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An Improved Genetic Algorithm for Power Losses Minimization using Distribution Network Reconfiguration Based on Re-rank Approach

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Abstract: This study presents the implementation of Improved Genetic Algorithm (IGA) to minimize the power losses in the distribution network by improving selection operator pertaining to the least losses generated from the algorithm. The major part of power losses in electrical power network was highly contributed from the distribution system. Thus, the need of restructuring the topological of distribution network configuration from its primary feeders should be considered. The switches identification within different probabilities cases for reconfiguration purposes are comprehensively implemented through the proposed algorithm. The investigation was conducted to test the proposed algorithm on the 33 radial busses system and found to give the better results in minimizing power losses and voltage profile.

Keywords: Distribution Network Reconfiguration (DNR), distribution systems, Genetic Algorithm (GA), Improved Genetic Algorithm (IGA), power losses

INTRODUCTION

In 1992, Malaysia suffers from a total blackout due to the lightning that strikes onto the transmission facility and leads failure for both transmission and distribution system. Another major disturbance occurs on the transmission line at Terengganu tripped. The power system network tripped and caused blackout once again in 1996 and consequently affected to Kuala Lumpur, Selangor, Putrajaya, Johor, Melaka and Negeri Sembilan for several hours. After that in 2003, a power failure caused 5 h of blackout that affected southern parts of Peninsular Malaysia including Malacca, Johor, Selangor, Negeri Sembilan and Kuala Lumpur. Then followed by 2005 the faults occurred at the main cable transmission line grid that caused blackout in northern peninsular including Perak, Penang, Kedah and Perlis.

Nevertheless, numerous reports were brought up regarding blackout around Peninsular Malaysia, Sabah and Sarawak in 2013. These kinds of circumstances happened because the distribution system itself suffers from overloaded, load variations, malfunction of equipment and damaged by third party or work quality (Niza Samsudin, 2009). Hence, many algorithms researches have been conducted mainly on conventional optimization approaches, heuristic techniques and artificial intelligence techniques (Cheraghi and Ramezanpour, 2012) with the aim of reducing the power losses at distribution system.

A discrete branch and bound method was introduced in Cheraghi and Ramezanpour (2012) in order to reduce power losses in distribution network. It involved meshed network by initially closing switches in the network. Then, a new radial configuration is reached by opening switches one at a time. While according to Hu *et al*. (2010), a modified heuristic algorithm is introduced to restore the service and load balance. This method is done through a modified fast decoupled Newton-Raphson Method to check the operation constraints.

A study in Zhao *et al*. (2012) offered a heuristic reconfiguration based on branch exchange to reduce power losses and to ensure balance of loads in feeders. However, this type of reconfiguration was very time consuming and it does not simply solve complexes constraint problems. While a study conducted in Zhao *et al*. (2009) that is applicable in radial-type distribution system presents optimization of radial distribution systems using an efficient algorithm by network reconfiguration and capacitor allocation. Through the usage of both capacitor allocation and dedicated genetic algorithm with special crossover and mutation operators, real power losses at 69-bus test system and 135-bus test system are reduced. Hence, by acknowledging the limitation of GA in solving the losses minimization of distribution network, an improved GA needs to be introduced.

This study proposes the use of IGA to reduce the power losses in the distribution network with an improvement in selection operator and the adjustment of crossover and mutation probabilities. The different probabilities cases for reconfiguration purposes are

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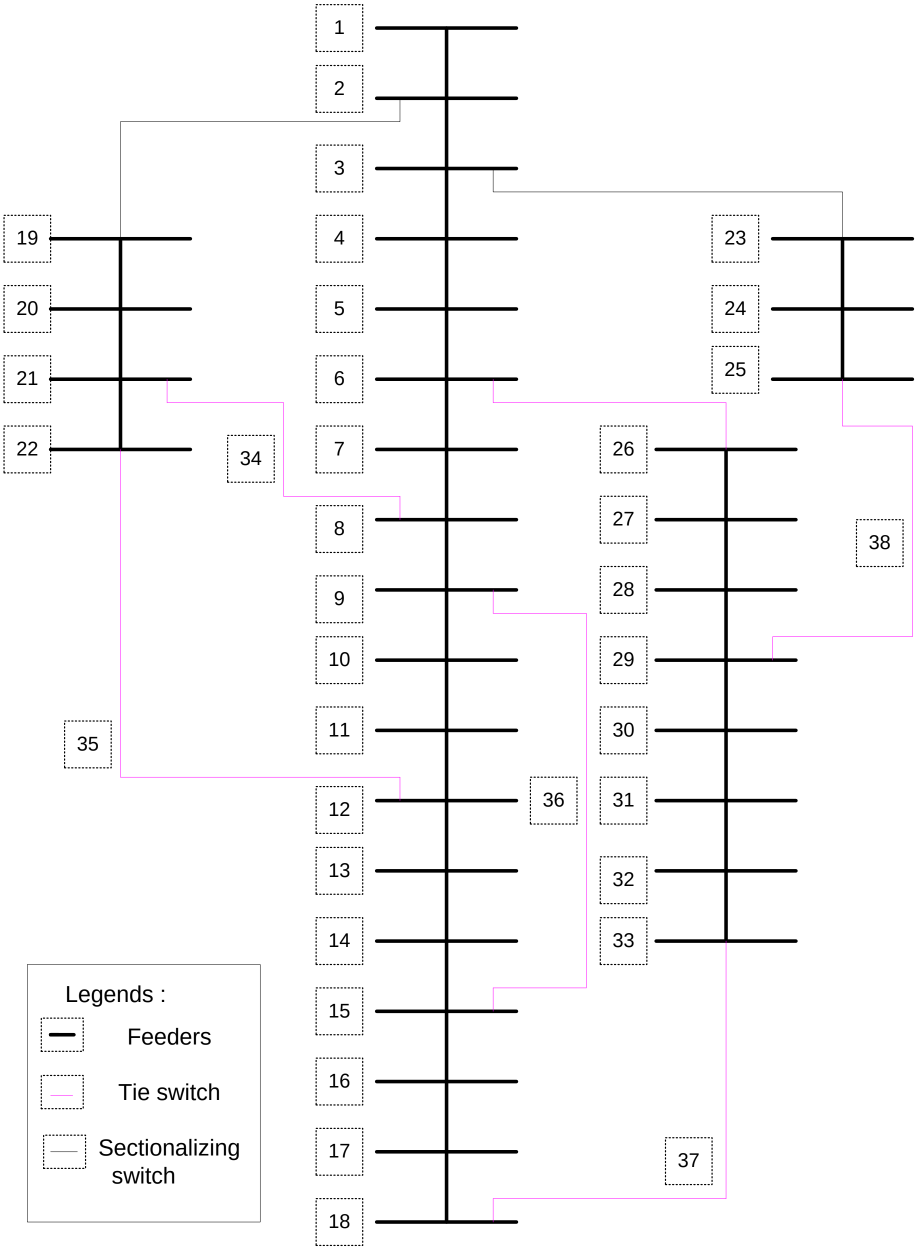

Fig. 1: Radial 33-bus network after reconfiguration

conducted through the proposed algorithm for switches identification. The IGA used re-rank approach to reduce the power losses and improve voltage profile of a 33-bus radial distribution network.

Model description: To demonstrate the effectiveness of the proposed algorithm, the radial 33-busses system is used which consists of 33 nodes, 38 switches where 5 of them are tie switches and the remaining 33 are sectionalizing switches (Shamsudin *et al.*, 2014; Sulaima *et al.*, 2013, 2014a, b). Figure 1 illustrates the distribution network after reconfiguration has been implemented.

METHODOLOGY OF IGA

A conventional GA seems to find global optimum when operating on a large scale systems and it cannot maintain constant optimization response time (Guimaraes *et al.*, 2010; Ritthipakdee *et al.*, 2013). Thus, implementing IGA in fact solve the constraint encountered by conventional genetic algorithm, unravel the global optimum faced in large scale systems and reduce the computational time. It has three essential genetic operators which are selection, crossover and mutation. The process of IGA applied in this study is presented below in Fig. 2 whereby the improvement is made towards the selection operator.

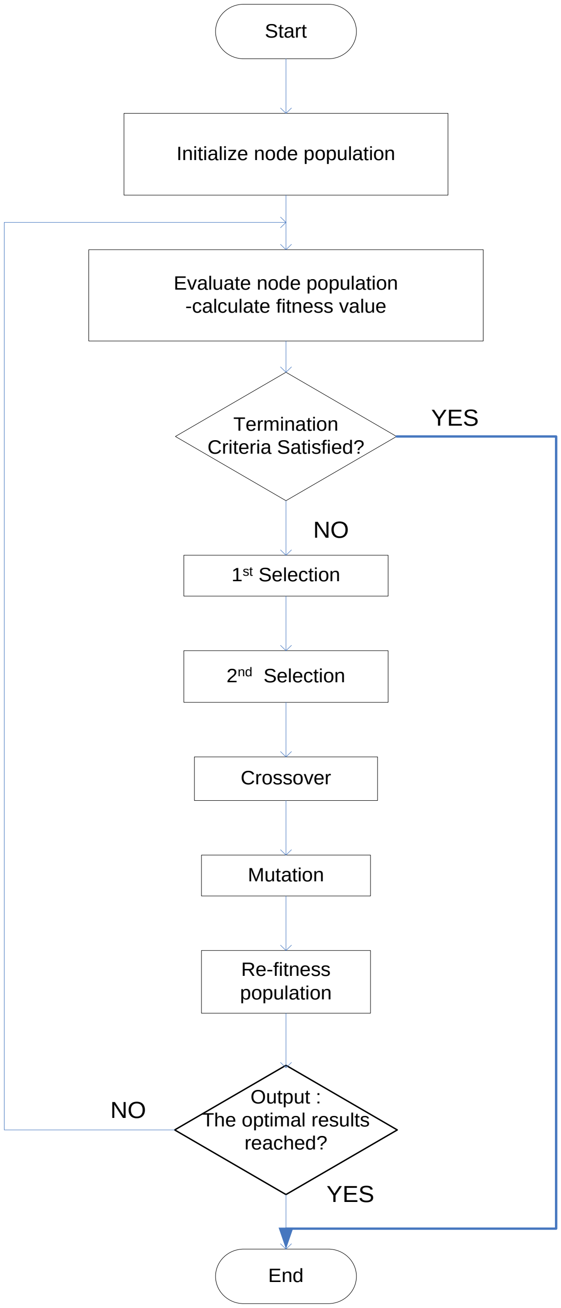

Fig. 2: Flowchart of IGA

The IGA procedure was briefly explained in accordance of their genetic definition followed by the working principle of the IGA.

Initialization: The availability for number of switches in the network reconfiguration is randomly generated from number of population selected for the initial implementation of the algorithm.

Fitness function: Genetic Algorithm is about finding the best generation from generated individuals or chromosomes. The individuals or chromosomes are evaluated according to their fitness value (Li *et al*., 2010; Shakerian *et al*., 2010). For IGA applied to distribution network, the individuals or chromosomes is represented by number of switches while power losses for each switches denotes fitness value for each individuals or chromosomes. The evaluation process is employed whereby at this stage fitness value is being calculated with the following equation:

$$Pi = \sum_{i\neq 1}^{n}\sum_{j\neq 1}^{n} A_{ij}(P_iP_j + Q_iQ_j) + B_{ij}(Q_iP_j - P_iQ_j) \tag{1}$$

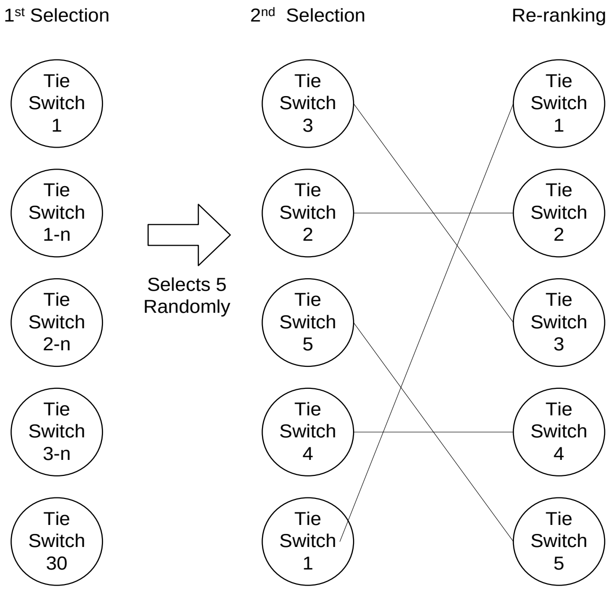

Fig. 3: Working principle of IGA

$$Aij = \frac{R_{ij}\cos(\delta_i - \delta_j)}{V_i V_j} \tag{2}$$

$$P_{loss}(\%) = \frac{P_{total}}{N}\ x\ 100\% \tag{3}$$

where,

P_i, Q_i = Real and reactive power at bus i, respectively
P_j, Q_j = Real and reactive power at bus j, respectively
R_{ij} = Line resistance of bus i and j
V_i, V_j = Voltage magnitude of bus i and j, respectively
δ_i, δ_j = Voltage angle of bus i and j, respectively
P_{loss} = Power losses for each tie switches
P_{total} = Total power loss

Determining the termination criteria: When applying this IGA, termination condition has to be specified at the earlier stage of implementing the algorithm. The termination condition is shown as:

Number of population = 30
Number of individuals for each population = 5
Maximum number of iterations = 10

An improved genetic algorithm: Selection process has been selected to be improved in this algorithm. The improved process is primarily depicted as shown in Fig. 3. Firstly, the first selection consisting of randomly listed 30 populations is done towards the network configuration within the termination criteria specified. While the termination criteria are being achieved, the population obtained will experience the second process of selection consists of only 5 randomly listed populations and then the re-ranking process takes place to put the second selection of population in ascending order of power losses, so as to assist the researcher for fast and optimal solution of total power losses obtained for each tie switches.

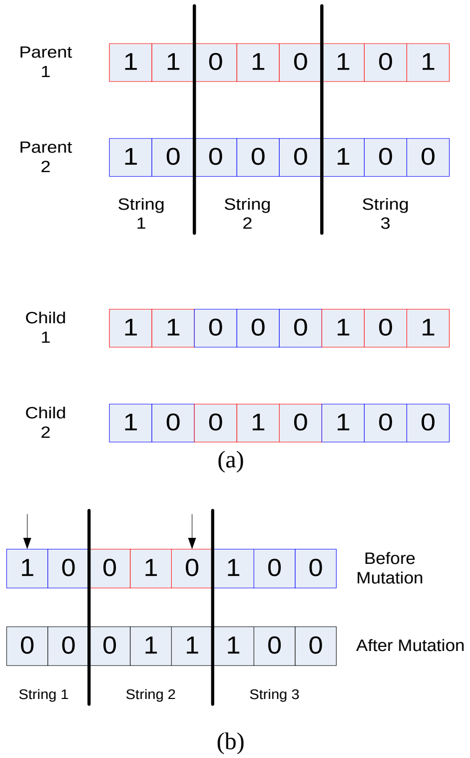

Fig. 4: DNA of genetic operators, (a) an example of crossover technique (b) an example of mutation in one generation technique

Crossover: This is the critical feature of IGA because it hugely accelerates search in the earlier evolution of a population and also guides an effective combination of sub solutions between non-similar chromosomes. The two offspring are generated from two parents where each offspring holds few genetic features of each parents.

Hence, applying this same concept of conventional genetic algorithm, crossover operator simply picks any combination of 5 switches under 2nd selection with probabilities of 0.7 and the result is being continued to mutation operator. The process continues until the maximum number of iterations is achieved.

Mutation: Conventional GA applies mutation operator to each offspring that being produced to avoid of trapping at local optimum and this operator only creates small changes to the offspring to stimulate diversity. Figure 4 portrays the DNA of IGA whereby Fig. 4a and b are the examples of crossover and mutation techniques accordingly.

CASE STUDY

The aims of the proposed algorithm are to reduce total power losses and to improve the voltage profile of the initial radial 33-bus test system. In order to verify the performance of network reconfiguration, 4 cases of crossover probability (cp) and mutation probability (cm) are being considered, as listed in the Table 1.

It can be seen from Table 2, the four cases involving the alteration of crossover and mutation probabilities essentially reduce the total power losses obtained to the network reconfiguration. As for case 1, a total of 67.2 kW power losses are reduced whereas only 61.2 kW is reduced for case 2. In the case of cm adjustment, the combination of tie switches 15, 27, 33, 8 and 12, respectively in case 1 produces 135.4 kW of total power losses meanwhile the same adjustment in case 2 produces 141.4 kW with tie switches of 28, 4, 9, 14 and 16, respectively. Hence, this shows that low value of cm, 0.4 is able to produce greater reduction of power losses compared to high value of cm, 0.6.

Meanwhile for case 3 and 4 with the adjustment of cp, case 4 demonstrates the highest percentage of total power losses reduction which is 21.10% whereas case 3 is only 16.44%. By having 132.0 kW of total power losses with tie switches 13, 7, 15, 27 and 10, respectively, case 4 is far better than case 3 that shows total power losses of 145.4 kW with tie switches

Table 1: 4 Cases considered

	Case 1	Case 2	Case 3	Case 4
Crossover probability (cp)	0.7	0.7	0.5	0.7
Mutation probability (cm)	0.4	0.6	0.6	0.6

Table 2: Tie switches and power losses

		After reconfiguration			
	Base case	Case 1	Case 2	Case 3	Case 4
Tie switches	34, 35, 36, 37, 38	15, 27, 33, 8, 12	28, 4, 9, 14, 16	8, 6, 5, 9, 16	13, 7, 15, 27, 10
Total power losses (kW)	202.6	135.40	141.40	145.40	132.0
Total power losses reduction (kW)	-	67.20	61.20	57.20	70.6
Percentage of total power losses reduction (%)	0	19.88	17.81	16.44	21.1

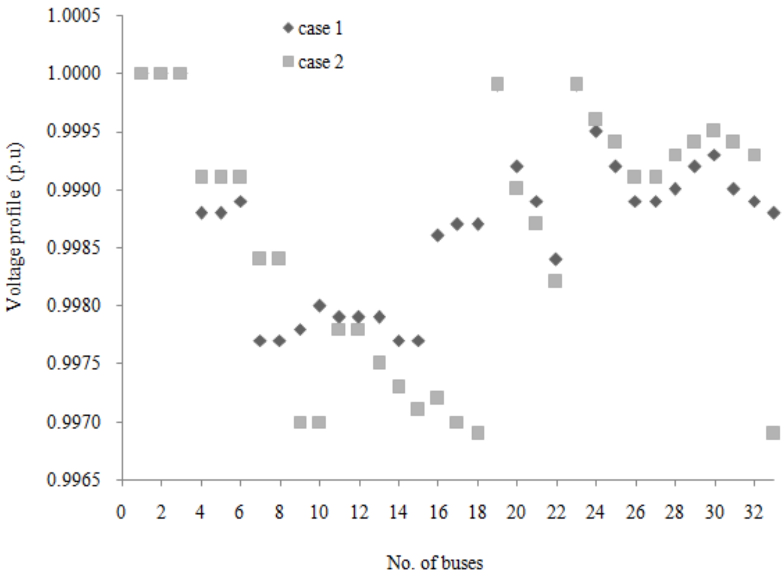

Fig. 5: Voltage profile for case 1 and 2

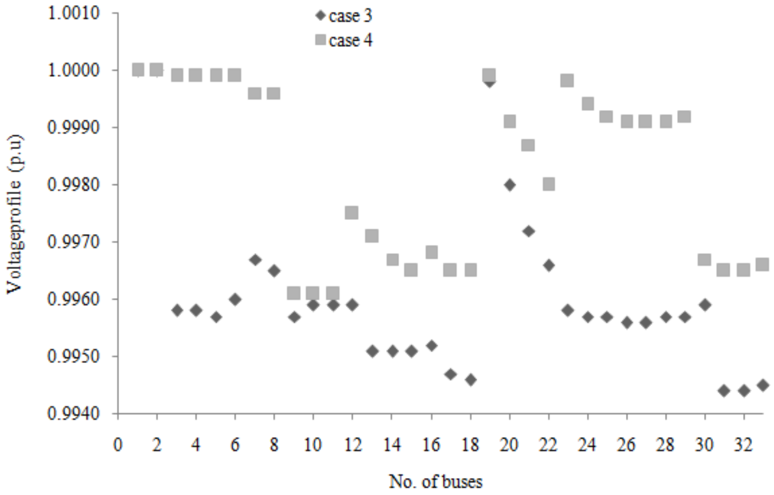

Fig. 6: Voltage profile for case 3 and 4

Table 3: Comparison of GA and IGA for case 4

After reconfiguration for case 4	Methods	Tie switches	Percentage of total power losses reduction (%)
	GA	9, 4, 31, 7, 13	15.60
	IGA	13, 7, 15, 27, 10	21.10

8, 6, 5, 9 and 16, respectively. Nevertheless, it can be said that a high cp value of 0.7 yields a better reduction of power losses compared to the low value of cp, 0.5.

As depicted in Fig. 5, voltage profiles for case 1 and 2 show only a slight difference at each number of buses. Initially, the voltages for both cases are at maximum before they dropped slightly from bus number 4 until bus number 8, whereby the voltage for case 1 dropped more than that of case 2. For bus number 9 until bus number 15, case 2 has greater fall compared to case 1, but reflecting the close proximity of the respective voltage profiles for both cases. The voltage profile between case 1 and 2 starts to differ extensively from bus number 16 to bus number 18 and both cases achieve the maximum value again at bus number 19.

From bus number 20 onwards, case 1 and 2 show small dissimilarities in their voltage profiles, but the dissimilarities start to increase from bus number 31 to bus number 33, with the bus number 33 possesses the largest difference.

Figure 6 displays the voltage profile obtained for cases 3 and 4 after the alteration of cp value takes place. From a brief overview, case 3 shows vast difference of voltage profile compared to that of case 4. At bus number 3, voltage profile for case 3 abruptly dropped to 0.9959 p.u while case 4 maintained its voltage profile near to the maximum value. However the pattern changed at bus number 9, where the value for case 4 excessively falls to 0.9961 p.u. Bus number 19 shows great improvement in voltage profile where it increases from 0.9965 p.u for case 4 and 0.9945 p.u for case 3 to the maximum value. Then at bus number 20, the voltage profile in both cases drops whereby case 4 is at 0.9980 p.u and case 3 at 0.9958 p.u. For the bus number 21 and onwards, cases 3 and 4 happened to be regulated by their previous bus number value and continues until bus number 33.

After analyzing all four cases for the regulated cp and cm values, the minimum cm value in case 1 and maximum cp value in case 4 exhibit better results compared with the other two cases. Genetically, the chosen bits in the next reproduction are complemented by mutation and crossover is the possibility of producing a good offspring in the next reproduction, thus showing that a high cp value and a low cm value is needed to yield good offspring and at the same time maintaining their genetic diversity.

In this study, case 4 is capable of demonstrating the highest reduction in power losses and greatest improvement of voltage profile. In order to verify the results obtained in case 4, it is compared with the conventional GA, as shown in Table 3, using the same value of cp and cm. After the simulation, it shows that the IGA has 21.10% reduction of power losses but the conventional GA only shows reduction of 15.60%. The probabilities utilized for both conventional GA and IGA are similar but different set of tie switches are produced due to the algorithm implementation that randomly search the set of tie switches identification with the best power losses reduction. As depicted in Table 3, conventional GA finds 9, 4, 31, 7 and 13 as its best set of tie switches while IGA search for the best set of tie switches from 13, 7, 15, 27 and 10, respectively. Instead of using conventional GA, a better improvement in voltage profiles can also be attained by using the improved GA.

CONCLUSION

An adjustment of crossover and mutation probabilities proposed in this study is used to improve the performance of conventional GA in terms of total power losses reduction and voltage profile improvement. The proposed algorithm is applied to a radial 33-bus test system, simulated into MATLAB software thus showing that case 4 produced the highest reduction of power losses and the best improvement of voltage profile compared to conventional GA and the other 3 cases involved. However, for further validation of the proposed algorithm, the values of cp and cm can be varied in a wider range.

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