A new technique for the reconfiguration of radial distribution network for loss minimization

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Abstract— Over 50 years Malaysia is using the same power transmission channel from the colonial of the British. It is very old and needs some improvement especially in distribution network system. An increment of load demand and losses occurrences in distribution network system have worsen the existing condition. Pertaining to that, a reconfiguration of the distribution network is introduced to resolve the problem. In this paper, a new technique called as Improved Genetic Algorithm (IGA) for reconfiguring distribution network simultaneously implemented with the placement of small scale power generation or Distributed Generation (DG) is presented. Both conventional and improved genetic algorithms are employed within parameter constraint to be significantly compared in response to power losses and voltage profile performances. The algorithm process is initially started with the search solution for the best switching combinations throughout 33 IEEE distribution bus systems. The results convey a better improvement in performance of the improved method compared with the genetic algorithm (GA).

Keyword-Distributed Generator, Distribution Network Reconfiguration, Improved Genetic Algorithm

I. Introduction

The large scale of power distribution was first established in early 1880s' by Thomas Edison in Manhattan. According to [1], the system enabled the street lighting consisting of 193 building with 4400 lamps in it for over 8 years. This fundamental distribution system uses DC current to generate electricity throughout the street. However, due to its limitation in transferring the electricity, an occurrences of losses and large cost of wires installation, the power distribution was changed by Nicola Tesla in early 1890s' to the AC power system in which has won the 'war of current' by applying the concept of step up and step down current using transformer to deliver power at distant area. Hence, AC power is used till now to distribute the electricity. However, neither AC nor DC power can cater the power outage or losses occurrence in the system [2].

Malaysia itself had faced multiple times of power shortage or known as blackout over these 20 years. It occurred due to the growth of population and development across the country. The worst power losses Malaysia had ever encountered started in 1992 when transmission and distribution are strike by a massive lightning. This accident causes hours of power shortage in all peninsular. While at Sarawak in 2013, it faced the same problem for over 6 hours of blackout, reflected from the load drop at Bakun dam, formerly known as the largest power generation at Sarawak. As a result of power shortage problems, customers at the affected region might experience major problem to do routines in their daily lives. Some approaches [3-5] are suggested to solve the problem such as providing alternative routes to deliver power supply at the affected area and the installation of distributed generator at certain busses.

A technique known as Distribution Network Reconfiguration is introduced to optimize planning of distribution network. It is said to be the most reliable technique to reduce power losses and improving voltage profile of the network [6].As distribution system consists a group of interconnected radial network connected with two types of switches known as sectionalized (normally close) and tie (normally open) switches, DNR will find the correct combination of this set of switches that provide a better performance of the system. The reconfiguration cannot be in loop to prevent any back flow of the power supply. Hence, if any fault occurs the affected area is isolated while the others received supply as usual. The successions of DG implementation depend closely to its location and sizing [4, 11]. Thus, a study in determining the best solution of these two parameters should be conducted.

II. Method of Implementation

The implementation of genetic algorithm (GA) and improved genetic algorithm (IGA) is stated.

A. Genetic Algorithm

As stated in [5], a natural way of producing new generation with improved traits from their parents chromosome is possessed by undergoing a process of evolution. The chromosomes in the distribution network problem refer to the sets of possible routes that have minimum values of power losses. The evolving process is done by genetic operators including of generation, mutation of the chromosomes and crossover. The operators choose the fittest solution to produce new generation. As the number of buses increased, the length of chromosomes is also increased. Consequently, more computation time is required that correspond to the occurrences of premature convergences. Another factor contributes to the performances of algorithm is the ability of the GA in solving the global search, instead of local search. Thus, it affects the performances of the algorithm.

B. Modified Genetic Algorithm

The search technique can be accelerated by eliminating the unfit candidates to undergo the process. In this research, the GA has been improved at the selection operator by re-ranking the candidates according to their fitness value [7]. The implementation of IGA can be seen as in Fig. 1.

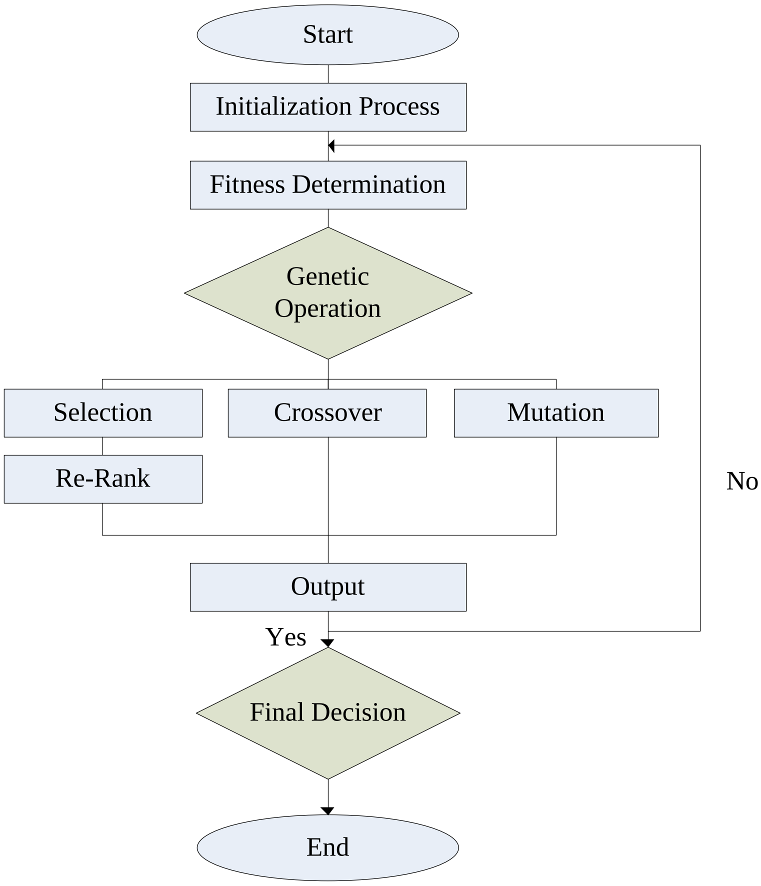


Fig. 1. IGA Flowchart

The affirmation requirement consisting of five (5) selection numbers for possible tie switches and the probabilities of crossover and mutation occurrences must be compulsorily done. In genetic operation, the possible chromosome or known as candidate is processed to become new offspring in each iteration. There are three main operators used in IGA, namely selection, crossover, and mutation. Based on these operators, new populations of better traits are performed.

1) Selection operator is improved in this paper by re ranking the candidates according to their fitness value. In selection process, the probability of percentages selection is determined by fitness value, where the percentages of probability selection should be higher for many chances of possible candidates to be selected. In order to get the percentages probability, fitness value must be divided with its average value. This method of selection is

known as Roulette-Wheel selection. The higher fittest value of candidates will result in higher chances to be selected to form new generations.

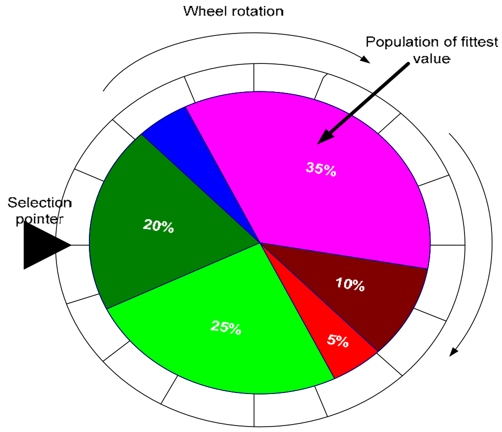


Fig. 2. Analogy of Roulette Wheel Selection

2) One point crossover operator is used to swift the genes at each parent candidates in order to generate new offspring with better characteristics.

3) Mutation operator is a unique operator where it creates a random new trait of chromosome with totally different genes from its parent. However, mutation operator needs a limitation to prevent a formation of unhealthy offspring. It is controlled by choosing a lower rate of mutation probabilities.

After the new population is generated, all new individuals with successive reproduction will be undergoing selection as the best solution in determining DG sizing. The successive selection is improved by reproducing the better trait to become the best. The placement of DG is fixed at bus 6, 12, 25, 32. The sizing of DG is controlled by the boundaries set up to prevent any backflow. The value of DG must be equal to the value of minimum power required at that bus to prevent from higher of cost DG installation.

C. Algorithm Steps

The algorithm steps of IGA are stated as below:

Step 1: Define N as number of population, k as number of iterations and x as the possible selected tie switches. The proposed algorithm start searching for first possible tie switches x1 for their total power losses using Newton-Raphson Method and the process continues until maximum number of iterations reached. The possible tie switches are listed in matrix form, declared as output1.

Step 2: Improved selection operator takes place where output1 is read and adjusted according to their total power losses. The possible tie switches are listed accordingly from the best case of power loss reduction to the worst case of power loss reduction. As an additional to that, the percentage of total power losses for each tie switches is calculated as:

$$\text{Power loss (\%)} = (\text{total power loss}/\text{number of population})*100. \quad (1)$$

Step 3: Perform crossover and mutation under consideration of pc and pm value.

Step 4: Consider re-fitness calculation for the new (population) combination of tie switches.

Step 5: The process ends when the optimal output is obtained

The initial population is randomly selected and encoded into binary bit where it depends on the length of the chromosome. Then, the power flow of newton Raphson is used to find the possible route with minimum power losses. Power flow in normal condition is set as a base point. Base point acts as a benchmark to rate the possible solution that can be used in determining the DG size. It compared the change of network flow and voltage during the changing of switches. Operators predefined the following parameters in MATLAB software such as:

- Number of buses and lines
- Types of buses (PQ or PV buses)
- Voltage magnitude and its angle
- Load at each buses

These parameters are essential in doing Newton Raphson method as shown in equation (2), (3) and (4). The number of iterations should be selected in order to produce accuracy.

$$P_i = \sum_{j=1}^{Nb} \left| Y_{IJ} V_J V_I \right| \cos\left[\theta_{IJ} + \delta_J - \delta_I\right] \quad (2)$$

$$Q_i = \sum_{j=1}^{Nb} \left| Y_{IJ} V_J V_I \right| \sin\left[\theta_{IJ} + \delta_J - \delta_I\right] \quad (3)$$

where, P_i and Q_i : active and reactive power of I, Nb: number of buses, Y_{IJ} : element in bus admittance matrices, V_I and V_J : voltage at bus i and j and θ_{IJ} : angle of Y_{IJ}.

For determining the losses, following equation is used:

$$Minimize\ losses = \sum_{t=1}^{Nl} \sum_{k=1}^{l} \left| I_k \right|^2 R_k \quad (4)$$

where, N*l*: number of load level, I_k: current flow in branch k, *l*: number of feeder and R_k: resistance at branch k.

In fitness determination process, the possible solutions produced from encoded of load flow analysis is screened with fitness function. If the chromosomes have deficiency and unfit to undergo mutation, these chromosomes are called as unfeasible solution. The listed chromosomes must be screened to ensure it fits to undergo genetic operation. The constraints that have been set are as below:

- Crossover probabilities of 0.5
- Mutation probabilities of 0.4
- 20 number of population

The unhealthy chromosome is terminated while the successful one is gathered in the mating pool for the genetic operation. In this research, the fitness function is determined by using following equation:

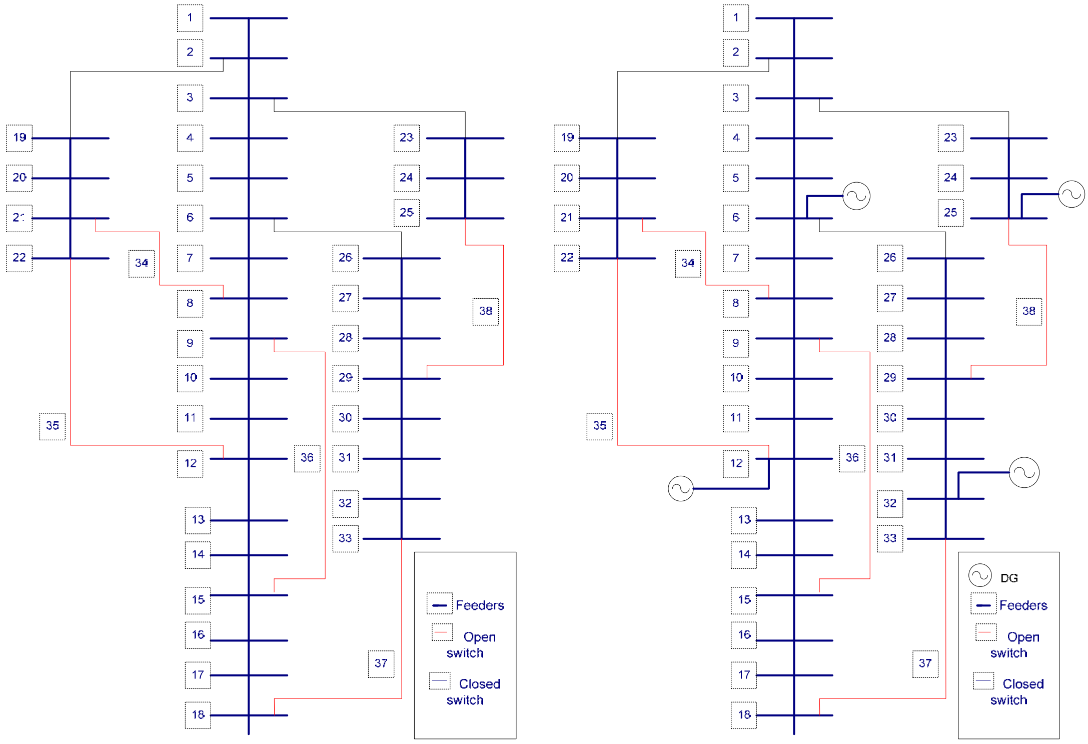
$$P(I_K) = \frac{f(I_K)}{\sum_{i=1}^{N} f(I_i)} \quad (5)$$

where, P (I_K)=probability of k^{th} fitness value, f (I_K)= fitness value of k^{th} , N= number of population, f (I_i)= fitness value of i^{th} and k= number of fitness value

Finally, the GA is compared between the successive population with the initial point of losses and voltage profile given from IEEE to ensure that the solution is improved towards the tested network before it can be chosen as the best solution. The least solution which is less than the base point is considered as optimum solution for proposed location otherwise, the proposed location and sizing is inconsiderable. Then, a new suggestion is computed.

III. TESTED SYSTEM

The modified algorithm is simulated in 33 IEEE distribution busses [8-11]. Four (4) DGs are connected at buses of 6, 12, 25, and 32 to be performed simultaneously with the network reconfiguration. The test system consists of 38 switches whereby 5 of them are tie switches and the remaining 33 are sectionalizing switches. Fig. 3(a) below shows the initial state of the 33-bus distribution system before it undergoes any changes from the proposed algorithm of this paper, while, Fig. 3(b) shows initial system with distributed generator (DG).



(a) (b)

Fig. 3(a). Initial 33 bus IEEE test system, (b) 33 bus system with DG

Before conducting the algorithm, the parameters range must be signified for ensuring the network stability in optimizing the power losses. Significantly, the system is prevented from being overloaded that lead to fault occurrence. The parameters are stated in TABLE I below:

TABLE I
Algorithm Parameters

Power	$P_i^2 + Q_i^2 \le S_i^2$
Voltage	$V_{\min} \le \lvert v_i \rvert \le v_{\max}$
Apparent Power	$\sum S_{generation} = \sum S_{load} + \sum S_{losses}$

1) Power

For the power capacity, the summation value of active and reactive power at each bus must be less than or equal to the apparent power.

2) Power

Compulsorily, the configuration of the network must be in radial structure to ensure all the feeders are supplied with power whenever any fault happen. The voltage should be in limit to prevent from overload.

3) Power balance

For the generation power, it must be equal to the usage power and the losses power for balancing. The losses must be reduced to prevent from wasting of generating sources such as coil and oil.

4) Distributed Generator (DG)

The comparisons of power, reactive power, voltage and DG sizing are clarified before and after DG installation for algorithm performances purpose as represented in TABLE II below:

TABLE II
Minimum requirement of DG

Requirement	Achievement
Active(PL) and reactive (QL) losses	P_L with DG ≤ P_L without DG Q_L with DG ≤ Q_L without DG
Voltage constraint •Voltage of any bus should be within the range	V bus-min ⩽ V bus ⩽ V bus-max
DG sizing •The sizing should within the specific range	25% load value ⩽ DG size ⩽ 75% load value

IV. RESULT ANALYSIS

The test system consists of 5 normally open switched and 28 normally closed switch is randomly selected to produce the best route if fault occurred. By improving the selection operator, the process is easily implemented and less computation time when the possible solution is ranked according to their fittest.

The voltage profile and power losses for three different switches are selected in conventional GA and IGA. The comparison will show that by altering the number of switches give significances factor in reducing the power losses. The effectiveness of DG implementation also gives a big impact in reducing losses and improved voltage profile.

Fig. 4 shows a graph for 20 times iteration of IGA in generating power losses shading for various set of switches selected. Obviously, two switches selection indicate the minimum power losses reduction among others. Four numbers of switches also show same pattern of increment with 2 set until 14th iteration where they starts to reduce more on power losses. The sharp climb remains until 17th iteration to 0.46p.u while two switches only able to reduce 0.19p.u at the same iteration.

The selection of five switches 5 opened the entire loop in the system, indicating the highest starting value of losses at its 1st iteration by 0.145p.u. The power losses are then steadily increased up to 20th iteration. Hence, the IGA is evidently proven to increase the reduction of losses for each iteration.

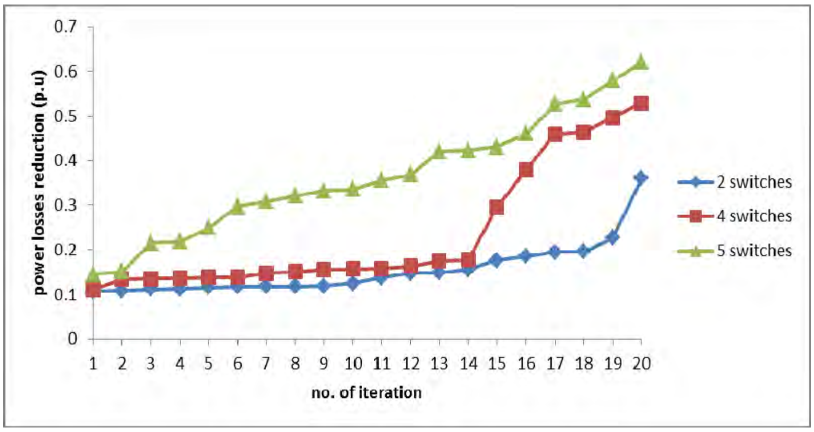


Fig. 4. Power losses reduction on various switches selected for IGA

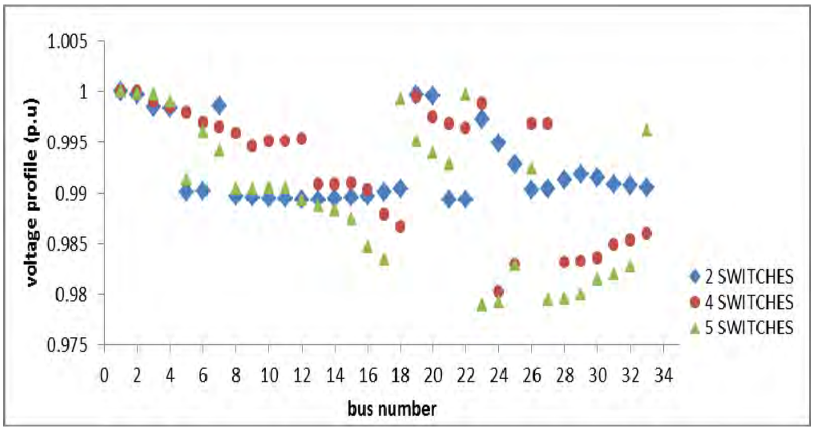


Fig. 5. Voltage profile comparison between various set of switches

The increment of voltage profile for various set of switches selected in the proposed algorithm is displayed in Fig. 5 above. All set of switches show same pattern of the increment but difference values of voltage profiles. Two switches selection mostly maintained its buses voltage at 0.990p.u. The voltage profile appeared to increase at busses number 7, 19, 20 and 24 ranging from 0.998pu to the ideal limit of 1.0p.u. However, the voltage profile for four and five switches selection fluctuated in each bus. For four switches, the highest voltage generated is 1.0 p.u at bus 2, but declined to 0.982 p.u at certain number of buses such as 18, 24, 25, and 30. Similar pattern is produced for five switches selection. This can be due to the load demand at each buses is greater when more switches is selected.

Although the GA served the same purpose with the IGA in deflating power losses and increasing the voltage profile, the IGA has fittest candidate to generate better result and reduce computational time. It is proven by the graph of comparison between IGA and GA for 5 switches selected as in Fig. 6 and 7 below.

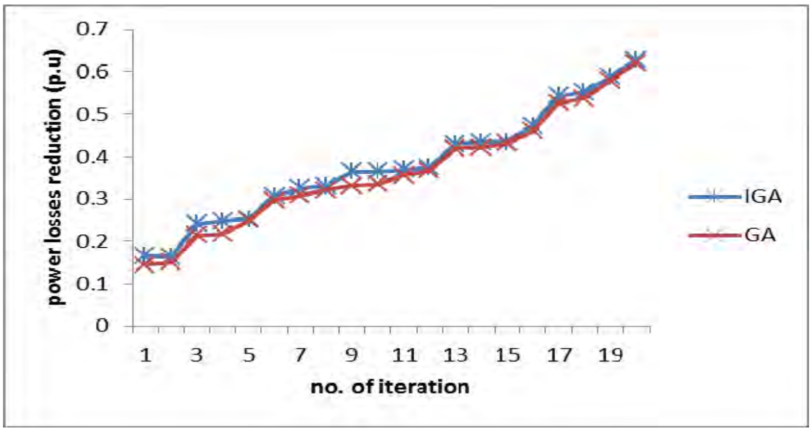


Fig. 6. Losses comparison for 5 switches selected between IGA and GA

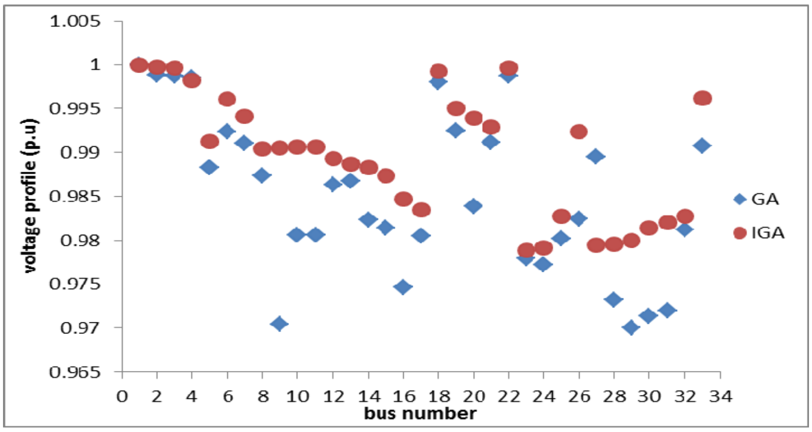


Fig. 7. Voltage profile at each bus between IGA and GA

From Fig. 6 and 7 above, the comparison between GA and IGA can be seen clearly in computational time. The computational time for IGA is faster than GA by 5 seconds. From Fig. 6 above, power losses reduction using the IGA led the graph by reducing much power in each iteration compared to the GA. At the 20th iteration, the IGA managed to reduce up to 0.628p.u from 0.165p.u at 1st iteration while the losses reduction in GA went from 0.146 p.u at 1st iteration to 0.621 p.u at maximum number of iteration. On the other hand, voltage profile each of bus using IGA gives better increment than GA. As shown in Fig. 7, an IGA point is always at the top of GA point. Consequently, better result is shown by using IGA compared to GA. The voltage at each bus is still in the range of 0.95p.u to 1.05p.u which is bearable to the system.

V. Conclusion

The selection operator developed in this paper enables the power losses to be organized orderly from minimum to maximum losses and improve voltage profile with lower convergence rate. Apart from that, the switches selection as pre-determined by user provides adverse effect in reduction of power losses whereby more switches selection contributes to more losses reduction. In comparison to the GA that retains longer processing time especially in a large distribution network, the IGA effectively reduce the computational time for the possible solution process.

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REFERENCES

[1] Jizhong Zhu, Optimization of Power System Operation (John Wiley & Sons, 2009).
[2] Esmaeilian, H.R, Fadaeinedjad R, Attari S.M, Distribution Network Reconfiguration to Reduce Losses and Enhance Reliability Using Binary Gravitational Search Algorithm, IEEE Electricity Distribution 22nd International Conference: 1-4, June 2013.
[3] Yitao Hu, Ning Hua, Chun Wang, Jiaolong Gong, Xiangshuo Li, Research on Distribution Network Reconfiguration, IEEE computer, mechatronic, control and electronic engineering conferences Vol.1:176-180, August 2010.
[4] Zuhaila Mat Yasin, Titik Khawa Abdu Rahman, Influence of Distributed Generator on Distributed Network Performance on Network Reconfiguration for Service Restoration, IEEE Power and Energy Conference: 566-570, November 2006.
[5] N.H. Shamsudin, N.F. Omar, M.F. Sulaima, H.I. Jaafar and A.F.A. Kadir, 2014. The Distribution Network Reconfiguration Improved Performance of Genetic Algorithm Considering Power Losses and Voltage Profile. International Journal of Engineering and Technology, Vol.6, No.2, pp.1247-1258.
[6] Jin lu, Qi Luo, Jun-Young Liu, Chuan Long, An Improved Particle Swarm Optimization for Reconfiguration of Distribution Network, IEEE Natural Computation 4th International Conference Vol 4: 453-457, October 2008.
[7] N.H. Shamsudin, M. S. Mamat, A.F.A. Kadir, M.F. Sulaima, M Sulaiman, 2014. An Optimal Distribution Network Reconfiguration and Sizing of Distributed Generation using Modified Genetic Algorithm, International Journal of Applied Engineering Research, Vol.9, No. 20, pp. 6765-6777.
[8] Mohamad Fani Sulaima, Nur Hazahsha Shamsudin, Hazriq Izzuan Jaafar, Wardiah M. Dahalan, Hazlie Mokhlis, 2014. A DNR and DG Sizing Simultaneously by Using EPSO, 5th International Conference on Intelligent Systems Modelling and Simulation, pp. 405-410.
[9] M. F. Sulaima, S. N. Othman, M. H. Jali, M. S. Jamri, M. N. M. Nasir, Z. H. Bohari, A 33kV Distribution Network Feeder Reconfiguration by Using REPSO for Voltage Profile Improvement, International Journal of Applied Engineering Research, 9(18), pp. 4569-4582, 2014.
[10] M. F. Sulaima, M. F. Mohamad, M. H. Jali, W. M. Bukhari, M. F. Baharom, Comparative Study of Heuristic Algorithm ABC and GA considering VPI for Network Recconfiguration, IEEE 8th International Power Engineering and Optimization Conference, pp. 182-187, 2014.
[11] M. F. Sulaima, N. F. Napis, M. K. M. Nor, W. M. Dahalan, H. Mokhlis, DG Sizing and DNR based on REPSO for Power Losses Reduction, IEEE 8th International Power Engineering and Optimization Conference, pp. 99-104, 2014.

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