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Student's Name : MOHAMAD FANI BIN SULAIMA

Date : 31 MAY 2016

MULTI-OBJECTIVE OF OPTIMAL DISTRIBUTION NETWORK RECONFIGURATION BY USING MODIFIED ARTIFICIAL BEE COLONY ALORITHM

NURUL SYAZWANI BINTI IDRIS

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

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA Melaka

2016

"I declare that this report entitle "Multi-Objective of Optimal Distribution Network Reconfiguration By Using Modified Artificial Bee Colony Algorithm" 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 other degree"

Signature : ....

Student's Name : NURUL SYAZWANI BINTI IDRIS

Date : 31 MAY 2016

Dedicated, in thankful application for support, encouragement and understandings to my beloved parents and family

Idris Bin Husin

HalimahBintiDrauh

NurulHidayah

Mohammad Syafiq

NurulNajihah

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ABSTRACT

Electric power distribution loss and reliability are major concerns in power system as the demand of electrical energy by customers keep increasing day by day. One of the suggested methods to minimize these problems is by doing reconfiguration process to existing distribution network. A reconfiguration is performed by opening or closing the sectionalizing switches and need to maintain the feeder in radial network. This study presents Distribution Network Reconfiguration (DNR) by using Modified Artificial Bee Colony Algorithm (IABC). The main objectives of this study are to minimize the power losses, enhance load balancing index, and improve the voltage profile simultaneously. The performance of the proposed method will be investigated and the impact to the distribution network will be analyzed. The algorithm (IABC) will be applied on IEEE 33 bus radial distribution systems network. The real result will be compared with the conventional initial network and other optimization techniques which are Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). The results of this study is hoped to help the electrical engineers (Power System) in Malaysia in order to solve the losses problem in the distribution network reconfiguration and at the same time increasing the efficiency of the real distribution system.

ABSTRAK

Kehilangan pengagihan kuasa elektrik dan keboleh percayaan adalah kebimbangan utama dalam sistem kuasa kerana permintaan tenaga elektrik oleh pelanggan terus meningkat hari demi hari. Salah satu kaedah yang disyorkan untuk mengurangkan masalah-masalah ini adalah dengan melakukan proses konfigurasi semula untuk rangkaian pengedaran yang sedia ada. Konfigurasi semula dilakukan dengan membuka atau menutup suis sectionalizing dan perlu mengekalkan feeder dalam satu jaringan radial. Kajian ini membentangkan konfigurasi semula rangkaian (DNR) dengan menggunakan Modified Artificial Bee Colony Algoritma (IABC). Objektif utama kajian ini adalah untuk mengurangkan kehilangan kuasa, meningkatkan indeks pengimbangan beban, dan meningkatkan profil voltan pada masa yang sama. Prestasi DNR akan disiasat dan impak kepada rangkaian pengedaran akan dianalisis. Algoritma (IABC) akan digunakan pada IEEE 33 bas jejarian sistem rangkaian pengedaran. Keputusan sebenar akan dibandingkan dengan rangkaian awal konvensional dan teknik-teknik pengoptimuman yang lain yang merupakan algoritma genetik (GA) dan Zarah Swarm Optimization (PSO). Hasil kajian ini diharap dapat membantu para jurutera elektrik (Sistem Kuasa) di Malaysia dalam usaha untuk menyelesaikan masalah kerugian dalam konfigurasi semula rangkaian pengedaran dan pada masa yang sama meningkatkan kecekapan sistem pengagihan yang sebenar.

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INTRODUCTION

1.1 Motivation

1.1.1 TNB Statistics of Supply Interruptions

TNB has disturbances of supply to a single consumer for more than 1 minute from September 2004. In Peninsular Malaysia, the number of supply disturbance per 1000 customer had recorded in TNB's distribution system which is from 4.9 to 9.1 interruptions in year 2003, it is increased by 85.7%. The number of supply disturbances per 1000 customer of TNB in the year from 2000 to the year of 2004 is shown in Figure 1.1. It is 96.6% was unscheduled interruptions whereas the remaining 3.3% was scheduled interruptions.

In the year 2004, the average number of supply disturbances of TNB in monthly increased by 91.5% from 2,365 to 4,529 in the year 2003 as shown in Figure 1.2. The highest number of supply interruptions in the year 2004 is Kedah, Wilayah Persekutuan, Johor and Selangor compared with the other states.

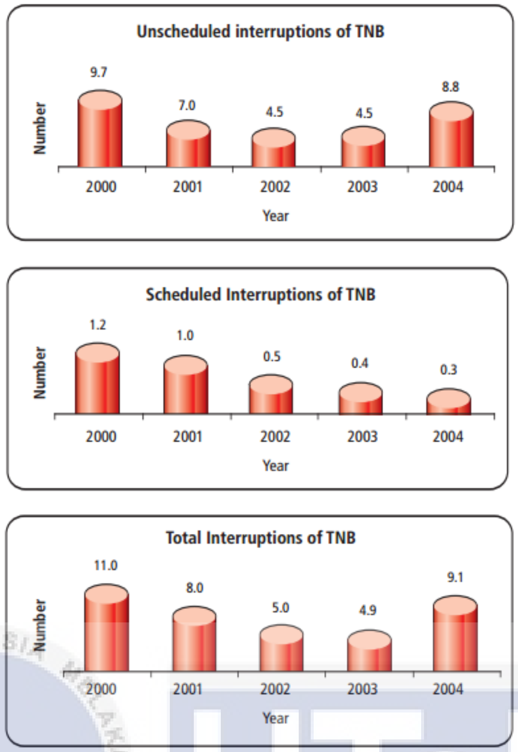


Figure 1.1: TNB's Number of Electricity Supply Interruptions per 1000 Customers from Year2000 to 2004

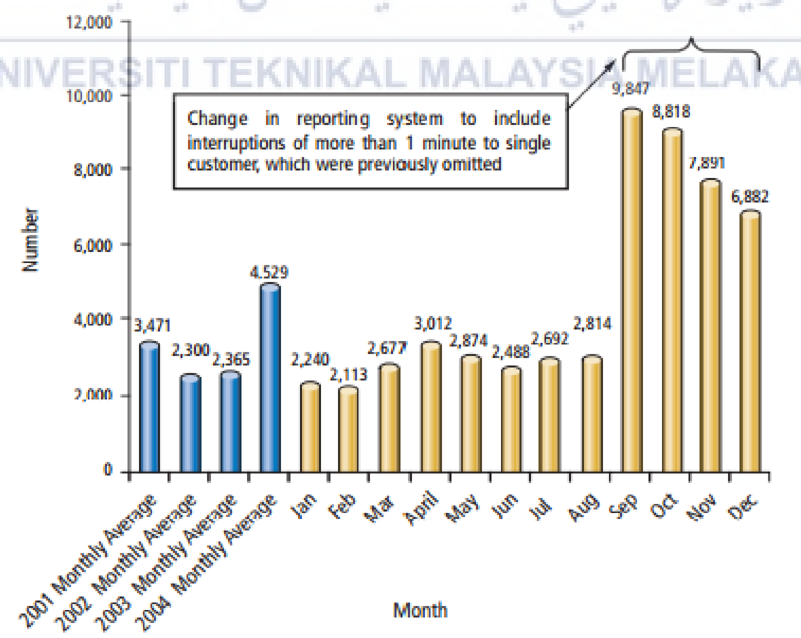


Figure 1.2: TNB's Monthly supply interruptions in 2004

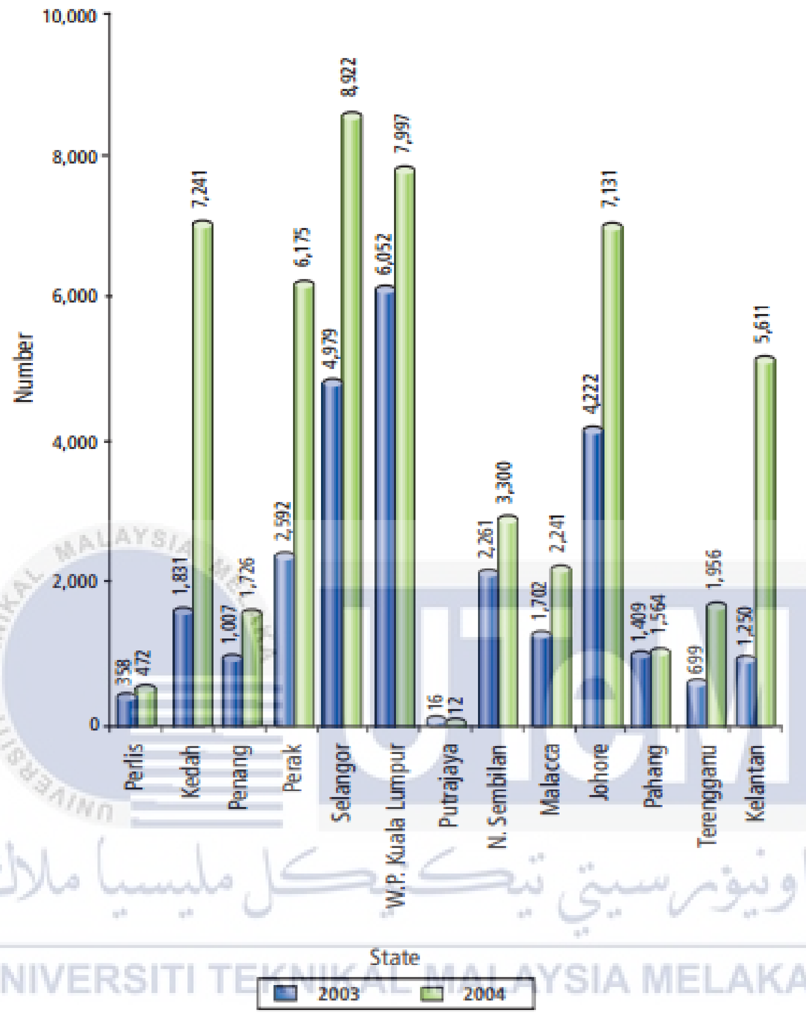


Figure 1.3: Various States of Total Number of Supply Interruptions in Peninsular Malaysia inyear 2003 and 2004

TNB conducted several efforts to improve the reliability of the distribution system such as:

(a) Enhancing preventive maintenance programmes which include:

- preventive testing of cables by very low frequency (VLF) test method
- condition monitoring of substation equipment, lines and cables
- scheduled preventive maintenance of substations on a continuous basis

(b) Reviewing manuals on operation and asset maintenance to enhance the quality of work.

(c) implementing various projects to strengthen the distributions network such as:

- injecting new feeders
- construction new substation
- changing bare conductors to insulated aerial bundled cable

1.1.2 Distribution System of TNB

The duration and the frequency of interruptions of supply experienced by consumers normally as reference to measures the reliability of electricity supply. System Average Interruption Duration Index (SAIDI) is one of the aspects that used to access the performance of the distribution systems in TNB and it is signifies the total duration in minutes on average that consumer is without supply in a certain period, usually a year. The SAIDI of TNB in different states in Peninsular Malaysia year from 2002 to 2004 shown in Figure 1.4. In the year 2004 the SAIDI had reduced if compared with the year 2003 (exception of Johor, Terengganu and Kedah). By referring in the year of 2004, overall TNB's SAIDI decreased from 167.6 (year 2003) minutes to 129.0 minutes, it is reduced by 22.8%. This address that the performance of the supply system of TNB having an improvement in the year 2004.

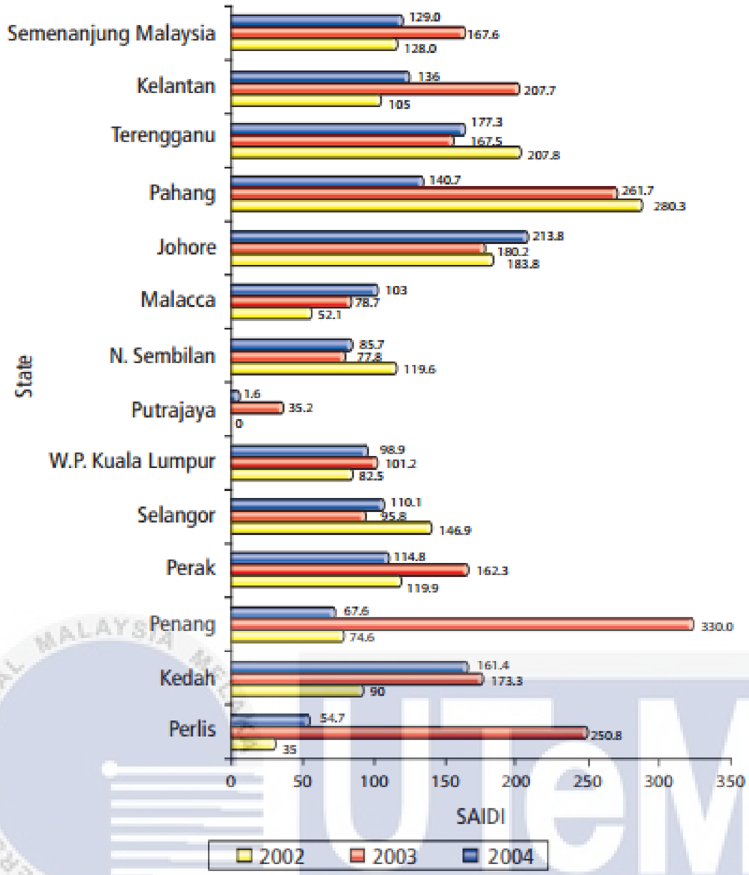


Figure 1.4: SAIDI (Consumers/Year/Minutes) in the Various States for Peninsular Malaysia inthe year 2002 to 2004.

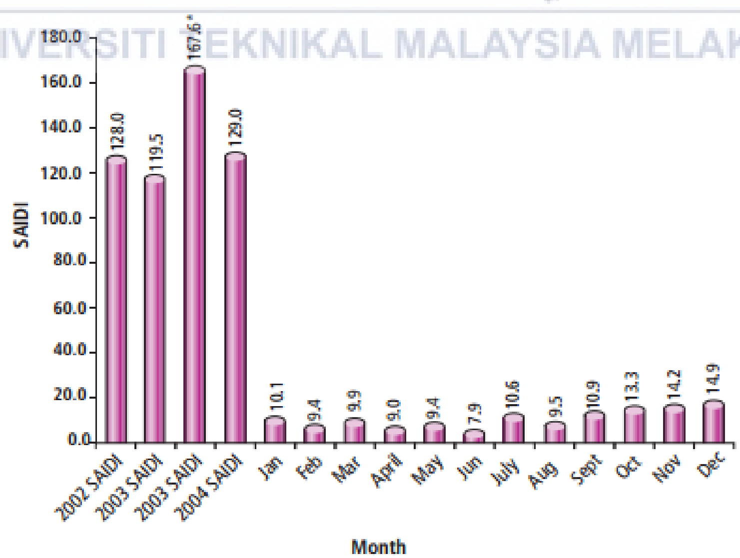


Figure 1.5: The monthly SAIDI in Peninsular Malaysia in the year 2004.

1.1.3 Distribution Network Configuration

Distribution System is the final segment of power system, bridging the gap between power supply system and user facilities. The major responsibility of the distribution system would be proper electric power distribution and guaranteeing users' normal power consumption.

Correspondingly, as a crucial part of the Distribution Management System, distribution network reconfiguration has great impact on the power quality. Network reconfiguration means changing network structure through operations of sectionalizing and loop switches to minimize power loss and keep the balance of power supply and consumption, meanwhile on satisfying capacity and voltage restraints. Currently, the distribution power grid construction in our country still remains to be modified. Equipment depreciation and inappropriate structure have led to low reliability and highly cost during the power transformation process. Considering the complicity of power distribution grid's mathematical model, the pursuit of optimal algorithm of network reconfiguration becomes inevitable and urgent [1] [2].

Theoretically, network reconfiguration is a complicated multi-objective nonlinear integral combinational optimization problem, which has characters of discontinuity, non-differentiability, multi-constraints and nonlinearity [1].

1.2 Problem Statement

Distribution Industry always wants to give consumer a good quality in electrical power network. The distribution industry tries to minimize the losses, balancing the load and improve voltage profile after network is reconfiguration, but at each panel of distribution network it will have losses and unbalance of load. Each unbalance system not just increases power losses into an advanced stage however could affect all the system and distribution generating sections. Losses could reduce the quality and the reliability of distribution networks. This will not just impact to distribution industry but including energy resources, money and cost. However to reach non interrupt in distribution network is almost impossible to get it. Therefore, this project is one of solution to distribution industry want to achieve a maximum stableness and reliability of an electrical power network to distribute to consumer.

From this, the method that can use is by applying the reconfiguration feeder distribution on 33-bus network system. By reconfiguration the feeder that means by changing the topology switch of feeder distribution, it can be used to balance the load on each bus in distribution network. Balancing the load is significant factor to minimize power reduction as well as increase voltage profile at the same time. In other words, accomplish those objectives; minimizing loss reduction, balancing the load and improve the voltage profile in simultaneously after reconfiguration by using modified Artificial Bee Colony (IABC) Algorithm will solve in distribution industry.

This algorithm is based on swarm bees that have been proposed to overcome the optimization problem in power system as an overall but, not specific to DNR. Therefore, new technique by using an Improved ABC algorithm has to be made for better system in distribution network reconfiguration.

.

1.3 Objective

In order to solve the network reconfiguration for this project, the modified Artificial Bee Colony (IABC) Algorithm method is implemented as the optimization algorithm. The objectives are:

1. To minimize total power loss in IEEE 33-bus network test system.
2. To enhance the load balancing index during distribution network reconfiguration.
3. To improve voltage profile after network is reconfigurated.

1.4 Scope

This project focuses on the implementation of IABC algorithm to solve optimization problems. This algorithm was developed to determine the best configuration of tie switches to optimize the networks while satisfying with several operating constraint, for instance power flow constraint, voltage constraint, enhance load balancing and to minimize the real power loss of the network. Moreover, this technique should maintain the radiality of the network. This algorithm was tested on IEEE 33-bus radial distribution networks and was performed using MATLAB softwareversion 2010b software package.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory

2.1.1 Electric Power System

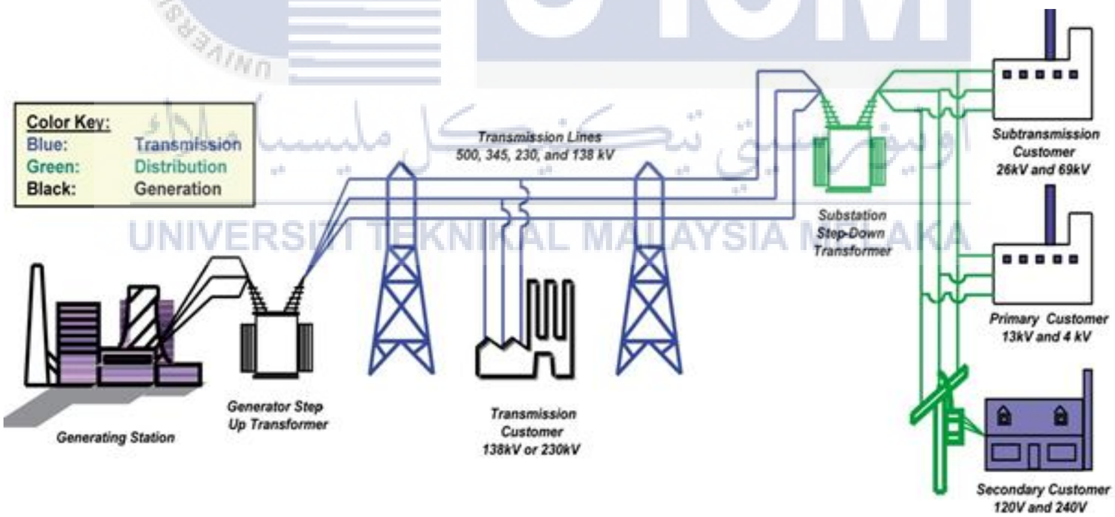


Figure 2.1: Electrical Power System of Basic Structure [31]

Power system is the network that related with the generation, distribution, transmission and consumption of electric power and electrical devices connected to the system including generators, motors and transformers. Network of electrical devices that used to supply, transfer and use electric power is an electric power system. Network supplies a region's homes and industry with power is an example of an electric power system. Power system that known as the grid is for sizable regions and it is can be commonly divided into the generators that supply the power, the transmission system that transmit the power from the generating centers to the load centers and the distribution system that supply the power to nearby homes and industries.

The final stage in the delivery of electric power is an electric power distribution system. It transmits electricity from the transmission line to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage with the usage of transformers. Primary distribution lines carry this medium voltage power to distribution transformers located near the consumer's locations. Distribution transformers again lower the voltage to the utilization voltage of household appliances and typically feed several customers through secondary distribution lines at this voltage. Commercial and residential customers are connected to the secondary distribution lines through service drop. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level.

2.1.2 Distribution Network Reconfiguration

Distribution networks have two types which is radial or network. [3] A radial system as shown in figure 2.2 is organized like a tree where each consumer has one source of supply while a network system has several sources of supply functioning in parallel. The secondary network is normally found in big cities and is the most consistent system. For concentrated loads is used spot network while in rural or residential areas usually used radial system and radial systems commonly contain emergency connections where the system can be reconfigured as shown in figure 2.3 in case of problems, such as a fault or required replacement. This can be complete by opening and closing switches. It may be acceptable to close a loop for a short time. Within these networks there may be a mix of overhead line construction utilizing traditional utility poles and wires and, increasingly, underground construction with cables and indoor or cabinet substations. However, underground distribution is significantly more expensive than overhead construction. In order to reduce this cost, underground power lines are sometimes share location with other utility lines known as common utility ducts. Distribution feeders coming from a substation are generally controlled by a circuit breaker which will open when a fault is spotted. Automatic circuit recloses may be installed to further separate the feeder thus minimizing the impact of faults. Long feeders experience voltage requiring capacitors or voltage regulators to be installed.

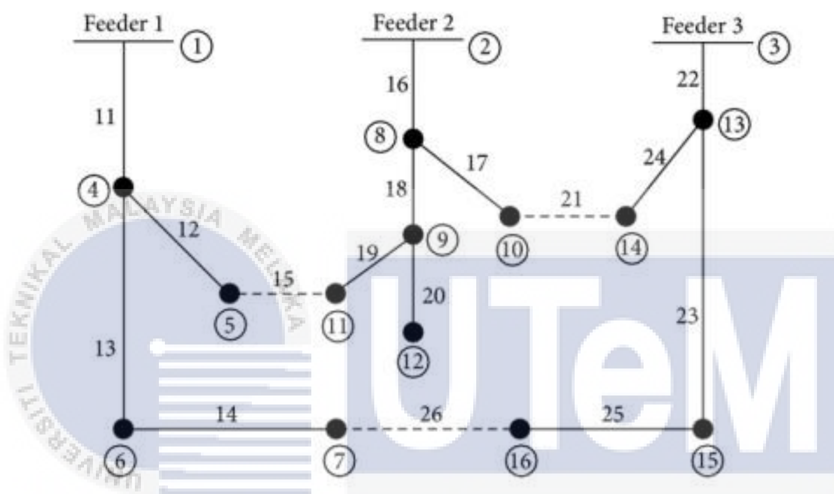


Figure 2.2: Example of 16 radial distribution bus system (original configuration) [32]

Exchanging the functional links between the elements of the system also called reconfiguration is the one of the most important measure which can increase the operational performance of a distribution system. In terms of its definition, the problem of optimization through the reconfiguration of a power distribution system is a historical single objective problem with constraints. In 1975, Merlin and Back[4] was introduced the idea of distribution system reconfiguration for active power loss reduction, until nowadays, a lot of researchers have planned various methods and algorithms to solve the reconfiguration problem as a single objective problem. For this purpose, different artificial intelligence based methods have been used such as microgenetic, [5] branch exchange, [6] particle swarm optimization[7] and non-dominated sorting genetic algorithm [8].

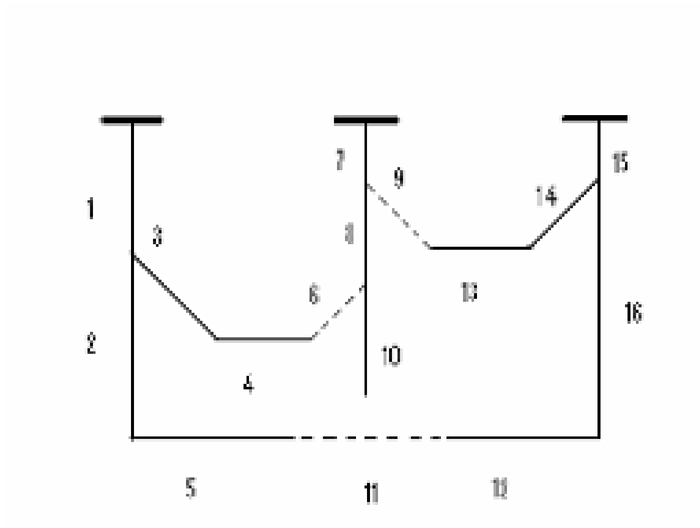


Figure 2.3: Example of 16 radial distribution bussystem (after reconfiguration). [32]

2.2 Previous Related Work

For network reconfiguration, a proposed study to reconfiguration distribution network for loss reduction and to keep load balancing problem has been made [11]. In this paper, a Plant Growth Simulation algorithm has been proposed with a view to enhance speed and robustness. Plant Growth Simulation Algorithm (PGSA) has emerged as a useful optimization tool for handling nonlinear programming. It provides the solution for loss reduction through network reconfiguration involves a guiding search over the relevant configurations. The contribution of PGSA is not requiring external parameters whereas most of the methods published require external parameters such as barrier factors, crossover rate etc. A novel model has been used to simplify the distribution network. An objective function of minimizing system losses and load balancing index is formulated as a non-liner optimization to security constrains. The PSGA method is tested to reconfigure 60-node radial distribution system for loss minimization and load balancing. The feeder reconfiguration problem can be solved efficiently for loss reduction as well as improving the load balancing index. Based on research, it shown that PSGA is an effective method to minimize loss reduction and also improving the load balancing index due to PSGA not require external parameter addressing it as a useful optimization tool for handling nonlinear programming.

A new type of evolutionary search methodology is proposed in this project for determining loss configuration of a radial distribution system. A fuzzy controlled evolutionary programming (FCEP) which based on heuristic information has been proposed to modify the performance of evolutionary programming [12]. During the evolutionary process, the designed mutation fuzzy controller adaptively changes the mutation rate. Moreover, to further speed up the guarantee the optimization process a chain-table and depth breadth search strategy is employed. Next, to guarantee the optimal solutions searched by the FCEP are feasible the equality and inequality barrier are fixed into the fitness function by some penalty factors. The outcomes of a fuzzy distribution load flow study are not only the probability distributions of substation current, node voltages, real and reactive power losses but also to evaluate the robustness of the system performance and the degree of exposure to an uncertain future. In addition, fuzzy set theory contributes an excellent framework for integrating the mathematical and heuristic approaches into a more realistic formulation of the reconfiguration. Referring on this paper, it shown an improved evolutionary programming technique has been proposed for radial distribution loss minimum reconfiguration. FCEP reduces combinatorial explosive switching problem into a realizable one and reduces the switching combination to a few number. A mutation fuzzy logic controller is developed to speed up the evolutionary process by adaptively adjusting the mutation rate, but in terms to balance the load this method have been not applied compared to [11]. Therefore this method can be effectively used in real time application of the large distribution system under widely varying load conditions.

Authors in [13], present a research on large numbers of infeasible solutions are produced according to problems during the distribution network configuration, corresponding cyclic decimal coding solution and corresponding mutation, crossover and selection strategy. This paper proposed Differential Evolution Algorithm to minimize the network loss which has the advantages of less control parameters and good robustness. This algorithm was introduced by Storn and Price in 1995 [14] and it has been solved distribution network. Based on the DE applied in the distribution network reconfiguration, the loop encoding is approach and effectively corrects the inadequate of the radial determination method of cyclic encoding. Thus, the problem of power flow calculation brought by coding changes during the network reconfiguration finally successfully solved. From the article, a loop gene coding method which is applies on Differential Evolution Algorithm was approved based on the optimal flow method. The Differential Evolution mutation operator has the independent variation bitwise. This paper gives an adjustment of the order of nodes. This method solved the problem of node numbering confusion after network reconfiguration and is fast and efficient same as method in [12] but compared to [11] this method also not applied load balancing index while to decreasing power losses rather than only solved node numbering after network is reconfigured.. Hence, it is shown that the proposed method in [11] is more effective.

Next, there is two objective of the study proposes in [15] including voltage deviation and total system losses. In this paper, a new way called sifting algorithm was presented for radial distribution networks reconfiguration. The algorithm workings based on eliminating infeasible states in the search space. The shifting algorithm that is almost similar to the well-known PSO algorithm is proposed in this paper with a few differences in generation first code and swarm position update. The benefits of this method over other methods are their high speed of convergence and simple structure. This method is fast due to generated codes are feasible. Moreover, the proposed method is that it guarantees fast convergence because answer space will reduce significantly. To show the speed and the effectiveness of the proposed method, a comparison is made between this method and three other algorithms. Based on this article, minimizing total losses and voltage deviation of the network by four different methods it makes clear that sifting method's time much less than the others which is more than 4 times and if the number of the network bus increase, the CPU time difference will be obviously more. So that the speed of the sifting algorithm was about 4 times better than the other algorithms. Comparing method in [11,12,13], this method more effective because it is proved that shifting's method time much less than three others algorithm that compared with while [15] minimizing total losses and improving voltage profile.

While in [16], they have improved ABC algorithm in scout bee phase. The method use Piecewise Logistic to enhance the global convergence. The experiment is conducted with six benchmark optimization function. The results show that, IABC by using Piecewise Logistic provide good performance compared to ABC algorithm. Throughout researched, it shows that there are many ways to improve Artificial Bee Colony algorithm. The difference is only on the method to improve it whether on the onlooker side or scout bee phase. It provides better and good performance compared to the conventional ABC algorithm and method in

[11,12,13,15]due to many ways to improve ABC algorithm and has been found satisfying the distribution network constraint. From this article it is shown that, ABC algorithm is the best algorithm in minimizing power losses.

2.3 Artificial Bee Colony (ABC) Algorithm

Based on the model first proposed by [9] on the foraging behavior of honey bee colonies the ABC algorithm is a swarm based, meta-heuristic algorithm. The model has three important elements such as employed foragers, unemployed foragers and food sources. The first two elements are the employed and unemployed foragers, while the rich food sources are the third elements which close to their hive. The two leading modes of behavior are also described by the model. These behaviors are essential for self-organization and collective intelligence: enlistment of forager bees to rich food sources, causing into positive feedback and simultaneously, the leaving of poor sources by foragers, which resulting negative feedback [10]. The ABC involves three groups of artificial bees which is employed foragers, onlookers and scouts. The first half of the colony contains the employed bees meanwhile the onlookers comprise the second half. The employed bees are related to specific food sources. The employed bees are linked to specific food sources. By way of explanation, the number of employed bees is equivalent to the number of food sources for the hive. The dance of the employed bees within the hive was observed by the onlookers to select a food source while scouts search at random for new food sources.

Likewise, in the optimization situation, the number of food sources (that is the employed or onlooker bees) in ABC algorithm, is equal to the number of solutions in the populace. Moreover, the location of a food source indicates the position of a promising solution to the optimization problem, meanwhile the condition of nectar of a food source symbolizes the fitness cost (quality) of the related solution. The search cycle of ABC contain three rules which is the first rule is transfer the employed bees to a food source and estimating the nectar quality, secondly onlookers selecting the food sources after accepting information from employed bees and evaluating the nectar quality and lastly defining the scout bees and sending them onto potential food sources. Their nectar qualities are measured when the positions of the food sources are randomly selected by the bees at the initialization stage. Then the employed bees share the nectar information of the sources at the dance zone with the bees that waiting within the hive. Each employed bee returns to the food source visited throughout the previous cycle, after sharing the information, as the position of the food source had been remembered and then chooses another food source by using its visual information in the neighborhood of the present one.

In the final stage, an onlooker uses the information obtained from the employed bees at the dance area to select a food source. The possibility for the food sources to be picked increases with increase in its nectar quality. Thus, the employed bee with information of a food source with the highest nectar quality recruits the onlookers to that source. Next, chooses another food source in the neighborhood of the one currently in her memory based on visual information. A new food source is randomly created by a scout bee to replace the one abandoned by the onlooker bees.

2.4 Summary

In order to reduce such power loss, great deals of researches have been conducted to improve the efficiency and reliability of distribution network. This is done by locating FACTS, capacitor bank and other devices in the distribution network as a control mechanism. However, these approaches are costly since requires expensive devices. None of the works performed optimization process for distribution network reconfiguration in order to give the lowest power loss.

Having all these, this project deals with multi-objective of optimal distribution network reconfiguration by using modified or improved artificial bee colony algorithm called IABC. Artificial Bee Colony (ABC) optimization method is employed to solve the case study. This is due to the superiority of the algorithm in solving the complex optimization problem. This algorithm is very simple and flexible, which does not require external parameters like crossover rates, especially suitable for engineering application. As a new search algorithm, a lot of research has gone into improving the performance. Meanwhile, in view of the parameter of controlling the behavior of the scouts is difficult to set and of a great impact on the performance of the algorithm, a mutation strategy based on opposition-based learning is propose instead of the behavior of scouts. All this is in hope that will reduce total power loss in 33-bus radial network distribution system and balancing the load during distribution network and along with improving voltage profile after network is configured.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this chapter, basic ABC and improve ABC algorithm will be explained in detail. There are 4 parts which are objectives function and constrains for network reconfiguration problem in part 1. For part 2, basic ABC algorithm will be discussed while improve ABC will be in part 3. Meanwhile, in part 4, IABC Implementation to network reconfiguration will be explained in detail.

3.2 Objective Function and Constrains for Network Reconfiguration Problem

The main objective of network reconfiguration is to find a set of combination switches to be open in order minimize the real power losses of the system and satisfying all the operational constrains while maintaining the radiality of the network. The problem can be described as in mathematical problem as follows.

$$\text{Min } P_{losses} = \sum_{i=1}^{n} |Ii|^2 ki\ Ri \tag{3.1}$$

Where:

i :number of lines in the system

Ii :current flow in branch i

Ri :total resistance of branch i

N : total number of branches in the system

ki :topology status of the branches (1 = close status, 0 = open status)

From (3.1), it shows that the total real power loss is depending on the current that flow to the branch feeder from main source. The higher the amount of current flowing to the branch to meet the requirement of the feeder, the higher the losses will occur in the network. Hence, the process of network reconfiguration takes into account the load congestion of each feeder, by shifting the overloads feeder to next feeder to relieve the tense of the feeder. This will allow the current to the branch feeder at acceptable level, thus will reduce the total real power loss in the network. Network reconfiguration also considers the ability to improve security, stability and reliability, without infringing the operational and topological constraints [14]. It is subject to:

a) Radial network constraint

The selection of switching combination should maintain the radial network structure after network reconfiguration.

b) Node voltage constraint

The voltage magnitude at each node should maintain within the acceptable range of 0.95 pu and 1.05 pu. This is to guarantee that the quality and reliability of the system can be optimized.

$$V_{min} \leq V_{bus} \leq V_{max}$$

3.3 Load Flow Analysis of a Power System

Load flow lessons are important requirements to determine the level of power and [16] voltage throughout the distribution system. This study are carried out to provide the steady state analysis of electrical power transfer between generation, transmission and distribution component in order to make sure that the stability and reliability of the system can be achieved. This study is also essential in planning, economic scheduling for power system operation and for future expansions of the distribution networks [17]. The Newton-Raphson load flow method was used in this purpose of optimization due to the capability of this method for approximation based on initial estimation.

The Newton-Raphson equation for real power and reactive power at any given bus i and j are given as:

$$Pi = \Sigma |Vi||Vj| nj=1 |Yij| \cos(\theta ij - \delta i + \delta j) \quad (3.2)$$

$$Qi = -\Sigma |Vi||Vj| nj=1 |Yij| \sin(\theta ij - \delta i + \delta j) \quad (3.3)$$

Where:

Vi, Vj: Voltage magnitude of bus I and j

δi, δj: angle of voltage for bus I and j

$\theta i, \theta j$: magnitude and angle of Yij element in the bus admittance matrix

The differences in real power (ΔPi) and reactive power (ΔQi) equation for the ith bus are:

$$\Delta Pi = Pi^{sp} - Pi \quad (3.4)$$

$$\Delta Qi = Q^{sp} - Qi \quad (3.5)$$

Where:

Pi^{sp}, Q^{sp}: specified real and reactive power at bus i

The Jacobian matrix of Newton-Raphson power flow is expressed as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial p}{\partial \delta} & \frac{\partial p}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \tag{3.6}$$

Power loss can be calculated as follows:

$$\text{Ploss} = \sum_{i=1}^{n} \sum_{i=1}^{n} Aij\ (PiPj + QiQj) + Bij\ (QiPi - PiQj) \tag{3.7}$$

$$Aij = \frac{Rij\ \cos(\delta i - \delta j)}{ViVj} \tag{3.8}$$

$$\text{B}ij = \frac{Rij\ \cos(\delta i - \delta j)}{ViVj} \tag{3.9}$$

Where:

Pi: real and reactive power of bus i

Pj: real and reactive power of bus j

Rij: Line resistance between bus i and j

Vi, Vj: Voltage magnitude of bus i and j

∂i, ∂j: Voltage angle of bus i and j

3.4 Load Balancing

In distribution network, network reconfiguration and phase load balancing may be used to reduce circuit losses while satisfying electrical constraints. Proper re-phasing of phase load positions and switching of sectional and tie switches follow a few rules, such as radial design of the network must be retained, supply to all loads, and new branches cannot be placed.

In three phases, re-phasing the loads may result to 0% imbalance and a decrease in circuit loss. Once using the optimal solution, percentage imbalance is calculated according to [18]. The loss in a line phase calculated using equation 3.10

$$Loss = (I_A^2 + I_B^2 + I_C^2) \times R \tag{3.10}$$

Where;

$I_A + I_B + I_C$: A, B, and C is line current phase

R: line resistance.

If the total load across all phases is I_{TOTAL}, it can be shown that reduce losses occurs if equation 3.11 is satisfied.

$$I_A = I_B = I_C = \frac{1}{3} I_{TOTAL} \tag{3.11}$$

Where;

I_A, I_B, I_C: A, B, and C is line current phase

I_{TOTAL} : total of current

For aim F is overall loss for optimum problem. The overall circuit loss can be determined of methods useful the distribution network is. From [19] and [20] show unbalanced three-phase for solve losses in system, including using backward/forward sweep load flow. The enhancement problem is formulated as:

$$\min F = Re\left(\sum_{k=1}^{b}[Iabc]_k\,\{[Vabc]_m - [Vabc]_m\}*\right) \quad (3.12)$$

Where;

$[Vabc]_m$: Phase voltage matrix at bus,

$[Iabc]_k$: Branch current matrix along segment k between nodes m and n

b : Total number of branches in the system.

At the feeder reconfiguration the distribution of load from the feeder is done in such a way that the load unbalance can be expressed by the Load Balancing Index (LBI) [21] given by

$$\mathrm{LBI} = \frac{1}{\mathrm{nb}}\sum_{\mathrm{j}=1}^{\mathrm{nb}}\frac{S_{(\mathrm{j})}}{S_{(\mathrm{j})}^{\max}} \quad (3.13)$$

Where;

nb : Number of branches

$S_{(j)}$: Apparent power flowing through the branch ‘j’

$S_{(j)}^{max}$: Maximum capacity of branch ‘j’

3.5 Voltage Profile

Lots of case present voltage instability might become a main power outage. Along with, the restructuring of power industry, the voltage stability can turn into a main problem. Thus, analysis together with plans in procedure to enhance voltage stableness margins and minimize power losses in order to retain protection of power system. Through radial distribution structure, supplying power towards whole load as keeping voltage degree in a suitable range can be one for the main system limitations. Generally there are two fundamental conventional means for retaining voltages in a suitable area distribution network are shunt capacitors and conventional voltage regulators. Usually in distribution network use conventional series voltage regulators for voltage control [28, 29, 30]

3.6 Basic Artificial Bee Colony (ABC) Algorithm

TheArtificial Bee Colony Algorithm was introduced by Karaboga as a heuristic method to solve optimization problem. ABC is base from foraging behavior of real honey bees. The colony of bees in the ABC model consists of three groups which are working bees, onlookers and scouts. It is assumed that there is only one working bee artificial to a food source. In other words, the number of working bees in the colony is equivalent to the number of food sources around the hive. Working bees go to the source of their food and go back to the hive and dancing in this area. Working bee food supply has been left to scout and start looking to find a new food source. Onlooker bees watch the dancing bee work and choose the food supply depends on the dance floor. Procedure for ABC algorithm is illustrated in Figure 3.1 [33]

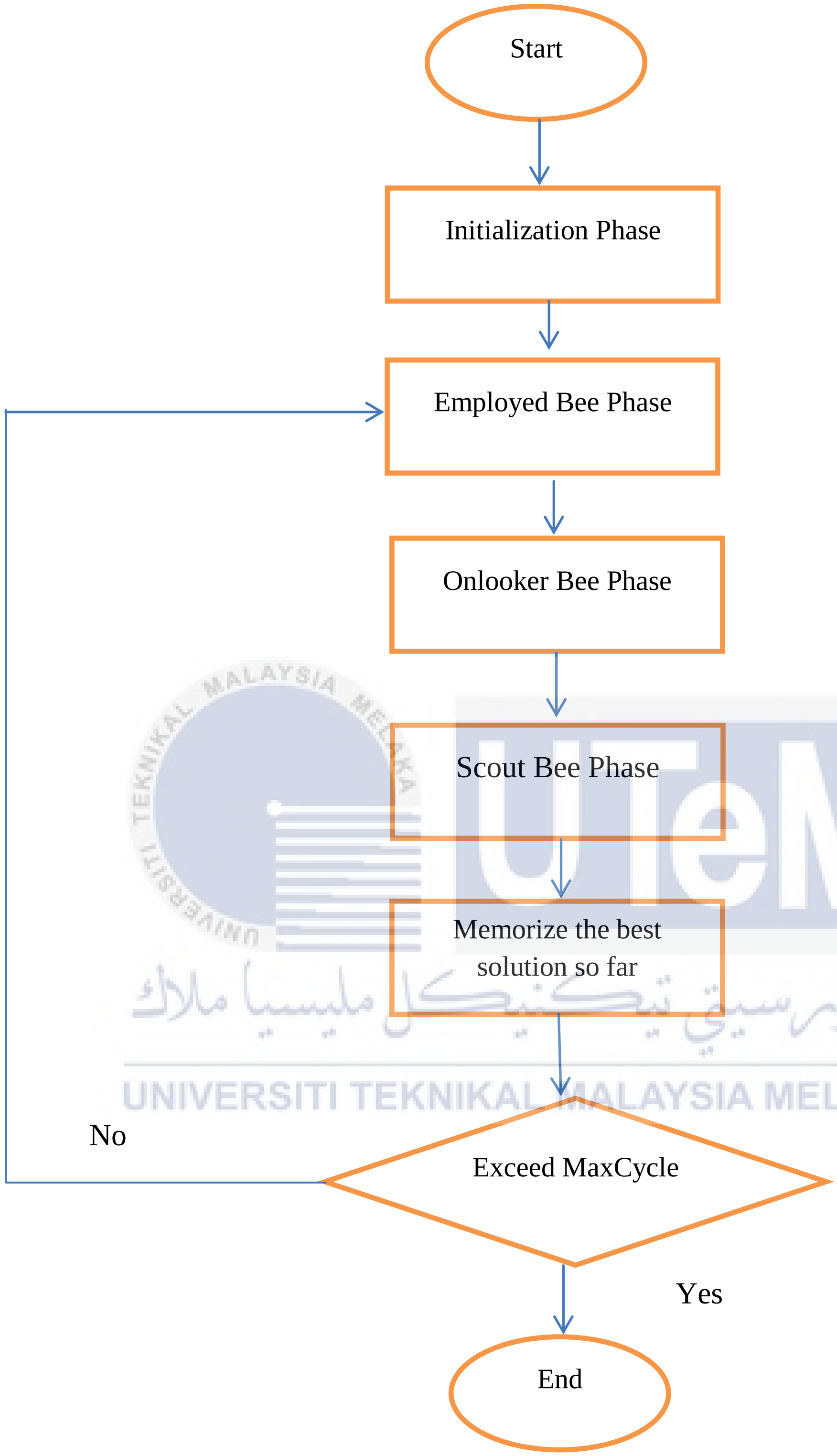


Figure 3.1: Flowchart of ABC [34]

3.6.1 Employed bees:

Employed bees randomly search for food source positions (solutions) and share the information which is nectar amounts by dancing with the bees waiting in the hive. Time taken of dance depends on nectar amounts (fitness value) of the food source.

3.6.2 Onlooker bees:

Observe the dances of employed bees and pick the best food source according to quality of the food source.

3.6.3 Scout bees:

The employed bees with abandoned food source will become scout bees and start to search new food randomly.

3.7 The improvement of ABC algorithm (IABC)

Generally, to get the best solution of the object function the algorithm that is best to use is ABC algorithm. However, the basic design of ABC algorithm of the onlooker's bee movement only considers relation between the employed bees, which is based on roulette wheel selection. Hence, it is not strong enough to maximize the exploitation capacity. [22] Therefore, influenced by the improved strategies of PSO [23] which will add some non-linear weight factors changing to obtain a better result and this technique has been implied in this study. As to improve the diversity of nectar sources, an inertial weight which known as *w* where it has been inspired by PSO evolution equation and its improving strategy is added. [23] The equations are as follows:

$$v_{ij\_new} = \mathrm{w}\,[x_{ij} + \phi_{ij}\,(x_{ij} - x_{kj})] \tag{3.14}$$

The non-linear initial weight shown in equation (3.15) has been presented in PSO algorithm, where the local searching process will shift to the global searching phase and will balance the two sides so that it can be converge to the optimal solution effectively. In a vigorous searching process, exploration and exploitation processes must be carried out at the same time. Other than that, in order to get a better and diverse food sources in ABC algorithm, the exploitation process executed by onlooker and employed bees, also the exploration process in scout bees phase need to be controlled and balanced. Thus, to achieve this, the idea of PSO parameter by adding “w”asequation (3.14) will be like this:

$$w = w_{max} - \frac{w_{\max} - w_{min}}{iter_{max}} \times ite \tag{3.15}$$

Where:

w_{max} : maximum weight equal to 0.9

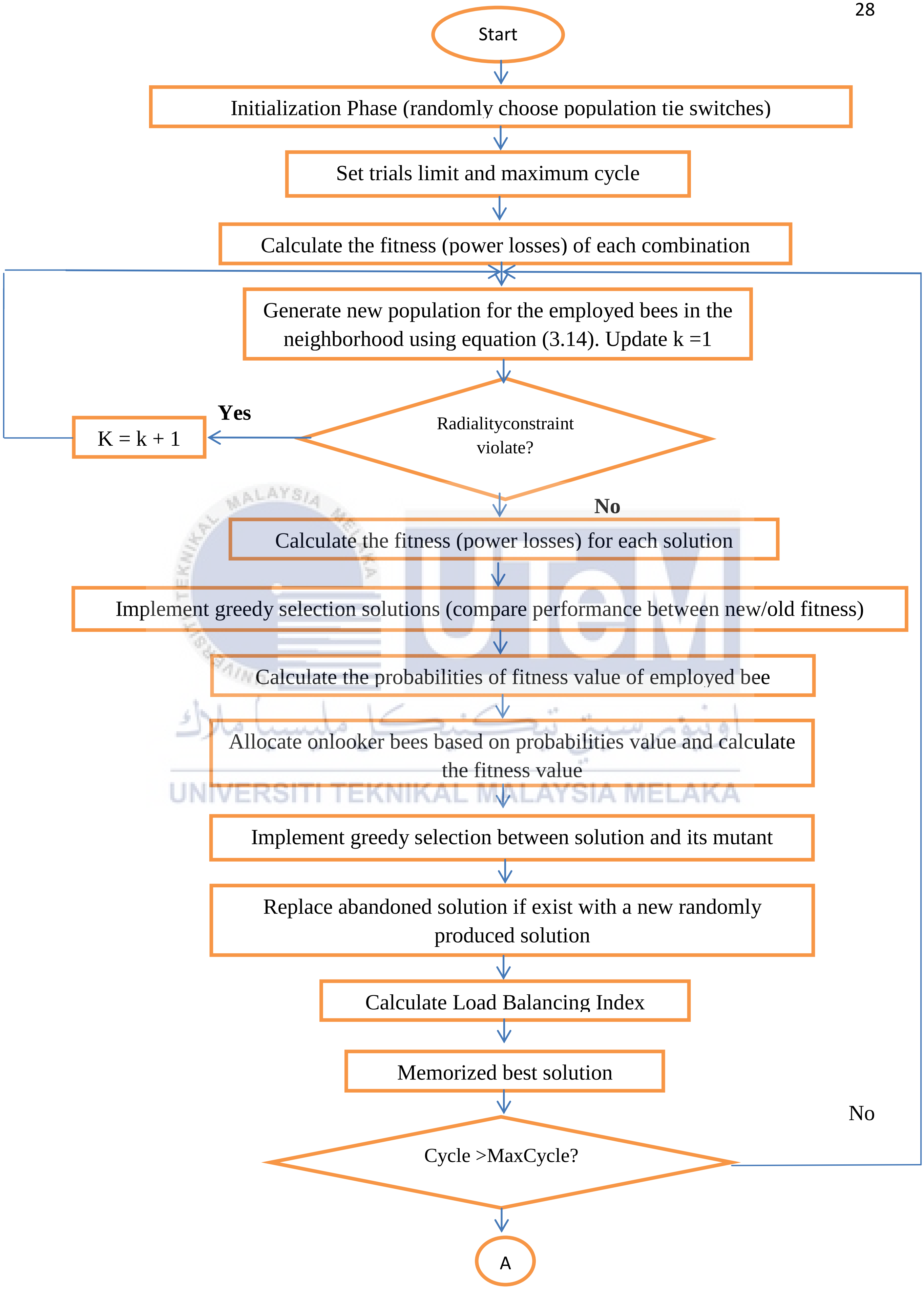
w_{min} : minimum weight equal to 0.4

$iter_{max}$: maximum iteration number

$iter$: current iteration number.

3.8 Implementation of Improved Artificial Bee Colony (IABC) Algorithm for Multi-objective Network Reconfiguration

The implementation of IABC Algorithm was applied three objectives of this project simultaneously. The improvement of ABC Algorithm is at the fitness equation where the equation above (3.15) will be added into equation (3.14). For the other of the system, it will follow the original ABC. The main steps of IABC for network reconfigurations are as Figure 3.2 flow chart below.


Start
Initialization Phase (randomly choose population tie switches)
Set trials limit and maximum cycle
Calculate the fitness (power losses) of each combination
Generate new population for the employed bees in the neighborhood using equation (3.14). Update k =1
Radialityconstraint violate?
Yes
K = k + 1
No
Calculate the fitness (power losses) for each solution
Implement greedy selection solutions (compare performance between new/old fitness)
Calculate the probabilities of fitness value of employed bee
Allocate onlooker bees based on probabilities value and calculate the fitness value
Implement greedy selection between solution and its mutant
Replace abandoned solution if exist with a new randomly produced solution
Calculate Load Balancing Index
Memorized best solution
No
Cycle >MaxCycle?
A

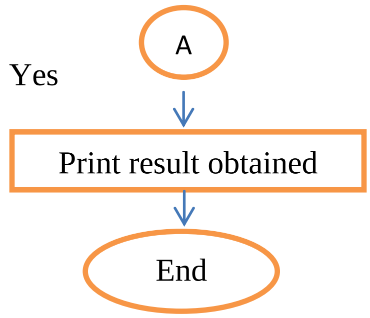


Figure 3.2: Flowchart of IABC algorithm in network reconfiguration.

3.8.1 Test System.

Figure 3.4 shows 33 bus test system that will use in this project. After the switching is applying in the network, the system usually required being in radial configuration and all the loads are energized. A normally open tie switch is closed to transfer a load from one feeder to another feeder, when an appropriate sectionalizing switch is opened to improve the radial structure. The situation is to recognize the position of combination network switches such that reduce losses and balance the load is obtained along with improving voltage profile after network is configured.

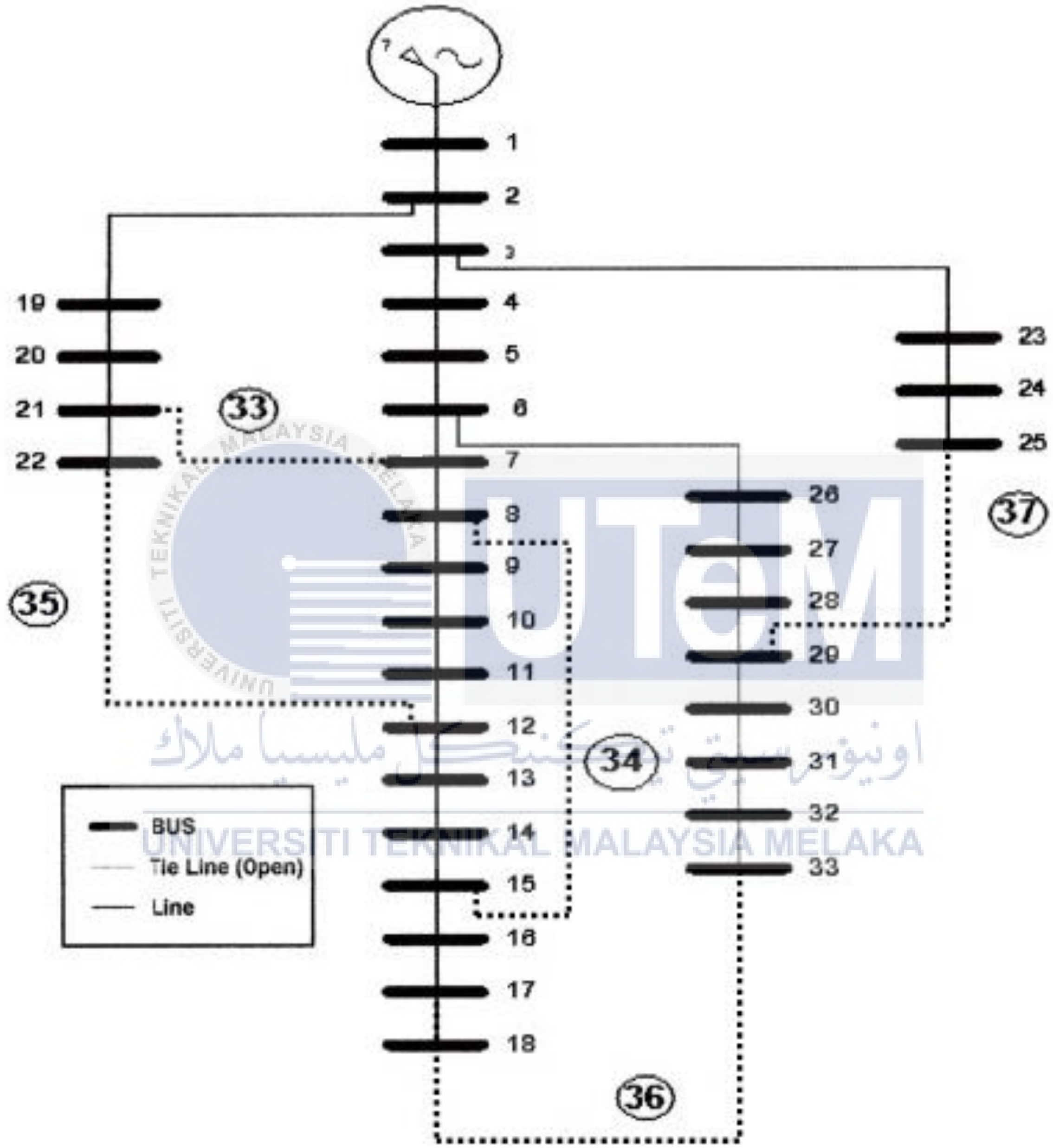


Figure 3.3: 33-bus test system

3.8.2 Initialization data phase

The data necessary for initialization procedure includes line data, bus data, and pre specified limit such as base apparent power, maximum number of iteration, total population size and accuracy of each iteration. The process begins by choosing randomly combination of tie switches from the original set of tie switches based on the predefined value of population size. Then all the new population set of tie switches are evaluated according to the network data to determine their power losses, and the voltage magnitude and angle of each bus.

The random populations of tie switches for this project is represent the position of food source that will produce possible solution to the optimization problem. The total position of food source is equivalent to the half of colony size which is combination of employed bees and onlooker bees. The set of tie switches is written as follows:

$$\text{Switch} = [k_1,\ k_2,\ k_3,\ldots..k_m] \tag{3.16}$$

Where:

k : The selected tie switches

m : The number of tie switches

Note that the number of employed bees is equal to the number of position of food source which will be exploited at the moment. To guarantee that the radiality of the network is maintained, several constraints need to be taken into consideration for selection of the switches such as all switches that do not belong to any loop are to be closed state secondly, all switches connected to the sources are to be closed state and lastly all switches contributed to a meshed network need to be closed state.

3.8.3 Fitness evaluation phase

The fitness value in this project value describes the quality of the solution. In ABC algorithm, the nectar amount of food source directly proportional to the quality of the associated solution. Respecting to the main determination of reconfiguration, the power losses of the distribution network is set as a fitness function that needs to be optimized. The power losses for each of the population are gained by using Newton-Raphson load flow program. Hence, the higher the power losses occur in the network, the lower the fitness value will be. The fitness value is formulated as shown below:

$$\text{Fitness } (fit_i) = \begin{cases} \dfrac{1}{1+P_{loss\ (i)}} & if\ P_{loss\ (i)} \geq 0 \\ 1 + abs\left(P_{loss\ (i)}\right) & if\ \ P_{loss\ (i)} < 0 \end{cases} \tag{3.17}$$

Where:

$P_{loss\ (i)}$:the real power losses at bus i

After estimating all the fitness value of each population, the best position of food source that give the higher value of fitness will be memorized. In terms of reconfiguration, the combination of switching achieved so far that can provide the best fitness level will be memorized.

3.8.4 Employed bee phase (Improved ABC)

In every iteration of the ABC algorithm, the employed bees will search randomly for a new neighboring food source location of its selected food source position. So as to define the new population in the neighborhood, the following equation has been applied:

$$v_{ij} = w\,[x_{ij} + \phi_{ij}\,(x_{ij} - x_{kj})\,] \qquad (3.14)$$

Where:

v_{ij} : new randomly produced solution in the neighborhood.

x_{ij} : food source position in its memory.

ϕ_{ij} : random number between [1, -1]

x_k : randomly selected position.

j : randomly chosen parameter.

If the new randomly produced solution (food source position) going beyond the upper or lower boundaries, the produced solution is shifted onto the boundaries. In other word, the produced solution will be set to its limit value if its value exceeds its predetermined limit. Afterward, the positions of food sources are re-evaluated to determine the fitness value according to the new generated population.

In order to get a better and diverse food sources in ABC algorithm [35], the exploitation process executed by onlooker and employed bees, also the exploration process in scout bees phase need to be controlled and balanced. Thus, to achieve this, the idea of PSO parameter by adding w into as equation (3.14)

$$w = w_{max} - \frac{w_{\max} - w_{min}}{iter_{max}} \times ite \tag{3.15}$$

Where:

w_{max} : maximum weight equal to 37
w_{min} : minimum weight equal to 1
$iter_{max}$: maximum iteration number
$iter$: current iteration number

If the new generated solution value is out of boundaries, the generated solution is shifted onto the boundaries. To explain in a simple way, the new generated solution will be set to its limit value if the value exceeds its predetermined limit. Then, the positions of food sources will be evaluated back to determine the fitness value according to the new generated population.

3.8.5 Greedy selection phase

The greedy selection method in this phase is implemented in order to compare the performance between the fitness of new food source position and the current fitness in the memory. If the new fitness is better than the one in the memory, the employed bee will shift to this new position of food source, replacing the old one in the memory. Or else, the old fitness is reserved in the memory and leaving the new one.

3.8.6 Onlooker bee phase

The data of nectar amount and location of food source obtained by the employed bee will be estimated by the onlooker bee. The onlooker bee will choose the food source according to the probability which proportional to the fitness of the food source. The greater the probability of the food source, the higher the possibility the food source will be selected as it can provide more profitable and quality food source. The following equation was developed to calculate the probability of the food source in each position:

$$P_i = \frac{fit_i}{\sum_{n-1}^{N} fit_n} \quad (3.18)$$

Where:

fit_i : fitness value represented by the food source i

N : total number of food source position

3.8.7 Scout bee phase (generate new population)

The food source will be abandoned by the bee if the food source is exhausted. Particularly, the food source that cannot be improved and exceeds the limit value will be removed from the population. Afterward, the employed bee corresponding with the food source will become scout bee. The scout bee will be allocated to discover new area of food source location randomly and will exchange the food source that has been abandoned with the new one using (3.19)

$$v_{ij} = x_{ij} + \phi_{ij} (x_{ij} - x_{kj}) \quad (3.19)$$

3.8.8 Load Balancing

The implementation of load balancing by using proposed IABC technique should follow a few rules, such as radial design of the network must be retained, supply to all loads, and new branches cannot be placed to achieve proper re-phasing of phase load positions and switching of sectional and tie switches. Re-phrasing the loads may result imbalance. The loss in a line phase calculated using equation (3.10) that has been mention previously.

$$Loss = (I_A^2 + I_B^2 + I_C^2) \times R \tag{3.10}$$

If the total load across all phases is I_{TOTAL}, it can be shown that reduce losses occurs if equation 3.11 is satisfied.

$$I_A = I_B = I_C = \frac{1}{3} I_{TOTAL} \tag{3.11}$$

For overall loss for optimum problem can determined by using (3.13) equation

$$\min F = Re(\sum_{k=1}^{b} [Iabc]_k \{[Vabc]_m - [Vabc]_m\}) \qquad (3.11)$$

The load unbalance at the feeder reconfiguration can be expressed by the Load Balancing Index (LBI) [21] given by

$$\text{LBI} = \frac{1}{\text{nb}} \sum_{\text{j}=1}^{\text{nb}} \frac{\text{S}_{(\text{j})}}{\text{S}_{(\text{j})}^{\text{max}}} \tag{3.13}$$

3.9 Summary

The difference procedure in ABC algorithm and IABC algorithm is that ABC algorithm really works in finding best solution of the object function but it only considers the relation between onlooker's bee movement and employed bees by roulette wheel selection. Hence, it is not strong enough to maximize the exploitation capacity. By applying IABC, it is hoping that this study will accomplish faster results and also achieve multi-objective functions which are having better power losses reduction in distribution network reconfiguration, enhancing load balancing index and improving the voltage profile simultaneously.

CHAPTER 4

RESULT

4.1 Overview

In this chapter, all the results that have been obtained through the proposed method will be discussed. The result for minimizing power losses, voltage profile and load balancing index for network reconfiguration of IEEE-33 bus system by using Modified Artificial Bee Colony (IABC) algorithm will be presented. These results will be obtained by via MATLAB. The main purpose of this test is to find the best possible combination of switching combination that will provide the best optimum solution simultaneously.

4.2 Case Study

Through this project will undertake three cases.The result form three cases are also compared with the result obtained in [24], which using Genetic Algorithm (GA) and [25] which using Particle Swarm Optimization Algorithm (PSO). The three cases are considered:

Case 1: Initial network reconfiguration

Case2: Reconfiguration feeder using conventional Artificial Bee Colony algorithm (ABC)

Case 3: Reconfiguration feeder using modified Artificial Bee Colony algorithm (IABC)

4.3 IEEE 33-Bus System

To verify the proposed IABC method in reducing power losses, a comprehensive testing is being implemented in the 33 bus radial initial network configuration system as shown in Figure 4.1 consist of 32 sectionalizing switches (normally closed switches) and 5 tie switches (normally open switches). The open switches are normally represented by the dotted lines and located at no 33, 34, 35, 36, and 37 branches. The line data and also for load data for 33-bus system has been gain from [27]. The total load data in the system is 3.715MW and the system load is expected to be constant and Sbase = 100MVA. Same as other test system, a high resistance and high reactance value will be modified in R and X column in line data to simulate the open line. Apart from that, combination of state variables will be executed using Newton-Raphson power flow program and optimization was done by using IABC algorithm to find the most optimum losses in the system. The simulation initial for IEEE 33-bus system before and after optimization with IABC algorithm is run in the MATLAB. Thus, the results are recorded and tabulated.

4.4 The Impact of Reconfiguration Process toward Power Loss

The combination of tie switches to be opened before the configuration process has been set to 33, 34, 35, 36 and 37. This is due to the standard arrangement of the distribution system. After the reconfiguration process, the combination of the tie switches that need to be opened given by ABC Algorithm has been changed to S32, S7, S9, S14 and S37.Otherwise, IABC Algorithm opened tie switches at S31, S6, S21, S13 and S37.

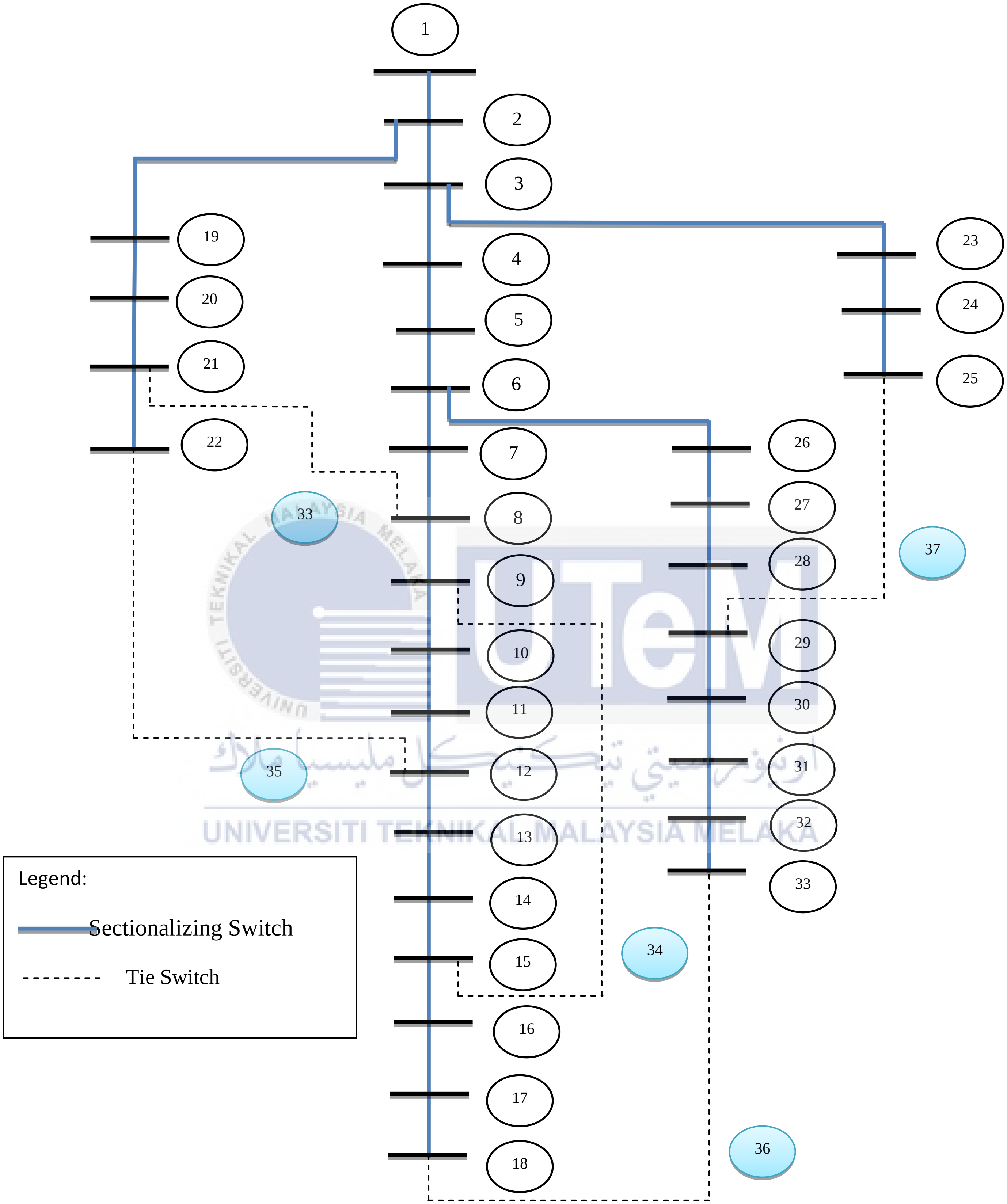


Figure 4.1: 33-bus radial distribution systems (original configuration)

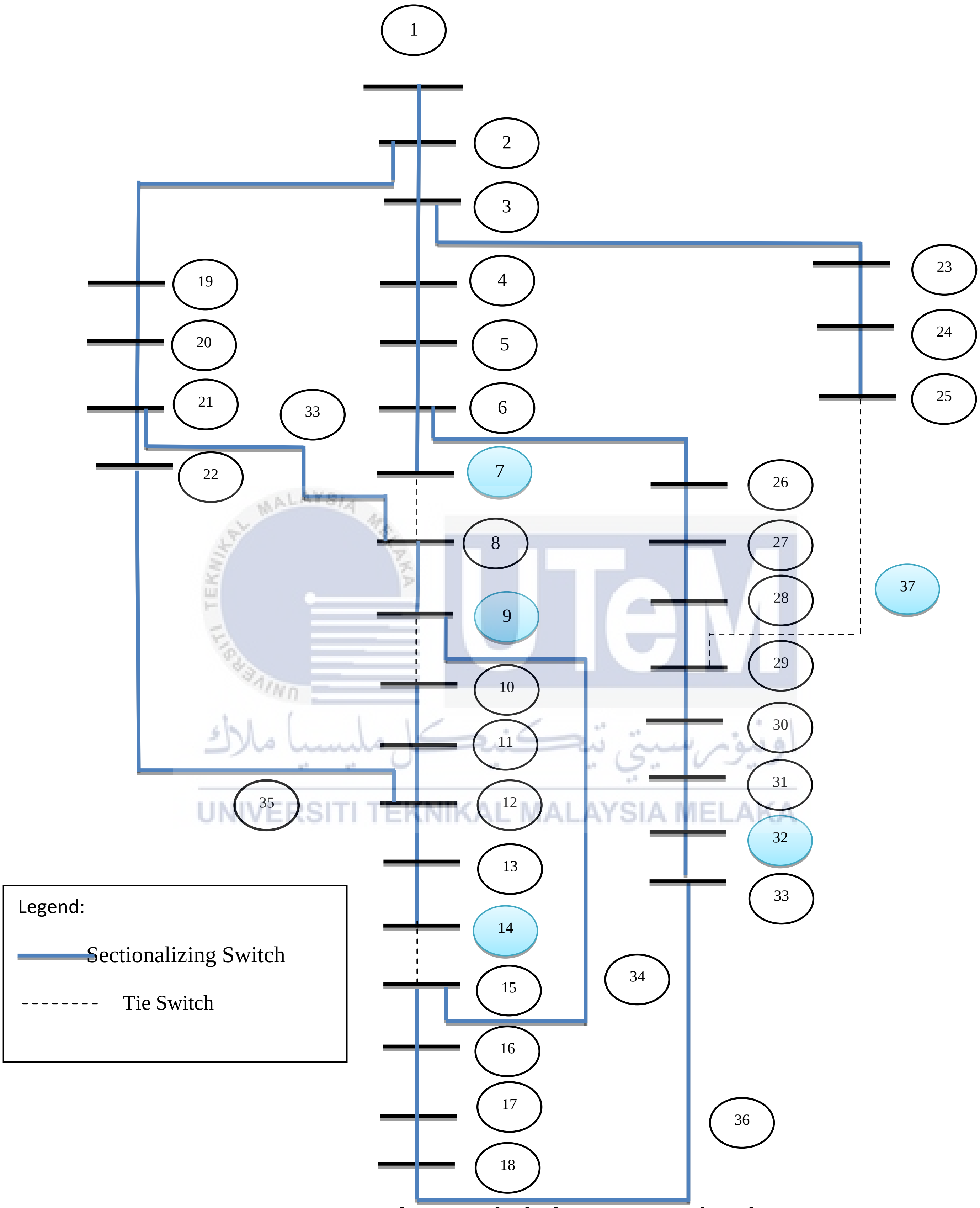


Figure 4.2: Reconfiguration feeder by using ABC algorithm

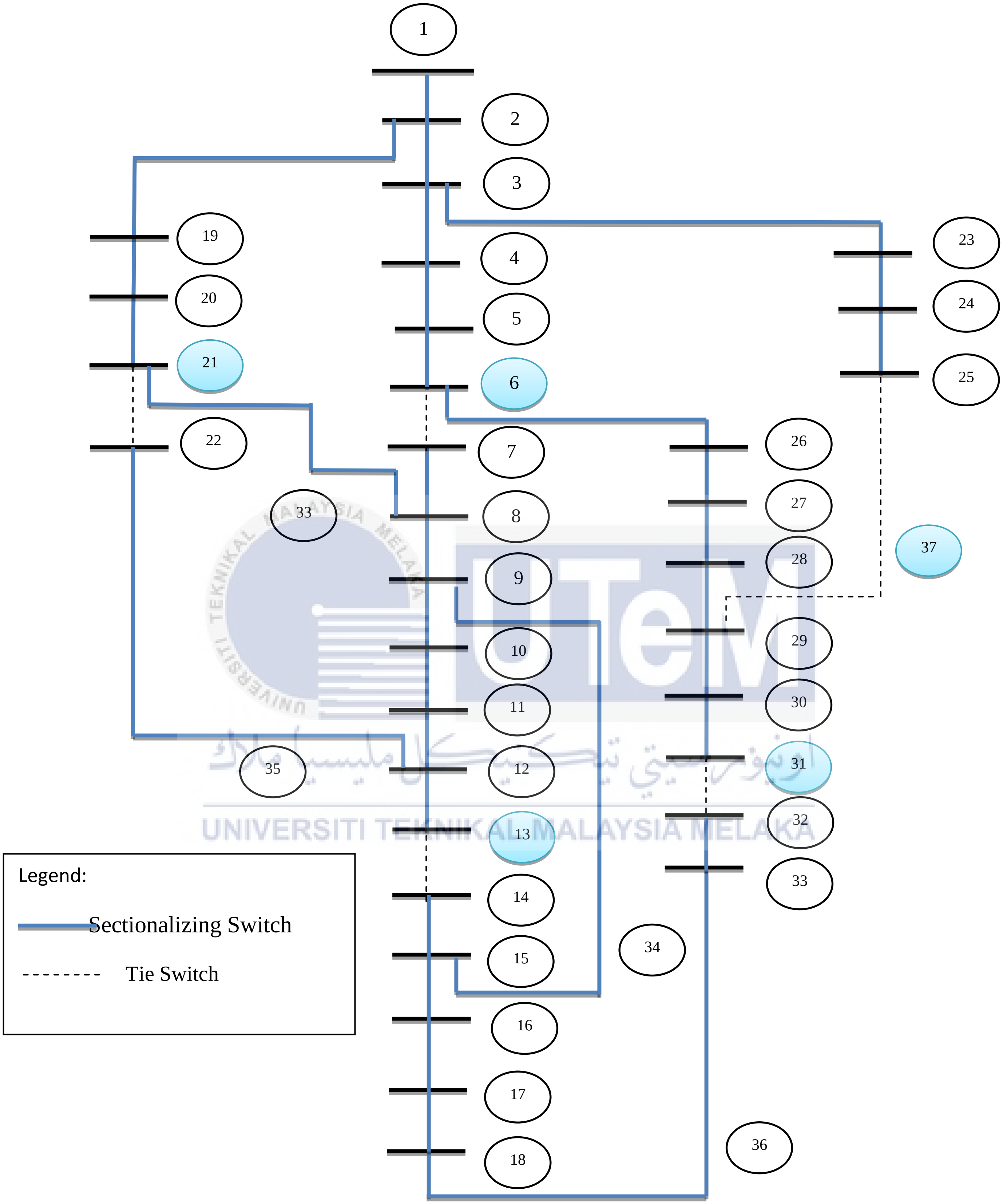


Figure 4.3: Reconfiguration feeder by using IABC algorithm

Figure 4.1, Figure 4.2 and Figure 4.3 shows the distribution network before and after reconfiguration feeder process is done. The dotted line in the figure above is represented the tie switches is normally open. It can be seen that the combination of tie switches of 33, 34, 35, 36 and 37 has been set to be opened. After the reconfiguration process, the combination of switches that need to be opened has been changed. Figure 4.2 and figure 4.3 shows changed tie switch to give optimum the power losses to distribution system. Table 4.1 summarizes the total power loss for reconfiguration using ABC algorithm is 141.8kW different to reconfiguration using IABC algorithm is 107.1kw. The result of power losses from the others two algorithm which is GA and PSO Algorithm also inserted in Table 4.1 to show the differences between five of them.

Table 4.1: Result of 33-node radial distribution network reconfiguration for power losses.

System	**Case 1: Initial Configuration**	**Case 2: ABC Algorithm**	**Case 3: IABC Algorithm**	**Genetic Algorithm (GA) [24]**	**PSO Algorithm (PSO) [26]**
Tie switch	33,34,35,36,37	32, 7,9,14,37	31,6,21,13,37	21,10,18,23,12	7, 10, 28, 14, 32
Total power loss(kW)	202.4	141.8	107.1	162.37	126.4

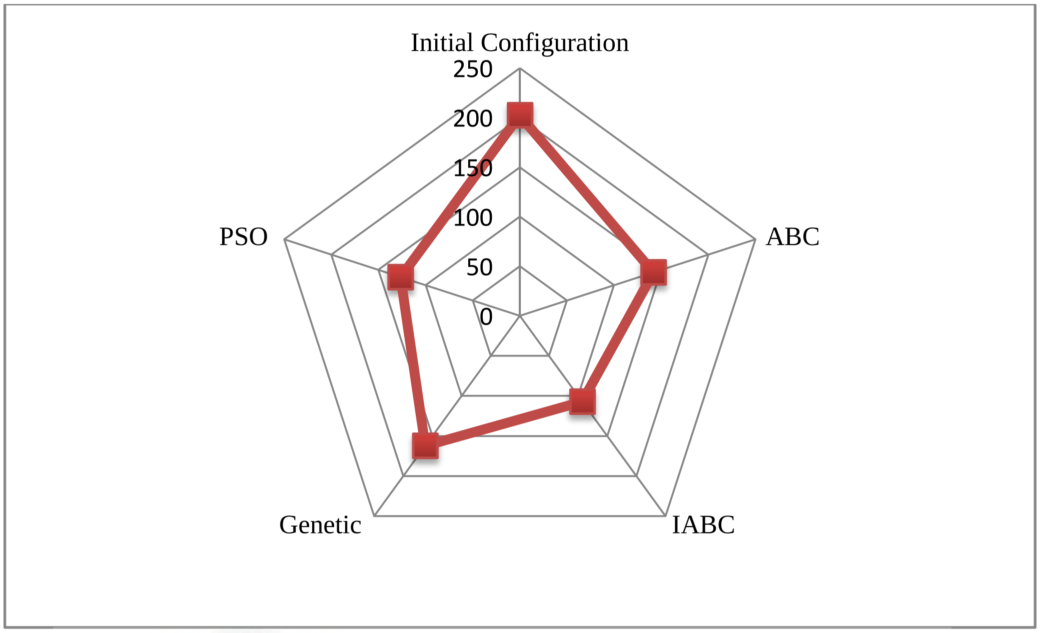


Figure 4.4: The comparison of total power losses

The relationship between power losses with four heuristic methods with those in relevant references [24,25] is shown in Figure 4.4. By the comparison the total power loss using ABC algorithm have decrease by 29.94%, then when applying IABC algorithm the percentage total power loss decreasing to 47.08% compared from initial configuration. For the GA the percentage totals power loss decreasing by 19.78% and for the PSO Algorithm decreasing to 37.55%. It is clearly showed after the reconfiguration process, the power losses have been optimize and make a better result, especially when applying IABC algorithm method.

It shows that by using different combination of tie switches, the power loss can be reduced. In theory, the action of opening and changing the switches can affect the value of power loss in the distribution network system.

4.5 Load Balancing Index

The proposed method is tested with 33-node radial distribution system. The single line diagrams of the test system before and after reconfiguration for load balancing is shown in

Figures 4.1, Figure 4.2 and Figure 4.3. Load balancing index has been calculated during simulation by applying at initial configuration, reconfiguration using ABC algorithm and reconfiguration using IABC algorithm. Table 4.2 shows the result for load balancing index due to the reconfiguration to the distribution system. This result has been operating in the MATLAB software and best results are recorded. From the simulation the load balancing index for ABC algorithm is 0.9959. At the case 3 by using IABC algorithm, the load balancing index for best minimum value is 0.9936. Otherwise, load balancing index for GA is 0.4572 and for the PSO Algorithm is 2.147. All these result have been showing in Table 4.2 below.

Table 4.2: Result of 33-node radial distribution network reconfiguration for load balancing index

System	**Case 1: Initial Configuration**	**Case 2: ABC Algorithm**	**Case 3: IABC Algorithm**	**Genetic Algorithm (GA) [24]**	**Particle Swarm Optimization (PSO) [25]**
Load Balancing Index	0.9438	0.9959	0.9936	0.4572	2.147

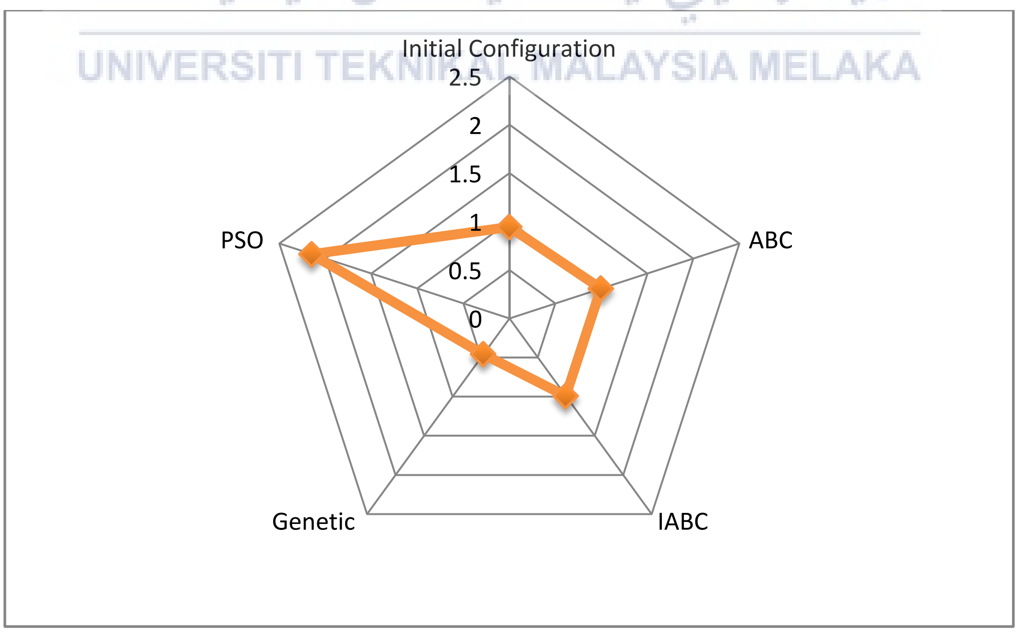


Figure 4.5: Comparison load balancing index

From the Figure 4.5 shows the comparison load balancing index for each case. From that graph it is showed that the load balancing index been increase with 5.52% by compared initial configuration with reconfiguration using ABC algorithm. Comparison when reconfiguration using IABC algorithm with initial configuration is also increase by 5.28%. While GA shows the best decreasing which is 51.55% compared to the initial configuration while PSO Algorithm shows 127.48% increasing.

4.6 Voltage Profile Improvement

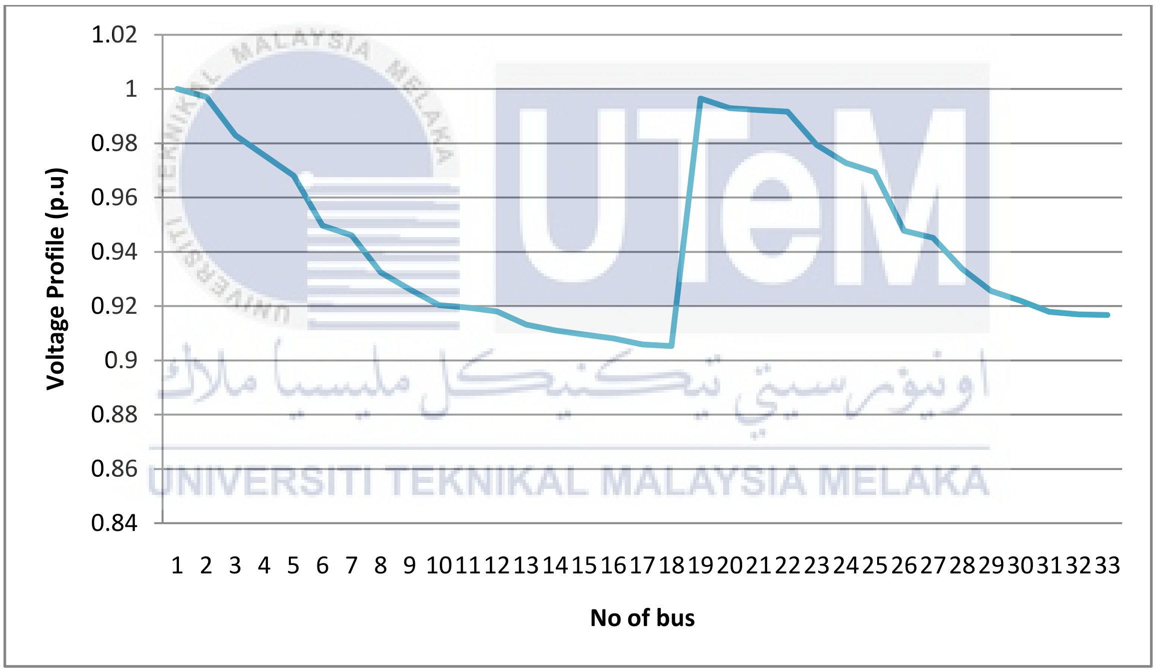


Figure 4.6: Number of bus versus the voltage profile for original configuration.

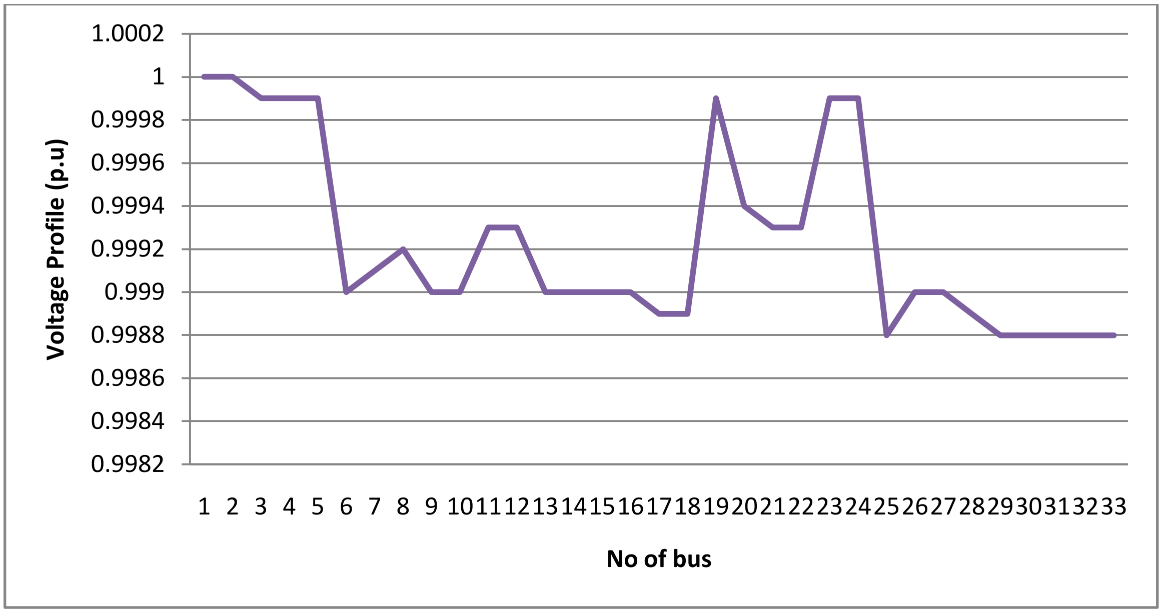


Figure 4.7: Number of bus versus the voltage profile for ABC algorithm.

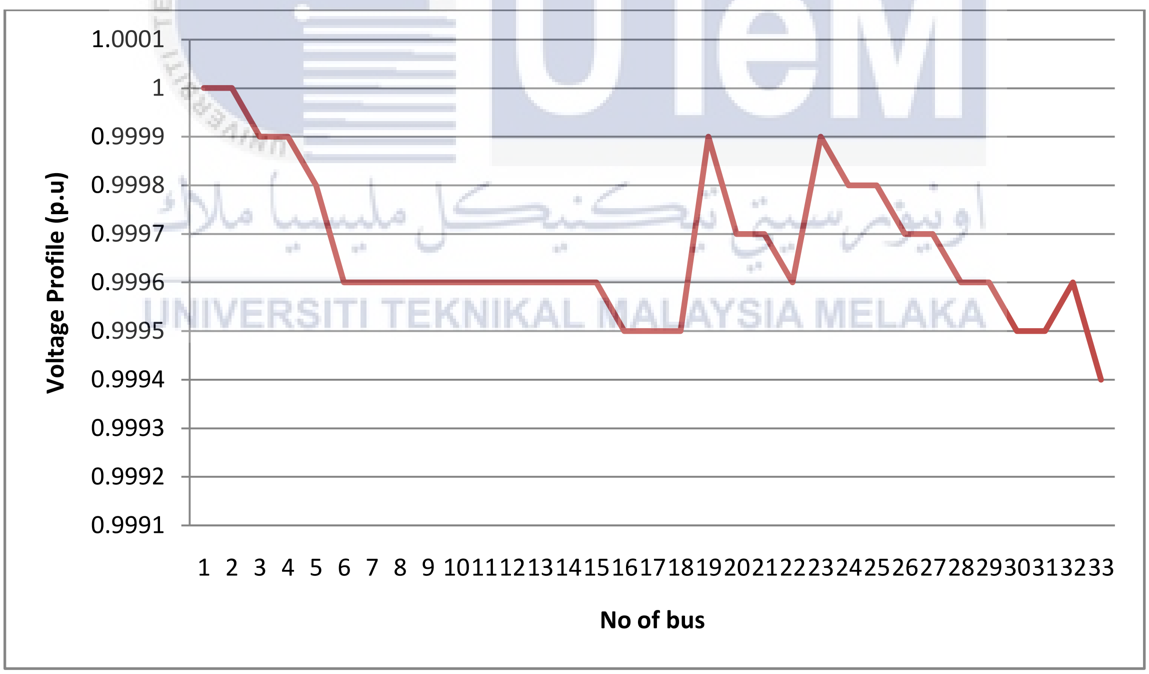


Figure 4.8: Number of bus versus the voltage profile for IABC algorithm.

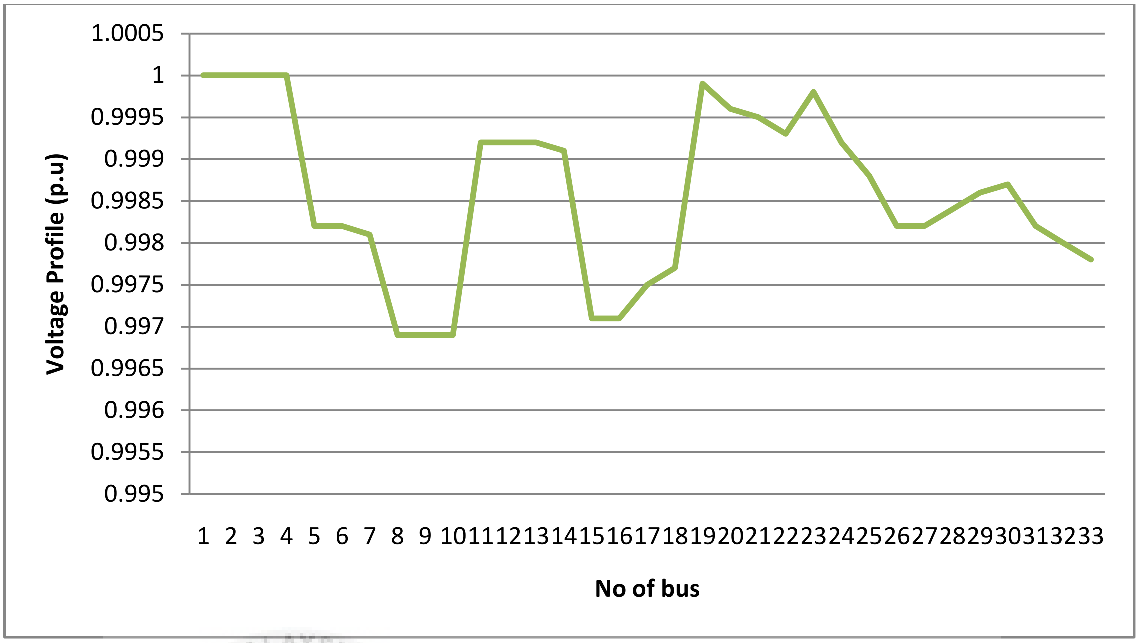


Figure 4.9: Number of bus versus the voltage profile for GA.

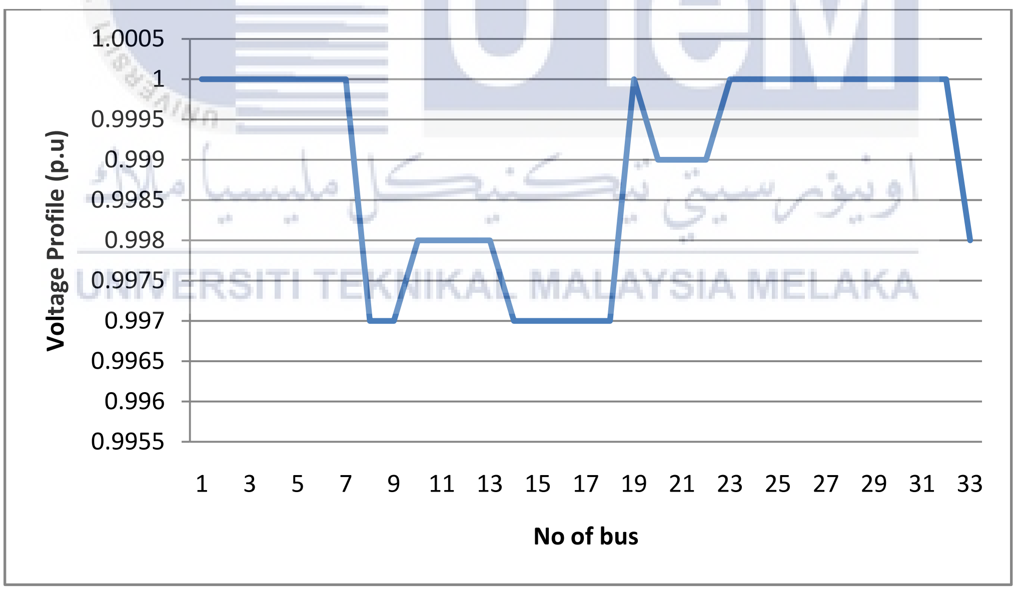


Figure 4.10: Number of bus versus the voltage profile for PSO algorithm

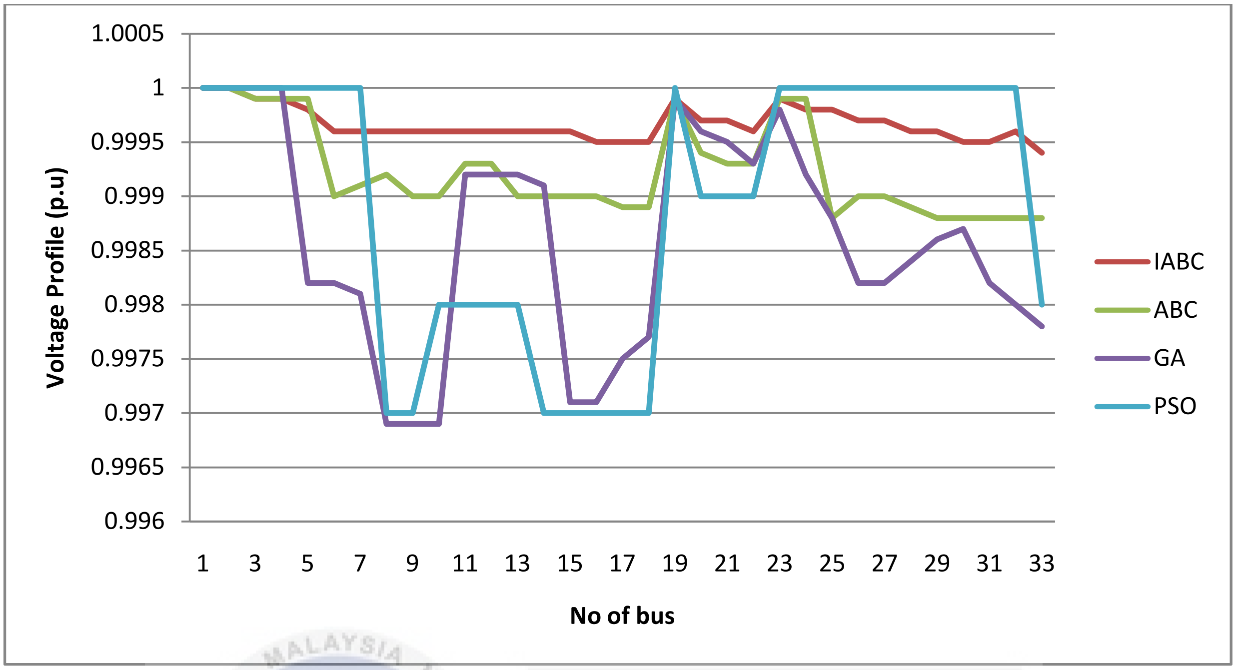


Figure 4.11: Comparison voltage profile

Meanwhile, for the reconfiguration distribution network using IABC algorithm, this proposed method does not only give the lowermost total of losses, but also improves the voltage profile in the overall network system. The voltage profile for the network after reconfiguration is demonstrated a significant improvement as illustrated in Figure 4.11. It also seen that bus voltages for all algorithms are within the allowable range. Regarding to the Figure 4.11, there is some improvements on voltage valued between buses 7 until 15 when IABC compared to ABC,GA and PSO. The increment of voltage value also can be seen in bus 19 as improvement. It is showed that by using IABC algorithm voltage more stable and majority nearly to 1 p.u. compared to ABC, GA and PSO.

4.7 Summary

All results are obtained by testing the IEEE-33 bus system with ABC algorithm and IABC algorithm in MATLAB software for the purpose of optimization. The result showed the capability of this technique to increase the performance of the system. The following evaluation can be drawn from results achieved. The power losses value achieved for ABC is 141.8 kW with the shortest time 634.95 seconds along with open switches is [32, 7, 9, 14, and 37]. While the power loss for IABC is 107.1 kW which better than power losses in ABC with the time 1222.66 seconds along with open switches is [31, 6, 21, 13, and 37]. It is obviously showed that total reduction of reconfiguration by using IABC Algorithm is much better than ABC algorithm which is 95.3 kW (47.08%) compare with ABC algorithm which is 60.6 kW (29.94%) from original configuration.

For the load balancing index, after reconfiguration, both algorithm showed increasing value which is 0.9959 (ABC) and 0.9936 (IABC) form the original configuration which is 0.9438. Even both algorithms did not showed the best value compared to original configuration but IABC showed best value compared to ABC. The result obtained in [25], which using PSO algorithm also presented that PSO having a higher load balancing which are 2.147 even the power losses of PSO (126.4 kW) showed the best value compared to ABC which is 141.8 kW. The summarization of results is shown in Table 4.3. Otherwise, from the Figure 4.12 below, the voltage profile showed that IABC Algorithm voltage more stable and majority nearly to 1p.u. Therefore, IABC algorithm technique is still competitive to be implemented to solve optimization problems for distribution system.

Table 4.3: The summarization results of proposed technique

Description	Original Configuration	ABC Algorithm	IABC Algorithm
Tie Lines	33, 34, 35, 36, 37	7, 9, 14, 32, 37	6,13, 21, 31, 37
Total Power Losses (kW)	202.4	141.8	107.1
Total Reduction (kW)	-	60.6	95.3
Loss reduction (%)	-	29.94	47.08
Load Balancing Index	0.9438	0.9959	0.9936

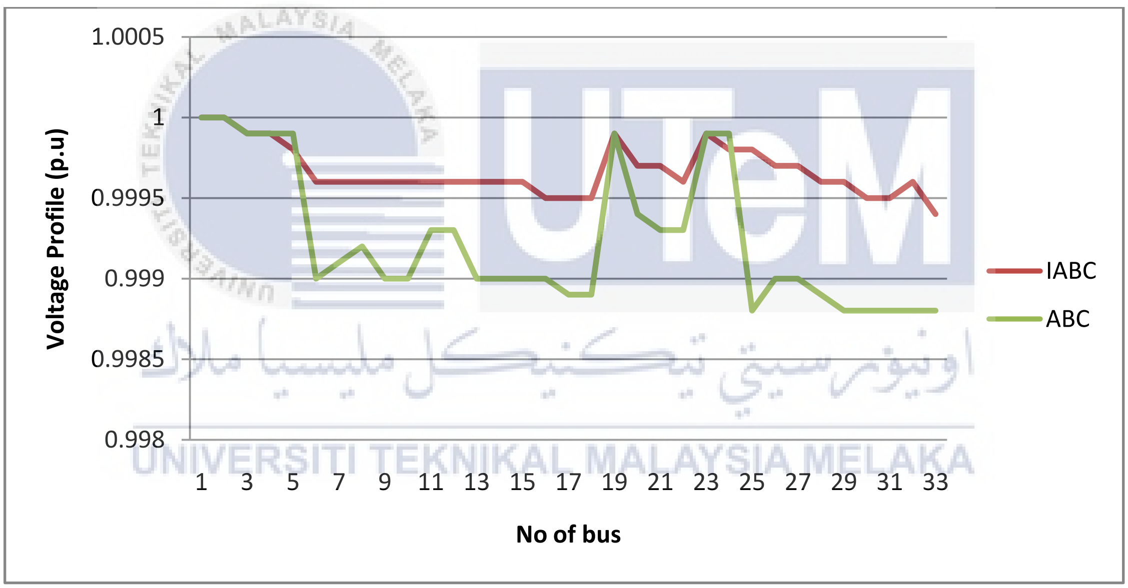


Figure 4.12: Comparison voltage profile of cases

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

The main objective for this study can be divided into three which are (1) to minimize power loss in 33-bus network system, (2) to balance the load during distribution network reconfiguration and (3) to improve voltage profile after network is configured by using new method of Artificial Bee Colony in network system. The IEEE-33 bus has been used in this test. The test is then run by using MATLAB to get the number of switches, the total power losses after reconfiguration, load balancing index, voltage profile at each bus and the last one is the computational time in second. This test was shown the best switching along with the least value of power losses.

Network reconfiguration will improve the reliability and quality of the power supplied to the consumer because it will overcome high power losses in network, the unbalanced load in each bus and the deviation of voltage profile. Thus, network reconfiguration is very important task. Considering the important of network reconfiguration, ABC algorithm and IABC are implemented for network reconfiguration in this project.

The proposed algorithm has been successfully been implemented for network reconfiguration to solve the problems in radial distribution system. This technique also produced a feasible and encouraging solution. The execution of ABC and IABC algorithms was done on structure of radial distribution system which is IEEE-33 bus systems. The algorithms were performed using MATLAB software package and the result obtained show significant improvement compared to initial configuration.

The distribution system experienced reduction in real power loss when the network is reconfigured using ABC and IABC algorithm. In terms of voltage profile at each branch also show significant improvement compared to initial configuration. While, in terms of load balancing shows that initial configuration is better than both algorithms after reconfiguration but load balancing index between both algorithms, IABC shows much better. Moreover, the radiality of the network is also maintained to fulfill the requirement of reconfiguration.

5.2 Recommendation

In order to get more convincing solution, further development can be suggested:

1. To consider Voltage Stability Index (VSI) in network reconfiguration.
2. To implemented of backward forward load flow analysis that can improve the computational time.
3. To consider Distribution Generation (DG) in network reconfiguration.

REFERENCES

[1] M.A Kashem, V. Ganapathy and G.B. Jasmon, "Network reconfiguration for load balancing in distribution networks", IEEE Proc.-Gener., Transmision Distribution, Vol. 146, No. 6, 199, p. 563-567, 2008

[2] Ching-Tzong Su, Chung-Fu Chang and Ji-PyngChiou, "Distribution Network Reconfiguration for Los Reduction by Ant Colony Search Algorithm", Electric Power Systems Research, Vol. 75, No. 2-3, 2013

[3] Abdelhay A. Sallam and Om P. Malik Electric Distribution Systems. IEEE Computer Society Press. p. 21. ISBN 9780470276822, 2011

[4] Merlin, A.; Back, H. Search for a Minimal-Loss Operating Spanning Tree Configuration in an Urban Power Distribution System. In Proceedings of the 1975 Fifth Power Systems Computer Conference (PSCC), Cambridge, UK, 1–5 September 1975; pp. 1–18, 2000

[5] Mendoza, J.E.; Lopez, M.E.; Coello, C.A.; Lopez, E.A. Microgenetic multiobjective reconfiguration algorithm considering power losses and reliability indices for medium voltage distribution network. IET Gener.Transm.Distrib, 3, 825–840, 2009

[6] Bernardon, D.P.; Garcia, V.J.; Ferreira, A.S.Q.; Canha, L.N. Multicriteria distribution network reconfiguration considering subtransmission analysis. IEEE rans. Power Deliv, 25, 2684–2691, 2010

[7] Amanulla, B.; Chakrabarti, S.; Singh, S.N. Reconfiguration of power distribution systems considering reliability and power loss. IEEE Trans. Power Deliv.27, 918–926, 2012

[8] Tomoiagă, B.; Chindriş, M.; Sumper, A.; Sudria-Andreu, A.; Villafafila- Robles, R. Pareto Optimal Reconfiguration of Power Distribution Systems Using a Genetic Algorithm Based on NSGA-II. Energies, 6, 1439-1455, 2013

[9] Goswami, S.K. and Basu, S.K. “A new algorithm for the reconfiguration of distribution feeders for loss minimization,” IEEE Transactions on Power Delivery, vol. 7, pp. 1484-1491, 1992

[10] Verho, P., Jarventausta, P., Karenlampi, M. and Partanen, J. “Reducing theoperation costs of a distribution network via reconfiguration”, IEEE/KTH Stockholm power tech conference.Stockholm. Sweden. pp. 264-269, 1995

[11] S. Sivanaharaju and P.V. Rama Rao, “Radial Distribution Network Reconfiguration for Loss Reduction and Load Balancing using Plant Growth Simulation Algorithm” International Journal on Electrical Engineering and Informatics, vol. 2, Number 4, 266, 2010

[12] JaydeepChakravority “Network Reconfiguration of Distribution System Using Fuzzy Controlled Evolutionary Programming,” ISSN: 2250-3676 International Journal of Engineering Science & advanced technology, vol. 2, Issue 2, 176-182, 2011

[13] Congjiao Wang, Xihuai Wang, Jidong Liu, “Distribution Network Reconfiguration Based on Differential Evolution Algorithm”, SciVerseScienceDirect, 203-208, 2012

[14] Yulin Zhao, Yu Qian and Chunguang Zhao, “Distribution Network Reactive Power Optimization Based on Ant Colony Optimization and Differential Evolution Algorithm”, 2nd IEEE International Symposium on Power Electronic for Distributed Generation System”; pp 471-476, 2010.

[15] EbrahimGhandehari and ShahrokhShojaeian “A Heuristic Multiobjective Method for Radia Distribution Networks Reconfiguration”, Chinese Journal of Engineering, Vol Article ID 654074, 4pages, 2013

[16] HadiSaadat, “Power System Analysis, Singapore: McGraw Hill, 1999

[17] Liongzhi Liu, LiqunGao, Xiangyong Kong, ShuyanZheng, “An Improved Artificial Bee Colony,” Control and Decision Conference (CCDC), 2013.

[18] IEEE Power System Engineering, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book), ANSI / IEEE Standard 141, 1993.

[19] Xiujuan Lei, Xu Huang, Aidong Zhang, “Improved Artificial Bee Colony Algorithm and Its Application in Data Clustering,” 978-1-4244-6439-5/10, 2010 IEEE.

[20] Eberhart RC and Shi Y., “Comparing inertia weights and constriction factors in Particle Swarm Optimization[C], Proceedings of the Congress on Evolutionary Computing, pp84-88, 2000

[21] A.L.Morelalo and A.Monticellii, “Heuristic Approach to Distribution Systems Restoration” IEEE Trans on PowerDelivery, Vol 4, No 4, 1983

[22] Cheng, C. S. and Shirmohammadi, D., “A Three-Phase Power Flow Method for Real-Time Distribution System Analysis”, IEEE Transactions on Power Systems, Vol. 10, No. 2, pp. 671-679, 1995

[23] Shirmohammadi, D. H., Hong, W., Semlyen, A**.,** Luo, G. X., “A Compensation-Based Power Flow Method for Weakly Meshed Distribution and Transmission Networks”, IEEE Transactions on Power Systems, Vol. 3, No. 2, pp. 753-762, 1998

[24] Y. Y. Hong and S. Y. Ho, ” Determination of network configuration considering multiobjective in distribution systems using genetic algorithms”; IEEE Transaction on Power Systems, vol. 20, no.2, 2005

[25] G. Balakrishna and Dr. Ch. SaiBabu "Particle Swarm Optimization based Network Reconfiguration in Distribution System ". IEEE Volume 3, Issue12,Pages 55- 60, ISSN (e): 2319 – 1813, ISSN (p): 2319 – 1805, 2014

[26] MohamadFaniSulaima, HazlieMokhlis, and HazriqIzzuanJaafar, "A DNR Using Evolutionary PSO for Power Reduction". ISSN:2180-1843 Vol.5, No1, 2013

[27] J.J. Jamian, H. Musa, M.W. Mustafa, H. Mokhlis, and S.S Adam,"Distribution Voltage Stability Index for Changing Station Effect on Distribution Network"; International Review of Electrical Engineering IEEE, 2012

[28] Bishop, M.T., Foster, J.D., Down, D.A.,"The Application of Single-phase Voltage Regulators on Three-phase Distribution Systems". The 38th Annual Conf. on Rural Electric Power, p.C2/1-C2/7, 1994

[29] Gu, Z., Rizy, D.T., "Neural networks for combined control of capacitor banks and voltage regulators in distribution systems", .IEEE Trans. on Power Delivery, **11**:1921- 1928.

[30] Kojovic, L.A., "Coordination of Distributed Generation and Step Voltage Regulator Operations for Improved Distribution System Voltage Regulation." IEEE Power Engineering Society General Meeting, p.232-237, 2006

[31] S. Karl. "Electricity Generation", 13 Dec. 2014

[32] "Fundamentals of Electricity", 17 May 2015

[33] D. Karaboga, “An Idea Based On Honey Bee Swarm For Numerical Optimization”, T echnical Report-TR06, Erciyes University, Engineering Faculty, Computer Engineering Department, 2005

[34] Civanlar, S. et al, “Distribution feeder reconfiguration for loss reduction,” IEEE Transactions on power Delivery, vol.3, pp.1217-1223, 1998.

[35] Eberhart RC and Shi Y. Comparing inertia weights and constriction factors in Particle Swarm Optimization [C], Proceedings of the Congress on Evolutionary Computing,pp. 84-88, 2000.