139 S188 S205 S27
Active Power Losses for 24-Hour	3,843.80 kW	2,605.97 kW
Active Power Losses Reduction	32.20%	
Reactive Power Losses for 24-Hour	6,821.12 kVAR	4,619.45 kVAR
Reactive Power Losses Reduction	32.28%	
Minimum Voltage for 24-Hour	0.95 p.u	0.97 p.u

Table 5 Comparison of the number of load busses in before and after reconfiguration without DG integration

Feeder	Number of Load Bus		
	Before	After	Condition
Gelombang	3	7	Increase
Laut	77	58	Reduce
Samudera	2	37	Increase
Buih	48	62	Increase
Surut	28	8	Decrease
Pasang	43	29	Decrease



(a)

(b)

Fig. 7 Comparison of power losses without DG: a) Active power losses; and b) Reactive power losses.

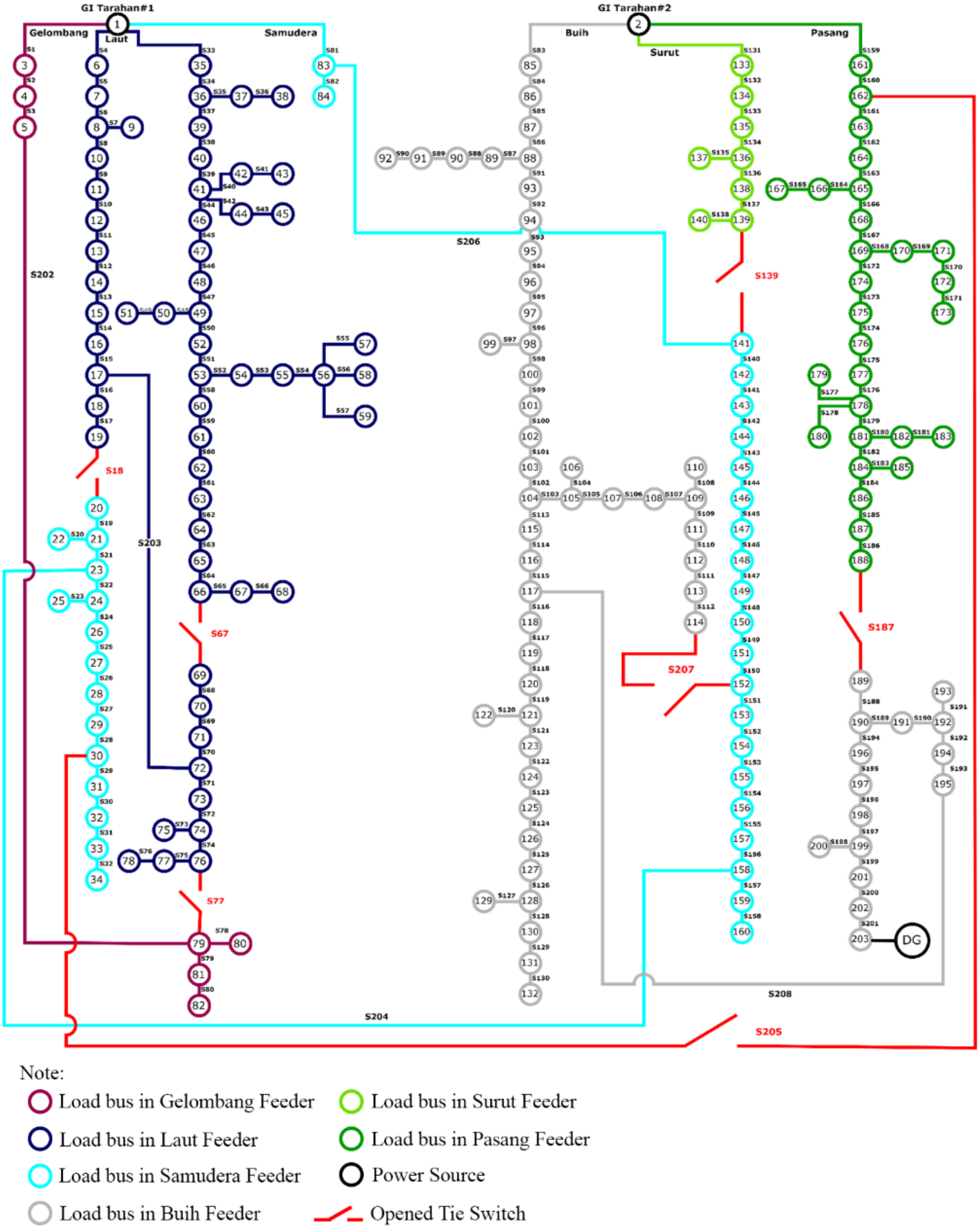


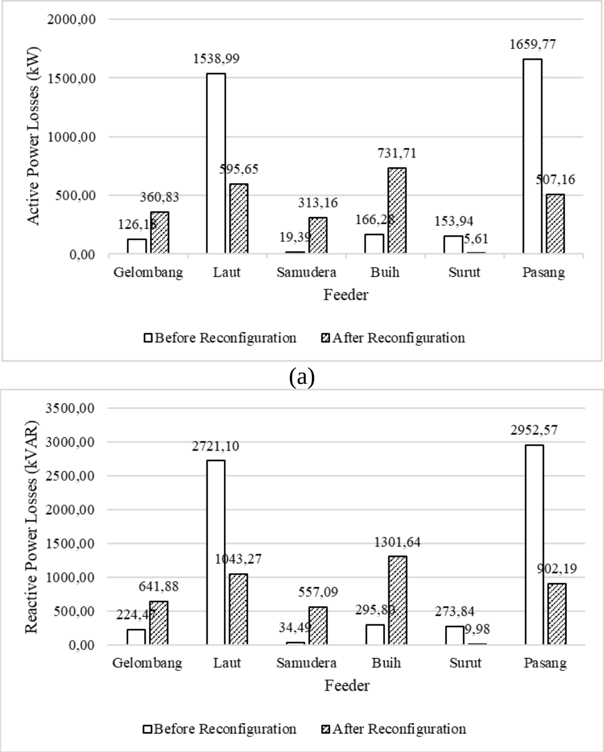
Fig. 8 Single line diagram of Tarahan Substation after the optimal reconfiguration processes.

Table 6. Comparison before and after reconfiguration with DG integration

Parameter	Before	After
Opened Tie-switch	S202 S203 S204 S205 S206 S207 S208	S18 S67 S77 S139 S187 S205 S27
Active Power Losses for 24-Hour	3,664.56 kW	2,514.12 kW
Active Power Losses Reduction	31.39 %	
Reactive Power Losses for 24-Hour	6,502.27 kVAR	4,456.06 kVAR
Reactive Power Losses Reduction	31.47 %	
Minimum Voltage for 24-Hour	0.95 p.u	0.97 p.u

Table 7 Comparison of the number of load busses in before and after reconfiguration with DG integration

Feeder	Number of Load Bus		
	Before	After	Condition
Gelombang	3	7	Increase
Laut	77	58	Reduce
Samudera	2	37	Increase
Buih	48	63	Increase
Surut	28	8	Reduce
Pasang	43	28	Reduce



(a)

(b)

Fig. 9 Comparison of power losses with DG: a) Active power losses; and b) Reactive power losses.

Table 8 Comparison of Scenario I and II

Parameter	Scenario I (Without DG)		Scenario II (With DG)	
	Before	After	Before	After
Tie-switch Opened	S202 S203 S204 S205 S206 S207 S208	S18 S67 S77 S139 S188 S205 S27	S202 S203 S204 S205 S206 S207 S208	S18 S67 S77 S139 S187 S205 S27
Active Power Losses for 24-Hour	3,843.80 kW	2,605.97 kW	3,664.56 kW	2,514.12 kW
Reactive Power Losses for 24-Hour	6,821.12 kVAR	4,619.45 kVAR	6,502.27 kVAR	4,456.06 kVAR
Minimum Voltage for 24-Hour	0.95 p.u	0.97 p.u	0.95 p.u	0.97 p.u

The power losses of this configuration are 2,514.12 kW dan 4,456.06 kVAR. The reconfiguration process reduces 31.39% and 31.47% of the active and reactive power losses, respectively. The power losses are decreased due to balancing the number of load busses in Table 7. The lowest voltage is also increased after reconfiguration. From the 24-hour average voltage per bus, the lowest bus voltage value before reconfiguration is 0.95 p.u on Bus 195. After reconfiguration, the lowest voltage is 0.97 p.u on Bus 200.

4.3 Comparison of Scenario I and II

The detailed comparison between Scenario I and II is described in Table 8. Before reconfiguration, the system without DG and the system with DG have the same tie-switch configuration. However, the electrical power losses of the system with DG are lower than the system without DG. The system with DG also has a higher minimum voltage than the system without DG. After dynamic reconfiguration, the power losses are decreased both in the system without DG and in the systems with DG. The power losses of the system with DG are lower than the system without DG. The system with DG has a higher minimum voltage than the system without DG. The reconfiguration with FA has reduced the power losses up to 31.39% without DG and 32.28% with DG.

5 Conclusion

The demonstration of the optimal reconfiguration of the integrated electrical distribution network with RE is successfully conducted. The investigated system is modeled based on a real system, the 20 kV Tarahan Substation with the integration of the PV and BESS. The reconfiguration process is conducted by using a dynamic reconfiguration approach that is implemented based on FA optimization. This reconfiguration process is simulated in MATLAB with three load profiles, there are residential, commercial, and industrial as load references. The optimal reconfiguration is achieved with the minimum power losses by using FA.

The investigation is conducted in two scenarios. In the first scenario, the optimal reconfiguration is performed without DG integration. While in the second scenario, the optimal reconfiguration is performed with DG integration. The results show that the optimal reconfiguration by using FA succeeded in reducing power losses by up to 31.39% and 32.28% in without and with DG integration, respectively. Moreover, DG integration has also succeeded in improving the lowest voltage bus from 0.95 p.u to 0.97 p.u.

With the success, the future work should be considered. The optimal configuration with this approach needs to be investigated with newer metaheuristic algorithms. Besides that, the addition of DG should be dispatched in detailed model. The detailed models open the opportunity to conduct the deeper investigations regarding the rewenable energy sensitivy cases, such as the impact of renewable penetration level in the optimal reconfiguration cases.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

M.A.P.: Idea & Conceptualization, Analysis, Original Draft Preparation; M.I.F.: Idea & Conceptualization, Research & Investigation, Methodology, Software and Simulation; M.R.D.: Project Administration, Software and Simulation, Revise & Editing; I.R.: Funding Acquisition, Supervision, Verification; D.F.U.P.: Supervision, Verification.

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Appendix

Symbol	Explanation
P_{PV}	The active power output of the PV module
P_{STC}	Maximum active power of PV module on STC
G_{ING}	Solar irradiation
G_{STC}	Solar irradiation on STC
M	The number of PV modules
k	Temperature coefficient
T_c	PV module temperature
T_r	Temperature reference
SOC_{t+i}	Battery SOC in *t*+1 iteration
SOC_t	Battery SOC in *t* iteration
$P_{battery\,+}$	Charging battery power
$P_{battery-}$	Discharging battery power
P_{gen}	Generator active power output
P_{DG}	DG active power output
P_{load}	Load power
P_{loss}	Active power losses
$P_{battery}$	Power supply from the battery
$P_{load\ real\ i}$	Active power load in *i*-th hour on the real condition
$P_{load\ curve\ i}$	Active power load in *i*-th hour on the load curve profile
$P_{peak\ real}$	Active power in peak load on the real condition
$P_{peak\ curve}$	Active power in peak load on the load curve profile
S_K	Tie-switch conditions on the *k*-th line
$S_{dim,n}$	Tie-switch on the dim-th loop dimension and the n-th population
I_K	Current on *k*-th feeder
R_K	Resistance on *k*-th feeder
K	The number of feeders
$\beta(r)$	Attractiveness when already affected by the distance between two fireflies
β_0	Initial attractiveness when value *r* is zero
γ	Coefficient of light absorption
r	Distance between two fireflies
$r_{i,j}$	Distance between the *i*-th firefly to the *j*-th firefly
x_i	Position of the *i*-th population
x_j	Position of the *j*-th population
$x_{i,k}$	Position of the *k*-th firefly in the *i*-th population
$x_{j,k}$	Position of the *k*-th firefly in the *j*-th population
α	Randomization parameter
$rand$	Random number [0,1]
n	Population of firefly
$iterm$	Maximum iteration limit for FA
dim	Firefly movement in dimension

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