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Date : ……………………………………

A COMPARATIVE STUDY OF OPTIMIZATION ALGORITHMS FOR 33KV DISTRIBUTION NETWORK RECONFIGURATION

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)

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2014

I declare that this report entitle "*A Comparative Study of Optimization Algorithms for 33kV Distribution Network Reconfiguration*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

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To my beloved mother and father.

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In the name of our creator, Allah. I ask His blessing to express my sincere appreciation to my heart to all those who were involved to contribute effort, time and energy either directly or indirectly to complete this final year project report.

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ABSTRACT

Distribution Network Reconfiguration (DNR) has been a part of importance strategies in order to reduce the power losses in the electrical network system. Due to the increase of demand for the electricity and high cost maintenance, feeder reconfiguration has become more popular issue to discuss. In a network which connects all electricity form generation, transmission and distribution, the quality of the power is important. The reducing in power losses and voltage profile improvement is a major aspect to achieve an efficient and secure distribution system. In this project, comparative studies among several optimization methods which are Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) had been done. The objectives of this study are to compare the performance in terms of Power Losses Reduction (PLR), percentage of Voltage Profile Improvement (VPI), and Convergence Time (CT) while select the best method as a suggestion for future research. The programming has been simulated in MATLAB environment and IEEE 33-bus system. Artificial Bee Colony (ABC) method has shown the superior results in the analysis of two objectives function that are Power Loss Reduction (PLR) and Voltage Profile Improvement (VPI).

ABSTRAK

Penyusunan Rangkaian Pengedaran (DNR) telah menjadi sebahagian daripada strategi penting bagi mengurangkan kerugian kuasa dalam sistem rangkaian elektrik. Disebabkan oleh peningkatan permintaan bagi bekalan elektrik dan kos penyelenggaraan yang tinggi, feeder konfigurasi semula telah menjadi isu yang lebih popular untuk di bincangkan. Dalam rangkaian yang menghubungkan semua generasi bentuk elektrik , penghantaran dan pengagihan , kualiti kuasa adalah penting. Pengurangan Kerugian Kuasa (PLR)dan Peningkatan Profil Voltan (VPI) merupakan aspek utama untuk mencapai sistem pengagihan yang cekap dan selamat. Dalam projek ini, kajian perbandingan antara beberapa kaedah pengoptimuman *Artificial Bee Colony* (ABC), *Particle Swarm Optimization* (PSO) dan *Genetic Algorithm* (GA) telah dijalankan . Objektif kajian ini adalah untuk membandingkan prestasi dari segi Pengurangan Kerugian Kuasa (PLR), peratusan Peningkatan Voltan Profil (VPI), dan Penumpuan Masa (CT) manakala memilih kaedah terbaik sebagai cadangan bagi kajian akan datang. Pengaturcaraan ini telah di simulasi dalam persekitaran MATLAB dan IEEE 33 sistem bas. Kaedah *Artificial Bee Colony* (ABC) telah menunjukkan keputusan yang lebih hebat dalam analisis fungsi dua objektif iaitu Pengurangan Kerugian Kuasa (PLR) dan Peningkatan Profil Voltan (VPI).

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Motivation

Nowadays, the world improves in every aspect such as economics, politics, and technology, so does the energy. Energy involve in many aspect, they are fuel, nuclear, gas, and also electricity. In a network which connects all electricity form generation, transmission and distribution, the quality of the power is important to achieve excellent work without wasting any cost. The reducing in power losses and voltage profile improvement is a major aspect to achieve an efficient and secure distribution system. A person or a people who live in this advance growing world all they care is for the light to turn on at time when they need it, for the power to generate when in used, to ease their life because all of them contributed their money on all of this effective lifestyle. To create a technologies world without a lack of demand so that our country will always be compatible with others in the world is not impossible.

1.2 Problem Statement

As demand for electricity in power system increasing compatible with worlds demand, it has been a crucial yet challenging task to power system engineers which require in reducing the distribution feeder losses and improve system security economically. During heavy load, a high load current drawn from the supply is increasing, which may also lead to increase in voltage drop and power losses [27]. All of this inefficient performances in distribution network that's exist will lead to increasing operation cost due to high power loss and reduced in voltage magnitude. This research will help in settling the problems.

1.3 Objective

The main objectives of this research are:

i. To analyze the power loss reduction for three heuristic methods that are ABC, PSO and GA respectively

ii. To investigate the voltage profile improvement of the IEEE 33 bus test system

1.4 Scope

This research only involve in determining the power losses reduction while considering voltage profile improvement carry out on IEEE 33 bus radial distribution network system in MATLAB environment using heuristic method Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA).

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

These parts are reviewed on five sections which are Distribution Network Reconfiguration, Voltage Profile, Power Losses, and related previous work. In Distribution Network Reconfiguration, research about the distribution network system will be presented to explain more about the distribution network system either for their type, or radiality. In voltage profile and power losses, the studies with specific research performing voltage profile improvement and power loss reduction will be shown. Meanwhile, for related previous work, it is a finding on distribution network reconfiguration for power losses considering voltage profile improvement by variety of optimization method tested on 11kV bus radial, 33kV bus radial, or 69kV bus radial.

2.2 Distribution Network Reconfiguration (DNR)

Electrical supply system have many important parts, one of them is distribution system. Distribution system is a link between power supply and utility's bulk transmission systems and consumers. Recent reported that 80% losses in a distribution network occur because of the failure in distribution systems [1]. The applied of distribution automation to the distribution feeders benefits in the customer services reliability improvement. Moreover, in primary distribution systems, switches play an important role in various applications for improving in reliability, isolate faults, reconfigure, restoring the networks, and reducing losses after a fault as said in the researches.

As the world growing, the regulations and public awareness are increased, therefore, the energy distribution utilities need to be more efficient for network efficiency as it is treated as more common around the world [2]. One of the tasks to achieve these efficiency is by reconfiguring the distribution feeders. Network reconfiguration in words mean the changes in the open and closed status of two types of switches called sectionalizing and tie in an attempt for power loss reduce in a system by relieving the overloading network components.

In [3] also stated the importance and usable operation of distribution network reconfiguration (DNR) in reducing the feeder losses while improving the system security. Feeder is where the load current can be transfer through it because of the numbers of distribution switches open and closed status and by changing their topology. While during fault occurrence, the switches helps in isolating the faults and restoring the services. DNR had become a complex decision making process for dispatchers to follow because of the numerous existing switches in the distribution systems that making the number of possible switching operation tremendous.

Distribution networks are normally radially configured and generally involved with two types of switches they are normally closed switches and normally open switches. Normally closed switches connects the line sections called sectionalizing switches, while normally open switches connect two feeders or loop type laterals called the tie-line switches. These switches are basically used for protection and configuration management. These switches topology status either open or closed are changes by network reconfiguration [4].

Based on recent studies which indicates that total wasted on power generation is up to 13% in the form of line losses at distribution level [5], therefore, it is a great benefits to find the suitable and best methods for network reconfiguration as it will help in power loss reduction and also improve the reliability of power supply which make the network more secured.

In operating and plan the distribution system, there will always be a long list of optimization problems that will occur. The problems can be a caused by network reconfiguration, which need to be alerted with certain objective function such as feeder, substation balancing, reduce losses, restoration, minimum switching and others [6]. While distribution networks are structurally meshed, they are radially operated. In fact, most optimization problems are simply aimed at finding the best radial configuration, among a huge number of combinations, for which efficient procedures to check or enforce radiality are needed.

2.3 Voltage Profile

Voltage profile can be calculated along a given transmission line during a system transient [7]. This method can be used to detect low level of voltage signals that appear along the length of a long transmission line during transients caused by switching events or faults also useful in obtaining screen shots of waveforms used in animation of travelling wave transients. Voltage profiles can be recovered at intermediates points along the length of the line using time-series model. During systems faults and switching events, power systems experience a voltage transients which may produce voltages and currents that may exceed allowable limits of operations and/or equipment.

The impacts of maintaining the load bus voltages within permissible limit will ensure the quality and reliability of supply to the consumer [8]. Changes in the power demands and system configuration will give impact towards voltage levels either high or low in the systems and by reactive power generation reallocating the voltage profile can be improved. To improve voltage profile system in a power system, it is necessary to improve the realization of reactive power generations.

By monitoring the voltage profile of distribution feeder can provide for the improvement in reliability and also the quality of the distribution power system as stated in

[9]. However, there is some constraint in economic which limit the widespread deployment of monitoring equipment. For an effective control of distribution system, knowledge on the load and voltage conditions is prior. Because of the constraints in the economic, an intelligent voltage estimation algorithm an optimization method is installed which is a more commercial approach which reduced the number of monitoring equipment and save the cost in installation also maintenance.

The security and reliability problem with the system operation will always occur if there is a stress condition in power systems. The factors such as overexploitation of existing transmission systems, limited number of new power station, are affecting them. One of these concerns also involve the voltage stability that refer to the ability in maintaining a steady voltages at all busses in the system after a disturbance occur from a given initial operating condition, maintaining and restoring the equilibrium between load demand and load supply. If the voltage instable, may results in loss of load in an area, transmission line tripping, and other elements by protective system that leads to cascading outages [10].

2.4 Power Loss

Active and reactive power in a system need to be control for power loss minimization and improving voltage profile, which by optimizing the active power flow with network reconfiguration and reducing reactive power by capacitor control can achieve these goals. Even with different properties and limitations, these two types of control will strengthen each other with their combination to achieve better results in distribution systems [11].

Considerable portion of overall loss which in practice is the power loss on distribution transformer [12]. This is due to Joule effect that there are power losses in a power distribution effect. Power losses are in the form of I^2R and it can be very large since it occurs throughout the conductors of the distribution system; it can account for 13% of the total power generation. Therefore, there have been strong incentives for utilities to try to reduce the losses. To reduce I^2R loss in a distribution system, one approach is to shorten the overall network resistant path that the current is passing through. This can be achieved by altering the network topology, known as reconfiguration.

2.5 Optimization Methods and Related Previous Work

For distribution network reconfiguration of electric energy distribution, a methodology based on Ant Colony System (ACS) algorithm is proposed in [13]. Constraints such as transmission capabilities and voltage magnitudes limits, it is said to be very flexible method in finding the optimal network with lower transmission losses. It said that ACS is the suitable method in reconfiguration because of its positive feedback, distributed computation, and greedy heuristic.

In [14], for power losses reducing in distribution network, the Network Partitioning Theory novel method is proposed which also offer numerous advantages without limitation towards the maximum size of distribution system in real time. The computational burden of the reconfiguration not only reduces by the partitioning operation serves but also minimize losses on line from the cut set. It is said that proposed algorithm can be used also in industrial and electric utility applications.

In [15], results that got reflects in distribution network reconfiguration sometimes is because of the computation time of the algorithm to finalize in the program. A method of load forecasting which adopted GA algorithm is proposed in solve the distribution network reconfiguration for power losses.

The minimum the feeder losses, the better the distribution network which will act as a target function [16]. Radical distribution network is decided each nodes in degree using Hopfield neural network and either it will be used or not. The state of switch can be decided correspondingly same as the scheme of reconfiguration. For energy function, radial supplying and feeder power losses are considered. Some line also may have no switches so the energy function takes that into consideration.

In [17], power distribution connects all from generation to consumer. The objective is to minimize the power losses of distribution network. The genetic simulated annealing algorithm is proposed which cover all the speed in simulated and solve for premature convergence in GA.

Ant Colony System Algorithm (ACSA) is proposed in [18]. In solving for the distribution network reconfiguration problem which combined with the features of distribution network, ACSA is said to simply the searching space of the distribution network structure and also improved information update strategy in reduce the local optimum. Compared with Ant Colony System, ACSA has faster speed which provides good method for distribution network optimization problem.

In [19], the contribution is a new fuzzy multicriteria decision making algorithm in emphasize the power losses reduction in a network reconfiguration. The computational system developed from flexibility of method, result in useful yet reliable easy used tool for utilities. Actual data was used and also providing the promising results for actual evaluation of the performances.

A Tabu search approach is proposed in [20]. It designed GIS that is Geographic Information System in terms of support for management, manipulation, analysis, and modeled spartial data. Tabu is a heuristic method that suitable in solving complex optimization problem for power losses. Distribution network also modeled in geometric network (GIS).

In [21], the changing of open/closed switch status modified the network structure of distribution feeder. An enhanced genetic algorithm (EGA) is proposed. The power losses is minimized and also the violation of voltage while current constraints also minimize.

For distribution system, loss reduction is important in saving the energy in [22]. The method using Ant Colony System (ACS) algorithm is proposed and is said to be very flexible in optimizes the transmission losses. Case study of Tamil-nadu Electricity Board (TNBE) consists of 14-bus transmission system, 3 generator and 11 sub-stations is taken as application of the algorithms with significant reduction and computational effort in optimal solution.

In [23], the DNRC distribution network reconfiguration based on comprehensive approach is proposed in minimize the system power losses. DNRC consist of modified heuristic method and rule base. Rules used in selection of optimal reconfiguration network which form from operations experience. Power summation based radiation distribution network load flow (PSRDNLF) is apply in order to get precise branch current also power losses and is applied in Guiyang South Power Supply Bureau.

By status change of sectionalizing switch open or close the distribution network for power losses is minimize. Tabu search algorithm is proposed and efficiently presented for distribution network optimization. Tabu method combines with switch group which adopt the coding concept for reducing infeasible solution and searched the best solution among candidates [24].

In [25], the customer interruption cost can reduce by figured network, means reducing in power losses and load balancing. This electrically supplied all load points radially by controlling the sectionalizing and tie switches of the system.

In planning the operation of electric power distribution system, topological reconfiguration is used as a tool in [26]. The main concerns in distribution operation planning are the power losses, voltage profile, and also reliability levels which need to be controlled. A new fuzzy multicriteria decision making is proposed to solve the entire problem. The flexibility of the fuzzy method provides wide audience developed tool which are useful yet reliable, while easy to use for utilities.

2.6 Summary

As presented in the previous related work, there are so many optimization methods in solving distribution network reconfiguration in minimizing power losses and voltage profile improvement. In this study, the optimizing methods which are ABC, GA, and PSO will be tested and the best optimization will be selected based on the better results in reducing power losses and voltage profile improvement in the distribution system.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this part, the process of ABC, PSO, and GA are explained in detail. It consists of four tasks. Task 1: Mathematical formulation and constraints. Task 2: Implementation method of ABC. Task 3: Implementation method of PSO. Task 4: Implementation method of GA.

3.2 Task 1: Mathematical Formulation and Constraints

The objective of the feeder reconfiguration is to minimize the total power losses. Therefore, the objective function of this study is:

$$P_{losses} = \sum_{i=1}^{n} |I_{ai}^{2}|\, R_i \tag{3.1}$$

Where:

i = Number of lines in the system

I_{ai} = Line real active current

Ri = Line resistance

The second consideration of this study is voltage profile improvement. So that, the voltage bus constraint has been set as follow:

$$V_{min} \leq V_{bus} \leq V_{max} \quad (3.2)$$

The voltage for each bus should operate within the acceptable limit which is in between1.05 and 0.95($\pm$5) in [27].

The simple constraint of radial configuration is an importance element for feeder reconfiguration. The configuration must be in radial to avoid excess current flow in the system. Therefore, in order to ensure the radial network is maintained, several constraints must be taken into account. Several standard rules have been adopted for selection of switches. Those switches that do not belong to any loop, connected to the sources and contributed to a meshed network have to be closed.

In this work, the particles consist of the tie switches *(S)* has been considered as set particles as shown in Equation (3.3).

$$X_{particle} = \{S_1, S_2, \ldots .S_\beta\} \quad (3.3)$$

Where:

β = Number of tie line switches

Only the particles that satisfy all the constraints above will be considered as the initial population.

3.3 Task 2: Implementation Method of ABC

Karaboga the founder of Artificial Bee Colony (ABC) optimization method that interested in the intelligent of the bee behavior which is foraging proposed an optimization numerical problem named Artificial Bee Colony (ABC) algorithm. In ABC there are: employed bees, and unemployed bees: onlookers and scouts. This divided by two parts between employed bees and unemployed bees. Food sources position as a solution that possible to optimization problem, while nectar amount food source represent quality (fitness).

The below steps is repeated until certain criteria achieved and satisfied:

A. Initialization Phase

Initialize the population of solutions X_{ij}within parameter j range (3.4):

$$X_{ij} = X_{minj} + rand\ (0,1) * (X_{maxj} - X_{minj}) \quad (3.4)$$

Where:

X_{minj} = Lower bound of the parameter j

X_{maxj} = Upper bound of the parameter j

B. Employed Bees Phase

Food sources V_{ij} determined which represent a site within neighbourhood in memory using formula (3.4) while sharing their information for the food sources with waiting onlookers in the hive that will pick a food sources based on employed bee information:

$$V_{ij} = X_{ij} + \emptyset ij\ (X_{ij}-X_{kj}) \quad (3.5)$$

Where:

X_k = Randomly selected solution

j = Randomly chosen parameter

$\emptyset_{ij}$ = Random number within the range [-a,a]

Greedyselection is applied between vi and xi.

Information sharing in dance area within employed bees, the prabability values P_i are calculated for solutions X_i for fitness F_{iti} values.

$$pi = \frac{fm}{\sum_{i=1}^{sn} fm} \quad (3.6)$$

Fitness value calculated:

$$fm = \begin{cases} \frac{1}{1+f1} & \text{if } fi > 0 \\ 1+abs(f1) & \text{If } fi < 0 \end{cases} \tag{3.7}$$

Where:

f_i = Cost value

C. Onlooker bees phase

Fitness based selection technique placed onlookers on food sources sites which creates new solution v_i from solution x_i (3.5)depends on pi selection.Greedy selection apply between vi and x_i for employed bees.

D. Scout Bee Phase

By (3.4), a new food sources is search by abondend employed bees that become scout. Without any guidance the scouts that colony's explorer only concern on finding any kind of food. While for artificial bees, artifical scouts had more fast discoveries for feasible solution. Artificial employed bees becomes artifial scout under circumstances such as exhausted food nectar or profitablility food drops under threshold level. The control parameter is''abandonment criteria" or "limit''. If solution is not improved by employed bees untill certain trials number, it is abonded and employed bee becomes scout. The number of trials for releasing a solution is equal to the value of ''limit''.

E. Artificial Bee Colony Algorithm for Optimization Problems.

Constrained optimization (CO) finds parameter vector *x* (8) that minimizes an objective function *f* (*x*) subject to inequality and/or equality constraints.

Minimize $f(x)$, x =(X1, X2, X3, X4,…Xn) $\in R^n$ (3.8)

$li \leq Xi \leq u_i$ i = 1,2, …n (3.9)

Subject to:

$g_j(x) \leq 0$ for j=1,2,..q (3.10)

$h_j(x) = 0$ for j=q+1, ...m (3.11)

The objective function f is defined on a search space, *S*, which is defined as a *n*-dimensional rectangle in $R^n(S \subseteq R^n)$. Domains of variables are defined by their lower and upper bounds. A feasible region $F \subseteq S$ is defined by a set of m additional constraints ($m \geq 0$) and $xinF \in S$. At any point $xinF$, constraints g_k that satisfy $g_k(x)$are called active constraints at x . By extension, equality constraints h_j are also called active at all points of S. Constrained optimization problems are hard to optimization algorithms but no single parameter (number of linear, nonlinear, active constraints, the ratio $\rho = [F]/ [S]$, type of the function, number of variables is proved to be significant as a major measure of difficulty of the problem.

3.3.1 Application ABC for Distribution Network Reconfiguration

Summarized:

1. One-line input data read; Initialize MNC (Maximum Iteration Count) and base case as the best solution;
2. Initialize the population of solutions xi,j. Open switches configure formed each bee. Employed bees number = onlooker bees.
3. Employed bee population evaluated by:

$$fitnes = \frac{1}{1+Plosses} \qquad (3.12)$$

4. If cycle = 1; repeat step
5. New population v_{ij} in neighbourhood of x_{ij} for employed bees generate using equation (3.5) and evaluate;
6. Between xi and v_i, greedy solution applied.
7. Probability values Pi for the solutions xi calculated using fitness values with equation (3.6);
8. From solutions xi, new solutions (new positions) vi produce by select depending Pi for the onlookers and evaluated.
9. Between xi and vi, greedy selection process applied.
10. Abandoned solution (source) determined, if exists, replace with new randomly produced solution xi for the scout using the equation (3.4);
11. The best food sources achieved is memorized
12. Cycle= Cycle+1

13. Until cycle is equal to Maximum Cycle Number (MCN).

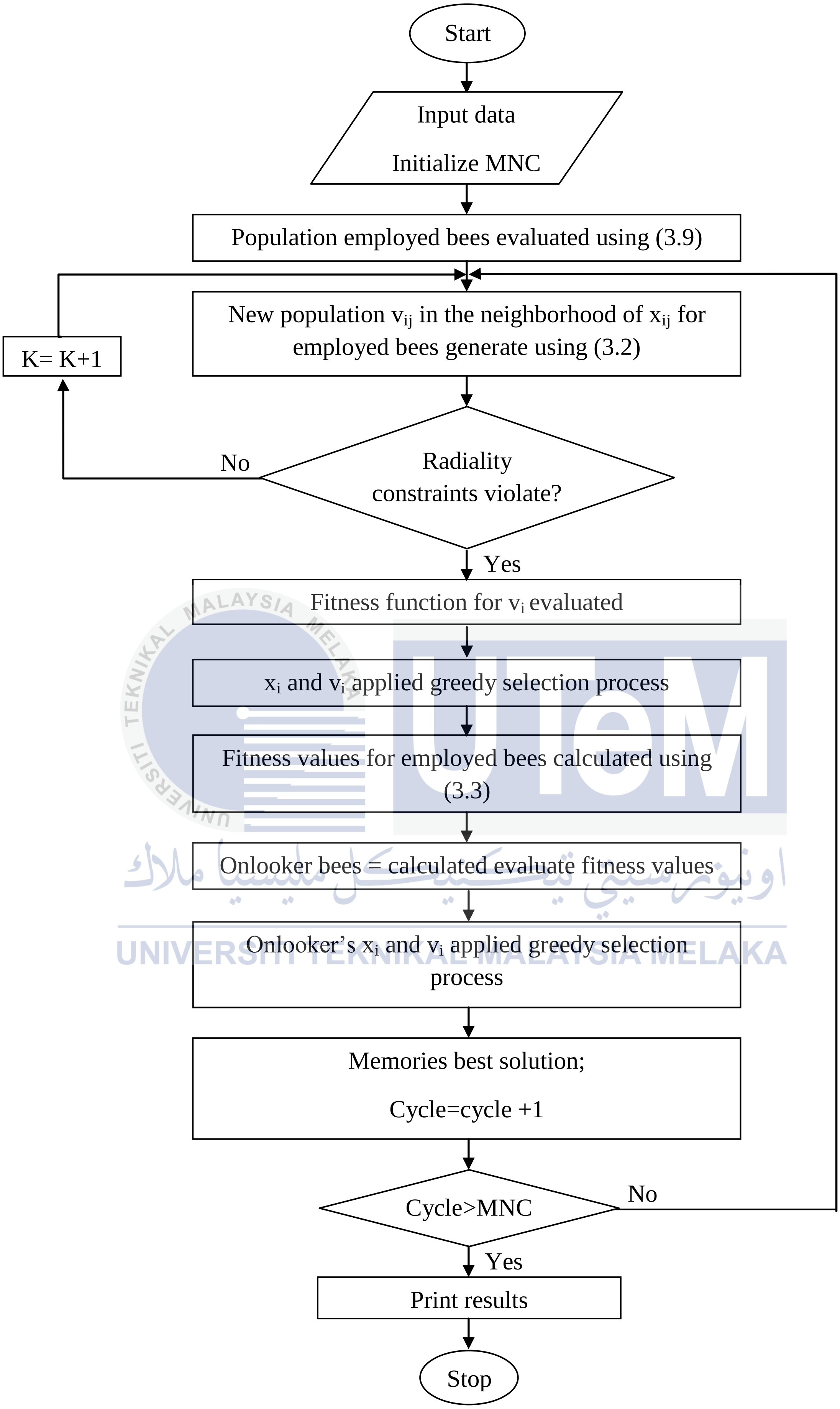

Figure 3.1: Diagram of ABC Algorithm

3.4 Task 3: Implementation Method of PSO

The PSO has been developed based on the behavior of social animals which live and move in group such as fish and bird. The birds or fish usually move in a group at a certain speed and position. Their design of movement is depending on their experience as well as the experience of others in the group ($P_{best}$and G_{best}). The new velocity, V_m^{i+1} and the new position, $X_m^{i+1}$for the fish or birds are obtained using Equations (3.13) and (3.14).

$$V_m^{t+1} = \omega \times V_m^t + wf_1 \times ran_1 \times (P_{bm}^t - X_m^t) + wf_2 \times ran_2 \times (G_b^t - X_m^t) \quad (3.13)$$

$$X_m^{t+1} = X_m^t + V_m^{t+1} \quad (3.14)$$

Where V_m^t is the velocity of particle *m* in iteration *t*, X_m^t is the position of particle *m* in iteration *t*, ran_1 and ran_2 are the random numbers between 0 and 1 [28]. P_{bm}^t is the best value of the fitness function that has been achieved by particle *m* before iteration *t*. G_b^t is the best value of the fitness function that has been achieved so far by any particle. Constants wf_1 and wf_2 are weighting factors of the random acceleration terms, which attract each particle towards $P_{best}$and G_{best} positions. Lower values of fitness function allow particles to move farther from the target region before they return. The inertia weight ω_i is typically set according to the following equation:

$$\omega_i(n+1) = \omega_i^{max} - \frac{\omega_i^{max} - \omega_i^{min}}{n_{max}} \times n \quad (3.15)$$

In Equation (3.14), n_{max} is the maximum number of iterations and *n* is the current iteration number. ω_i^{max} and ω_i^{min} are maximum and minimum of the inertia weights, respectively. The summary process of implementation of PSO algorithm is as follows:

Step A- Initialization- generates randomly all particles.

Step B- Evaluate the fitness function.

Step C- Determine $P_{best}$and G_{best} for all populations.

Step D- Evaluate the new speed for each population.

Step E- Update the existing position to a new position.

Step F- Update the existing speed to the new speed.

Step G- Check the stopping criteria –otherwise go to Step B.

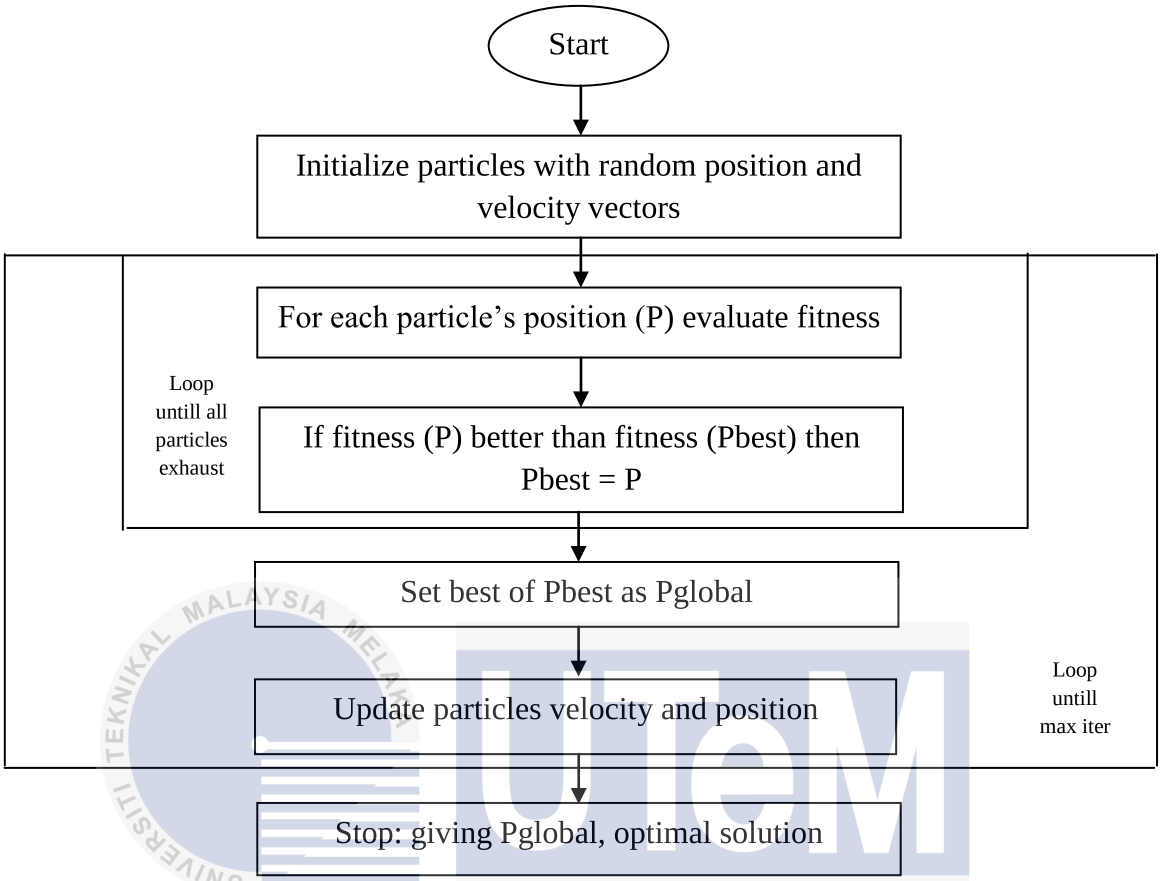

Figure 3.2: PSO Algorithm

3.5 Task 4: Implementation Method of GA

In GA, there are Genetic Algorithm, Genetic String, Fitness Function, Crossover, Adaptive Mutation, and lastly Genetic Termination. Their function will be explained in detailed.

3.5.1 Genetic Algorithm

In solving for network reconfiguration problem, genetic search is proposed. Flowchart for genetic algorithm shown in Figure 3.3.

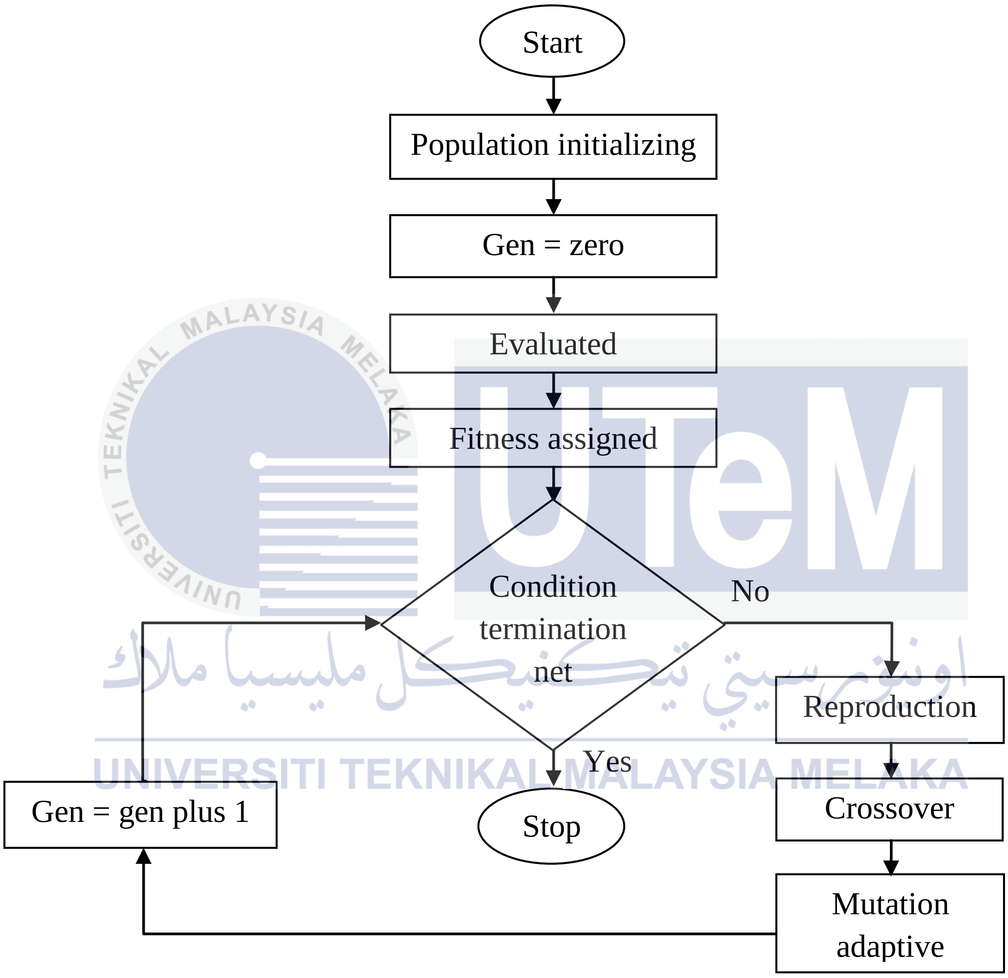

Figure 3.3 : Genetic Algorithm Working Principle Flowchart

3.5.2 Genetic String

Position for normally open sectionalizing switches used as parameter for loss minimization configure. Number of open switches position identical in keeping radial system even its open switch position changed when fixed in topology of distribution network. By numbering the open switch position, the radial configuration minimized as shown in Figure 3.4 (a) and (b).

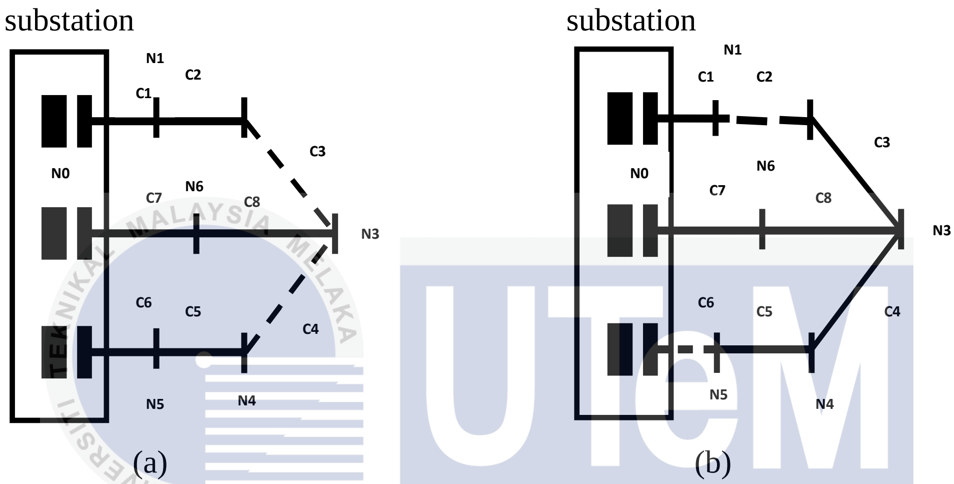

Figure 3.4: A Simple Distribution Network Closed and Open Switches

3.5.3 Fitness Function

Combining the objective with penalty function formed a fitness function.

$$Minf = L \tag{3.16}$$

Where:

$$L = \sum_i |Ii|^2 \; kiRi + \beta 1 \; max\{0(|Ii| - Ii\text{max})^2\} + \beta 2 \; max\{0(Vimin - Vi)^2\} + \beta 3 \; max\{0(Vi - Vimax)^2\} \tag{3.17}$$

Where βi(i=1,2,3) is a large constant.

The strings are sorted according to their fitness which are then ranked accordingly. The roulette wheel selection scheme is used for selecting the individuals for reproduction.

3.5.4 Crossover (Recombination)

Recombination (crossover) involves creation of new offspring from the mating of two selected parents or mating pairs. It is thought that the crossover operator is mainly responsible for the global search property of the GA. In this paper, line recombination is performed between pairs of chromosomes in the current population and returns a new population after mating. The pairs are mated in order, odd chromosome with the next even chromosome. If the number of chromosomes in the population is odd then the last chromosome is not mated and added at the end of the population. The algorithm of line recombination is shown below.

offspring1 = parent 1 + rec x range x delta x diff' (3.18)

offspring2 = parent2+rec x range x delta x (- dfl) (3.19)

rec= ±1with probability Pc else 0 (3.20)

range = 0.5 x domain of variable (search interval defined

by field description of real value) (3.21)

$$delta = \sum_{t=0}^{m-1} \alpha i 2^{-1} \ , \alpha i = 1$$

With probability 1/m, lese 0, m=20 (3.22)

$$diff = \frac{parent2-parent1}{\|parent1-[parent2\|} \quad (3.23)$$

3.5.5 Adaptive Mutation

Mutation is a changing in genetic in introducing a new information according to probalistic rules. Throughout GA process, it is usaully constant, but a small fixed mutation can resulted in premature convergence. Therefore, in changing the probability of mutation, adaptive mutation is used.

$$p(k+1) = \begin{cases} p(k) - Pstep iff \min(k)\, unchanged \\ P(k) iff \min(k) unchanged \\ Pfinal if P(k) - Pstep < Pfinal \end{cases} \quad (3.24)$$

P(o)= P initial =1.0 (3.25)

P step = 0.001 (3.26)

P final =0.05 (3.27)

Where:

k = generation number, *p* = mutation probability.

Increased in generation number, increase in mutation probability as minimum value is 0.05. This prevent premature convergence and leads to smooth convergences.

In algorithm:

mutated variable = variable + Milt xrangex delta (3.28)

Mut= ±1with probability *p*, (+ or - with equal probability) else 0 (3.29)

range = *0 . 5* domain of variable (real value) (3.30)

$$delta = \sum_{i=0}^{m-1} \alpha i 2^{-i}, \alpha i = 1$$

probability 1/m else 0, m = 20 (3.31)

With m = 20, mutation operator locate the optimum up to a precision of range x2^{-19}.

3.5.6 GA Termination

Because the GA is a stochastic search method, it is difficult to formally specify convergence criteria. As the fitness of apopulation may remain static for a number of generations before a superior individual is found, the application of conventional termination criteria becomes problematic. A common practice is to terminate the GA after a pre-specified number of generations and then test the quality of the selected best members within population with the problem definition. No acceptable solution, GA restarted a fresh search.

3.6 Summary

There many differences in the method of ABC, PSO, and GA. The differences are highlighted to determine which between this optimization will improve the efficiency of the distribution system for power loss reduction, voltage profile improvement and also computational time.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

The method has been written by using MATLAB version (R2011a) package in window based computer. The CPU unit installed with 4GB of RAM while the processor used is Intel® Core™ i5-460M. The proposed algorithms have been tested using an IEEE 33-bus system.

4.2 The Simulation and Test System

The case study used the test system which consists of 33-bus radial distribution system as shown in Figure 4.1. The system contains of a feeder, 32 normally closed tie switches and 5 normally open tie switches at 33, 34, 35, 36 and 37. The system load is assumed to be constant and Sbase is approximately 100MVA. The total load on the system is 3715kW and 2300kVAr. The minimum and maximum voltages are set at 0.95p.u. and 1.05p.u. respectively [27]. All calculations for this method are carried out in the per-unit system. The convergence value is taken as 0.0001.

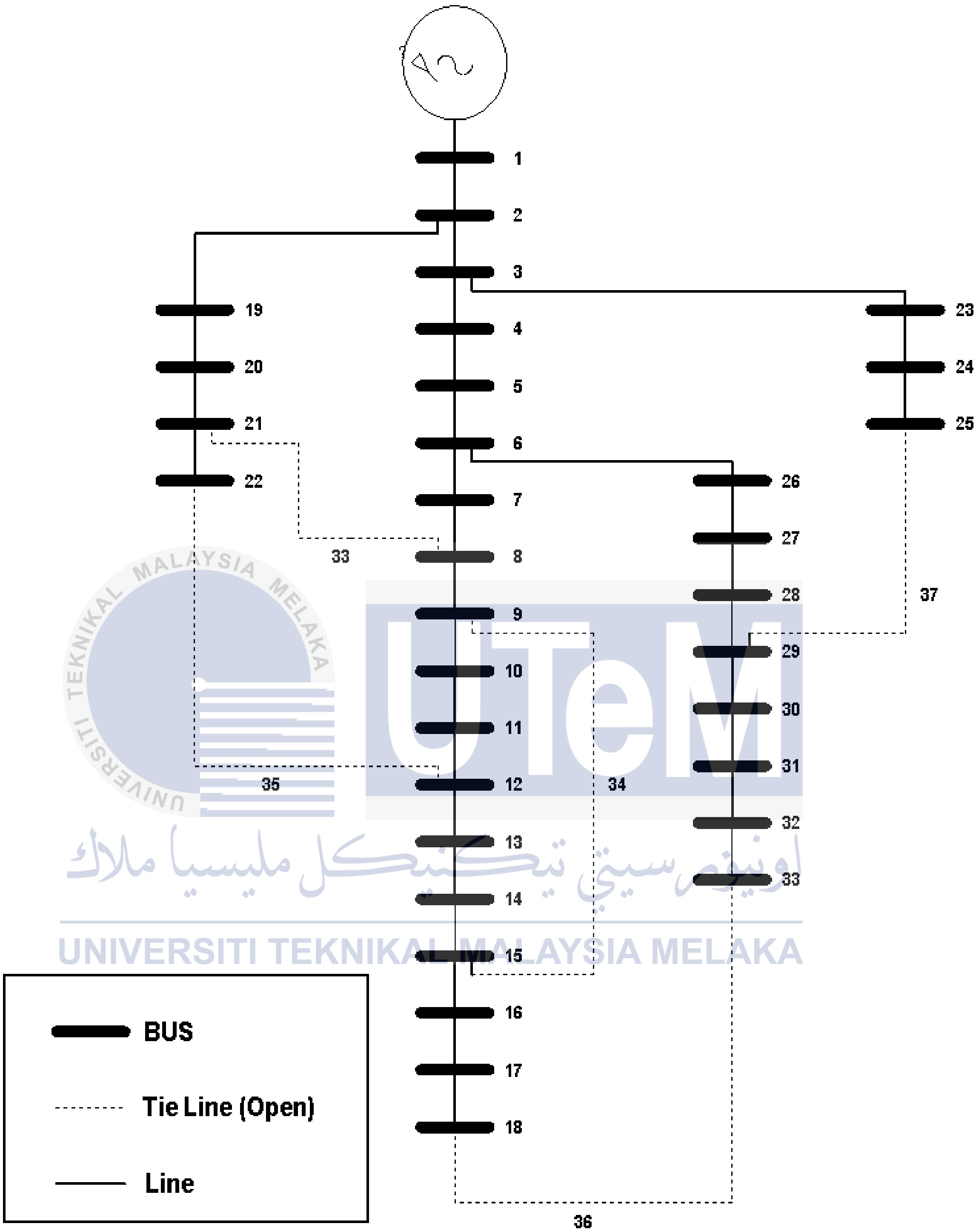

Figure 4.1: Initial Configuration of the 33-Bus Radial Distribution System

Four cases have been executed in determining their reliability of having ABC, PSO and GA in the test system to achieve the best configuration.

A. *In this first case*

The system follows the original network distribution of 33-bus without any alteration done. All the tie switches in the network remains as they are.

B. *In this second case*

The reconfiguration strategy is applied in the system is based on ABC method.

C. *In this third case*

The reconfiguration strategy is applied in the system is based on PSO method.

D. *In this fourth case*

The reconfiguration strategy is applied in the system is based on GA method.

4.3 Results and Discussion

The analysis of the reconfiguration is done by using ABC, PSO and GA methods. Tie switches and sectionalizing switches are considered as the main control variables and obtain using the optimization methods. The optimal power losses depend on the flexibility of the switches. The programming is running randomly and takes approximately 100 times by using MATLAB software and the minimum power losses with the voltage profile of each busses is selected. The results are presented consists of five opened switches, total power losses and voltage profile value. Three important parts will be discussed; for part A and part B, the analyses of the results are mainly focused on the power losses reduction and voltage profile improvement while part C focuses on computating time for the cases 2, 3 and 4 accordingly.

4.3.1 Part A: Power Losses Reduction (PLR)

Table 4.1 shows the result obtain after distribution network reconfiguration for case 2, case 3 and case 4. The parameters that has been considered are switches opened, total power losses, power loss reduction and percentage of loss reduction.

Table 4.1: Performance Analysis of ABC, PSO and GA

Parameters	Case 1: Original Network	Case 2: After Reconfiguration using ABC	Case 3: After Reconfiguration using PSO	Case 4: After Reconfiguration using GA
Switch Open	33, 34, 35, 36, 37	31, 7, 9, 14, 37	7, 10, 14, 28, 32	7, 9, 14, 32, 37
Total Power Loss (kW)	202.7	107.1	126.0	137.0
Power Loss Reduction (kW)	-	95.6	76.7	65.7
Percentage of Loss Reduction (%)	-	47.16	37.83	32.41

From Table 4.1, there is greatest difference of PLR between these three cases if to be compared with original network. In Case 2, the total power loss is 107.1 kW through 95.6 kW power loss reductions while the percentage of reduction is approximately 47.16 % which is almost half percent of reduction. On the other hand, the total power losses in Case 3 is 126.0 kW while the total loss reduction is 76.7 kW and the percentage is around 37.83 % of reduction. Meanwhile, for the case 4 which is DNR by using GA, the total power loss is 137kW. The PLR for this case is 65.7 kW and the percentage is 32.41%. From the results, it can be concluded that ABC algorithm is better in PLR if to be compared to PSO and GA method with 9.33% and 14.75% improvement respectively. The cooperation method between employed bees, onlooker bees, and scout bees process in ABC show a better result compare to GA method that used only the process of crossover and mutation and also a global and local best population in PSO. In ABC, the higher the fitness value, the lower the power losses in the network system. The Figure 4.2 reviews the PLR plotted in graph for better analysis while the Figure 4.3 represents the percentage of PLR.

In getting the optimal value of power losses for these three cases, the sectionalizing switches are contributed in getting the value. The original switches have been opened for original network are at 33, 34, 35, 36 and 37. For Case 2, ABC algorithm after reconfiguration, the sectionalizing switches to be opened are 31, 7, 9, 14, 37 while for PSO technique are 7, 10, 14, 28, 32 and GA technique are 7, 9, 14, 32, and 37 respectively.

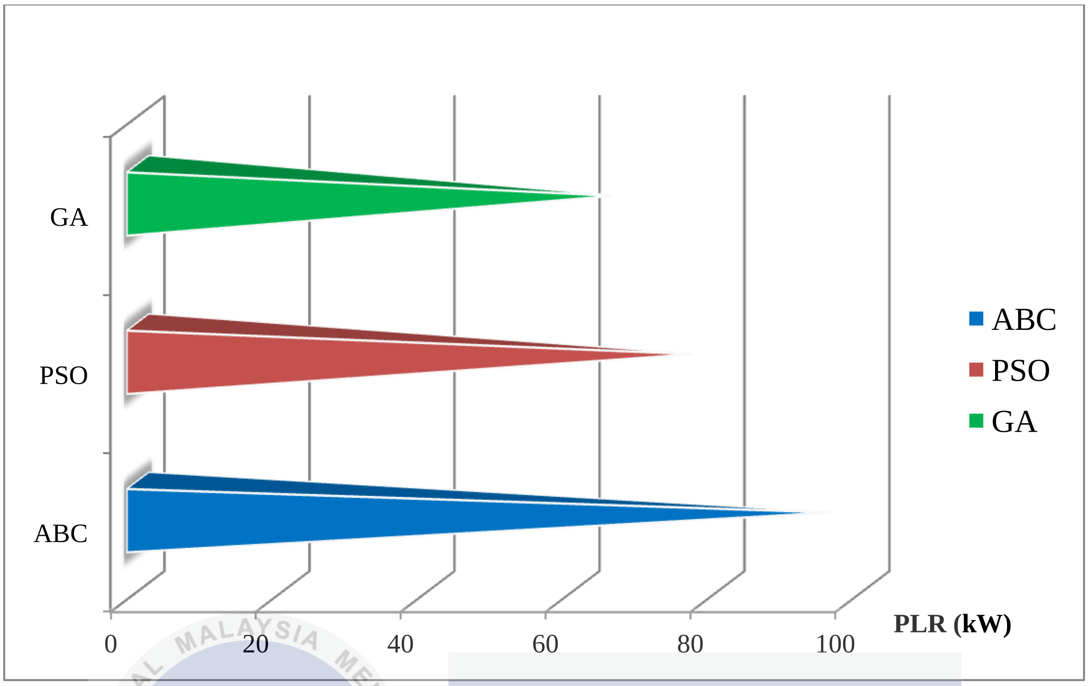

Figure 4.2: PLR for ABC, PSO and GA

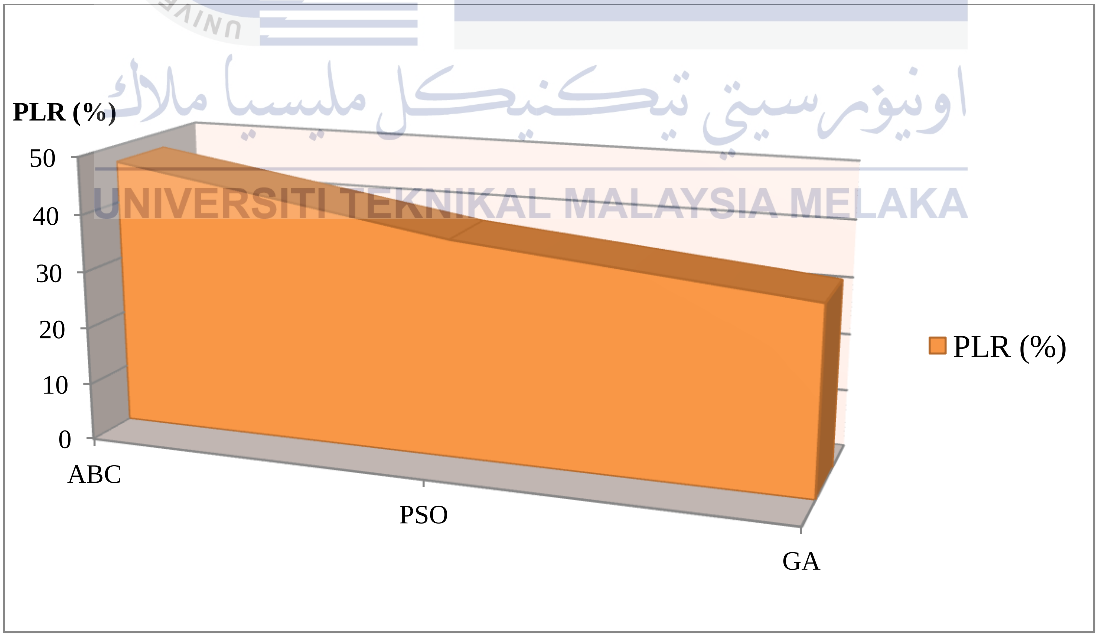

Figure 4.3: Percentage of PLR for ABC, PSO and GA

4.3.2 Part B: Voltage Profile Improvement (VPI)

Table 4.2 shows the results obtain for case 2, 3, and 4 respectively. The VPI is considered based on the increment of voltage profile value in p.u unit.

Table 4.2: Voltage Profile Improvement for ABC Compared to PSO and GA

Bus Number	Voltage Magnitude in p.u		
	ABC	PSO	GA
1	1.000	1.000	1.000
2	1.000	1.000	1.000
3	1.000	1.000	1.000
4	1.000	1.000	1.000
5	1.000	1.000	1.000
6	1.000	1.000	1.000
7	1.000	0.999	0.995
8	1.000	0.999	0.995
9	1.000	0.999	0.995
10	1.000	0.999	0.995
11	1.000	0.999	0.995
12	1.000	0.999	0.995
13	1.000	0.999	0.999
14	1.000	0.999	0.999
15	1.000	0.999	0.999
16	1.000	0.999	0.999
17	1.000	0.999	0.999
18	1.000	0.999	0.999
19	1.000	1.000	1.000
20	1.000	1.000	1.000
21	1.000	0.999	0.982
22	1.000	0.999	0.982
23	0.999	1.000	0.982
24	0.999	1.000	0.982
25	0.999	0.999	1.000

26	1.000	1.000	1.000
27	0.999	1.000	0.999
28	0.999	0.999	0.999
29	0.999	0.999	0.999
30	0.999	1.000	1.000
31	0.999	0.999	0.999
32	0.999	0.999	0.999
33	1.000	0.999	0.999

From the Table 4.2, the results of VPI show that ABC method has a better value when it is compared to PSO and GA method. Regarding to the data at bus number 7 until 18, ABC algorithm has an improvement value from 0.999 to 1.000 if to be compared to PSO results. For the comparison between ABC and PSO, the increment can also be seen at the bus number 21, 22, 31, 32, and also 33 instantaneously. The significant improvement of voltage profile also can be seen at the bus number 21 until 24 for ABC when it is compared to GA method. The plotted graph in Figure 4.4 shows the VPI between ABC, PSO and GA techniques. As in ABC, the tie switches represents the position of food sources which is contributed to optimization problem solution. The onlookers bees process in ABC are contributed to voltage profile improvement which in GA applied crossover and mutation and global and local best population in PSO did not overall contribute to better voltage profile.

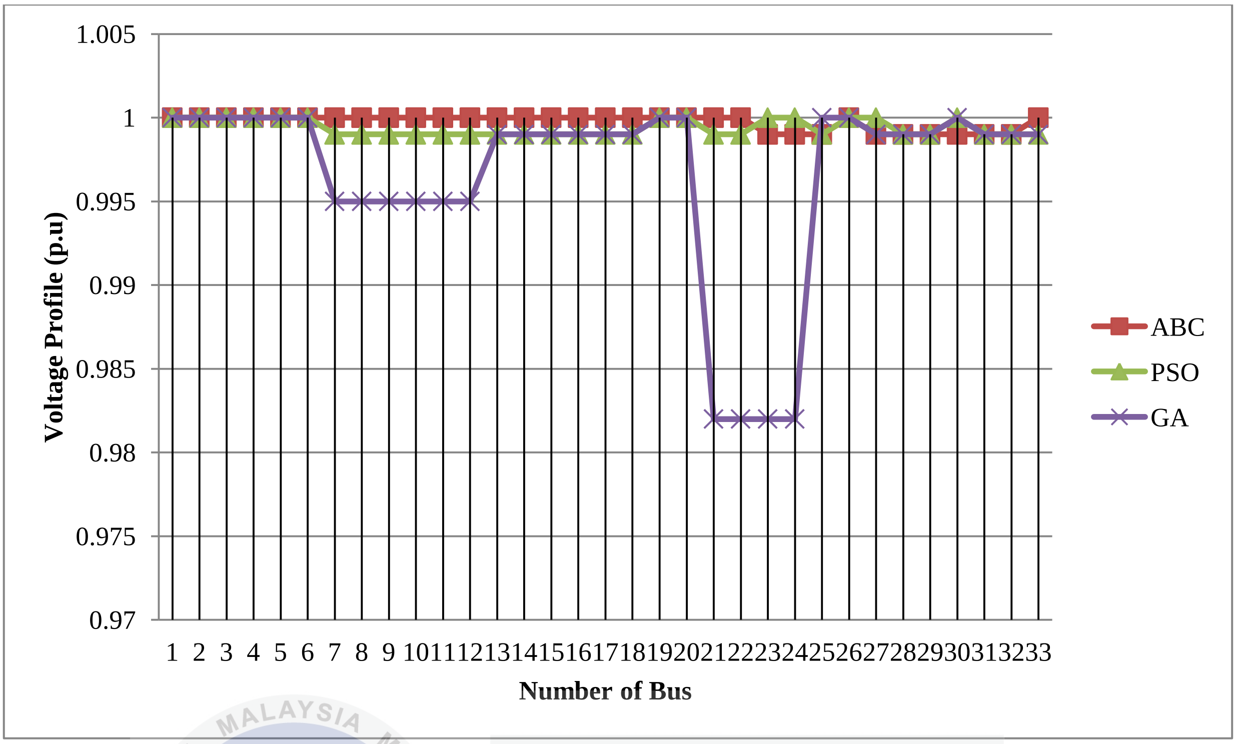

Figure 4.4: VPI between ABC, PSO and GA methods

4.3.3 Part C: Convergence Time (CT)

CT completed the element of analysis for the comparative study of these three cases. From the Table 4.3, the computation time for GA is better than ABC in getting the optimal value; it is because of the process genetic, mutation and crossover in GA contributes to converge in 24 seconds by using Intel Core i-5 while ABC algorithm takes 10 minutes to converge by using the same processor. Nevertheless, PSO method shows the superior point for this criterion by 18 seconds in order to achieve the last iteration in the simulation process. The practice of determining the global and local best population in the PSO flow make it fast to solve the complex problem effectively. The Figure 4.5 represents the graph for CT analysis between three test methods which are ABC, PSO and GA accordingly.

Table 4.3: Convergence Time for ABC, PSO and GA

Technique	ABC	PSO	GA
Computational Time (s)	600	18	24

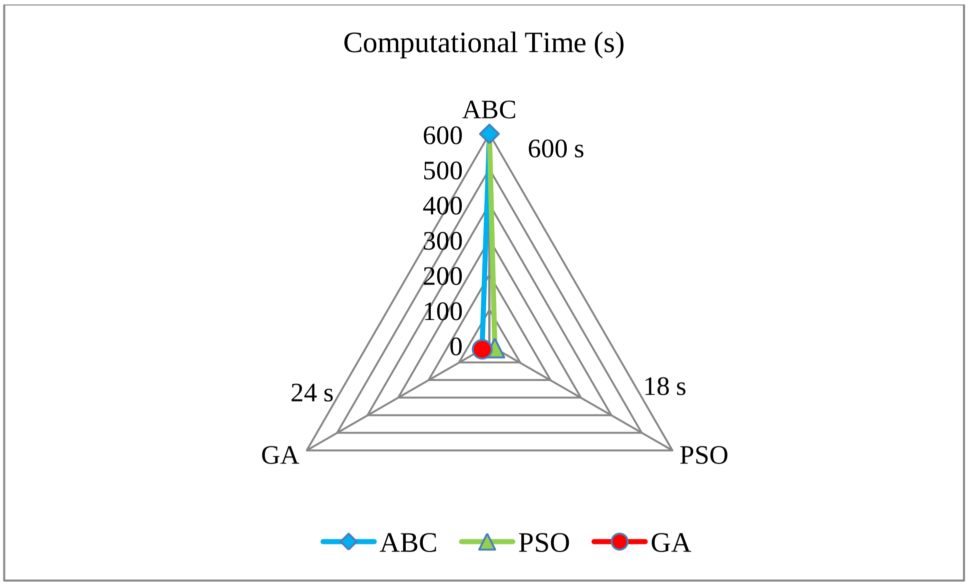

Figure 4.5: CT between ABC, PSO and GA method

4.4 Summary

From results and analysis, as a whole, ABC, PSO, and GA has been successfully applied and implemented in a test data 33kV distribution system. All of the results obtain show the capability of each algorithm in power loss reduction also voltage profile improvement. ABC show superiority in all of the objective study because of the special features in ABC that implementation of two modes of behavior which are move toward to the best location of rich food source while abandoning the poor one in order to get the optimization solution for the system.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This report discuses a comparative study of optimization algorithm ABC, PSO and GA by considering Power Losses Reduction, Voltage Profile Improvement and Convergence Time for feeder reconfiguration. The results of the reconfiguration has shown that in comparison between the four cases, ABC gives better result in PLR and VPI which achieving the objective function of the optimization development. Even though, the computational time for ABC is lower if to be compared to PSO and GA technique; this technique can be improved by modifying its process in terms of employed bees, onlooker bees and scouts bees.

5.2 Recommendation

In order to get more convincing solution, further development can be suggested such as by improving the ABC technique by modifying its process in terms of employed bees, onlooker bees and scouts bees. The superior of ABC technique also can be applied to the huge test system such as 69kV distribution system by also considering distributed generations in the future research.

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APPENDIX B

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APPENDIX C1

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APPENDIX C2

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