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"I hereby declare that I have read through this report entitle "Distribution Network reconfiguration (DNR) and Voltage stability analysis for radial distribution network using Improved Genetic Algorithm (IGA)" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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DISTRIBUTION NETWORK RECONFIGURATION (DNR) AND VOLTAGE STABILITY ANALYSIS FOR RADIAL DISTRIBUTION NETWORK USING IMPROVED GENETIC ALGORITHM (IGA)

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

STUDENT DECLARATION

I declare that this report entitle "Distribution Network reconfiguration (DNR) and Voltage stability analysis for radial distribution network using Improved Genetic Algorithm (IGA)" is the result of my own project 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 :

Name : NOOR FATHIN NABILA BINTI KAMARUDDIN

Date :

To my beloved mother and father

ACKNOWLEDGEMENT

First of all, I am greatly thankful to ALLAH SWT on His blessing to make this Final Year Project successful.

I would like to express my gratitude to my supervisor, Miss Nur Hazahsha Binti Shamsudin for her valuable guidance, enthusiasm and motivation given throughout the progress of this project.

I would also like to thank my parents for always being there to support me at all times and for giving me the courage and strength that are necessary to carry on with this project. Thanks for their encouragement, love and emotional supports that they had given to me.

I would also like to thank all my friends who had given me the advice, courage and support in completing this Thesis. Their views and tips are very useful.

Last but not least, I would like to thank all the lecturers who have been very friendly and helpful in providing me with necessary information for my project.

ABSTRACT

Distribution system is carried out to improve the reliability, stability, efficiency and service quality of a system. An increment in load demand has affected the reliability and effectiveness of the distribution system. Operation and planning of large interconnected power system are becoming more complex with the increase in power demand, so power system will become less secure. It is important for distribution system to be more reliable, flexible and stable electric system. This project is to determine the best combination set of open switches with lowest power losses and maximum voltage stability. Thus, the distribution network reconfiguration (DNR) method is introduced to protect the distribution system. Distribution network reconfiguration (DNR) is applied to determine the best combination of open switches that acts as the best route to optimize the reduction of power losses during load restoration process. At the same time, a radial network structure is maintained with all loads energized. Another major concern in power distribution networks recently is the problem of voltage stability. Voltage stability is the ability of the power system to maintain the voltage at all buses system at normal operating condition and after the occurrence of disturbance. A disturbance or an increase in load demand causes an uncontrollable and continuous voltage drop in system voltage. The voltage drop occurs at the receiving end in the system can cause voltage collapse in a power system or even leads the system to be blackout. Therefore, by using voltage stability index (VSI), it is possible to compute the stability index value at every node. The most sensitive node that has the lowest voltage stability index might experience the voltage collapse. Improved Genetic Algorithm (IGA) is proposed in this project and tested on the IEEE 16 and IEEE 69 buses system using MATLAB vr2015b. The improvement of genetic algorithm is implemented at crossover operator. Double point and multi point crossover are now apply for IEEE 16 and IEEE 69 buses system respectively rather than single point crossover. The improvement of genetic algorithm shows that there is a reduction in power losses and increment in voltage stability index.

ABSTRAK

Sistem pengagihan berfungsi untuk meningkatkan kebolehpercayaan, kestabilan, kecekapan dan perkhidmatan kualiti sistem. Peningkatan dalam permintaan beban telah memberi kesan kepada kebolehpercayaan dan keberkesanan sistem pengagihan. Operasi dan perancangan sistem kuasa menjadi lebih kompleks dengan peningkatan permintaan kuasa, oleh itu sistem kuasa akan menjadi kurang selamat. Ia adalah amat penting bagi sistem pengagihan untuk menjadi lebih fleksibel dan sistem elektrik yang stabil. Projek ini bertujuan untuk menentukan set kombinasi suis terbuka yang terbaik dengan kehilangan kuasa rendah dan kestabilan voltan maksimum. Oleh itu, kaedah rangkaian pengedaran konfigurasi semula (DNR) diperkenalkan untuk melindungi sistem pengagihan. Konfigurasi semula rangkaian pengedaran (DNR) digunakan untuk menentukan kombinasi yang terbaik suis terbuka yang bertindak sebagai laluan yang terbaik untuk mengoptimumkan pengurangan kehilangan kuasa semasa proses pemulihan beban. Pada masa yang sama, struktur rangkaian jejarian dikekalkan. Satu lagi kebimbangan utama dalam rangkaian pengagihan kuasa baru-baru ini adalah masalah kestabilan voltan. Kestabilan voltan adalah keupayaan sistem kuasa untuk mengekalkan voltan pada semua sistem bas pada keadaan operasi biasa dan selepas berlakunya gangguan. Gangguan atau peningkatan permintaan beban menyebabkan kejatuhan voltan yang tidak terkawal dan berterusan dalam voltan sistem. Penurunan voltan berlaku dalam sistem boleh menyebabkan kejatuhan voltan dalam sistem kuasa atau menyebabkan sistem terganggu. Oleh itu, dengan menggunakan indeks kestabilan voltan (VSI), ia adalah mungkin untuk mengira nilai indeks kestabilan di setiap nod. Nod yang paling sensitif yang mempunyai indeks kestabilan voltan yang paling rendah mungkin mengalami kejatuhan voltan. IGA dicadangkan dalam projek ini dan diuji pada IEEE 16 dan IEEE 69 bas sistem menggunakan MATLAB vr2015b. Penambahbaikan algoritma genetik dilaksanakan pada operator ‘crossover’. ‘Double point’ dan ‘Multi-point’ digunakan pada IEEE 16 dan IEEE 69 sistem bas. Penambahbaikan algoritma genetik menunjukkan bahawa terdapat pengurangan dalam kehilangan kuasa dan kenaikan dalam indeks kestabilan voltan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Motivation

An electric power system is basically a form of network from electrical components used to supply, transfer and distribute the electric power to the consumers. Human or also known as the consumers need electricity to make sure that their daily routine is able to be completed. Without electricity, many works are affected such as a disconnection of communication system and the industry sector need to close down the factory.

Power system can be divided into several parts including generation, transmission, and distribution. Generation system is responsible to generate an electrical energy by conversion of energy available in numerous forms for example kinetic energy of blowing winds, water head and also nuclear energy. After that, the electric power generated to meet customers' demands is moved to the next system which is transmission system. Transmission system is to transmit the electric power from the generation to distribution system. In order to compensate the power losses and voltage stability index during power dispatch, the voltage in transmission line is stepped up by using transformer. For distribution system, it acts as a distributor that distributes the electric power to the consumers. Typical voltage levels for distribution system are 33kV, 22kV and 11kV. As consumers keep increasing day by day, there is an increment in demand of electric energy. As a result, the distribution lines are heavily loaded. Therefore, a good grid power system is very important and the reliability of power supply is needed to minimize power losses and able to improve the voltage stability index based on the distribution systems.

Commonly, distribution systems are operated with radial structure for effective coordination of the protective systems and for reduction of fault levels. Distribution systems contain number of switches that are normally closed (sectionalized switches) and switches that are normally opened (tie switches). These switches are known as groups of interconnected radial circuits that are used for protection and configuration management. In a distribution system, each feeder has a different commercial, residential, and industrial type of loads. These load types have various daily patterns which cause the peak load of feeders happen at particular times. In normal operating conditions, different load can be transmitted by using distribution network reconfiguration.

Distribution network reconfiguration (DNR) is a method of changing the topological structure of distribution network by closing the open or close status of sectionalizing and tie switches. Network reconfiguration is performed by the opening or closing of the network switches under the constraints of transformer capacity, feeder thermal capacity, voltage drop and radiality of the network when the operation conditions changed [4]. Distribution network reconfiguration (DNR) involves the process of selection of the switches that determine the best combination set of the switches to be opened. This is to ensure the system is optimized. The objective of DNR is to shift the heavy load feeders to the lightly feeders so that the load is balanced [5]. This is done to reduce power losses thus upgrade the distribution system security, stability and reliability.

According to [6], the ability of the power system to maintain the voltage at all buses in the system at normal operating condition and after the occurrence of disturbance is known as voltage stability. Power system is stable if the voltage after the disturbance is close to the voltage at normal operating condition. If the power consumption from the system goes beyond its capability, it causes voltage instability in distribution networks. Other than that, voltage instability occurs due to the voltage sources are too far from the load centers and the source voltages are lowest. Unstable voltage in the distribution networks lead to the voltage collapse. Voltage collapse is the phenomenon that occurs in a transmission or distribution system operating under the heaviest loading conditions. Hence, to perform the voltage stability analysis of power distribution system, voltage stability index (VSI) of all nodes is verified. VSI is a numerical solution which helps operator to monitor how close the system is to collapse [8]. The main objective of VSI is to find the most sensitive node of the system. The node having the lowest value of voltage stability index tends to experience the voltage collapse.

In order to find the lowest power losses and maximum voltage stability index, the distribution network can be reconfigured based on several ways of developing heuristic algorithms such as Particle Swarm Optimization (PSO), Simulated Annealing (SA), Tabu Search (SA) and Genetic Algorithm (GA) [14, 15]. Genetic algorithm (GA) is a search algorithm method based on the evolutionary ideas of natural selection and genetic that uses direct binary coding. The principle used in GA is the evolution through natural selection, employing a population of individuals that undergo selection in the presence of operator such as mutation and crossover. The improvement of GA leads to a new method called improved genetic algorithm (IGA). The IGA consists of the same main idea as the GA but some improving is done either at selection, crossover or mutation. The solution from IGA method is more global than the GA method.

1.2 Problem Statement

According to Tenaga Nasional Berhad (TNB) Consumer [18], there are about 7.8 million registered as electricity users in 2013. As stated before, distribution system is to distribute and supply the power to the consumers. With this high amount of electricity users, the electricity demand will increase and finally affect the effectiveness of distribution network system. Heavy loaded network would leads to an increment in power losses in distribution system. Other than that, the major concern problem in distribution system is the voltage stability. The increment in electricity demand affects the voltage stability and cause the system to blackout. Therefore, by reconfigure the initial configuration of bus system, a distribution system become more reliable and secure. By using improved genetic algorithm (IGA) method in load restoration can contribute to the lowest the power losses and an optimal value of voltage stability index.

1.3 Objective

The objectives below need to be successfully achieved in order to meet all requirement of minimizing the power losses and maximize the voltage stability of distribution network system:

i. To develop Improved Genetic Algorithm (IGA) for IEEE 16 buses system and IEEE 69 buses system in determining the best combination set of switches via distribution network reconfiguration (DNR) by using MATLAB vr2015b.

ii. To compare the performance of power losses and voltage stability index for IEEE 16 buses system and IEEE 69 buses system of distribution network configuration.

1.4 Scope

There are IEEE 16 and IEEE 69 buses system of distribution network with base voltage of 132 kV being utilized in configuring the best status of open switches and also best value of voltage stability index. MATLAB vr2015b is used to implement the proposed algorithm which is improved genetic algorithm (IGA).

1.5 Significance of Project

An improved voltage stability index and the minimizing of power losses are provided with the reconfiguration of the distribution network of IEEE 16 and IEEE 69 buses test system of distribution network configuration. IGA is used as a search engine to achieve the objective of the reconfiguration.

1.6 Report Outline

The main objective of this report is to determine the best combination set of open switches with lowest power losses and maximum voltage stability. This report is divided into five chapters such as introduction, literature review, research methodology, results and conclusion.

In chapter 1 which is introduction is about the research background, problem statement, objectives, scope, significant of project and report outline.

Chapter 2 is the literature review. The theory and basic principle that will be used in the project are discusses in this chapter. There are also related works and studies and research paper that reviewed as the references.

The operations, techniques and methods to do in this project is discusses in Chapter 3. The tested system is also presented in this chapter.

In chapter 4, discussion on the result of the project outcome is made in terms of the comparison between the two methods used which are the GA and IGA method.

Chapter 5 is about the conclusion of the gathered results for both methods. Besides that, there is also recommendation for future work plan.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principles

Based on the problem statement, objectives and scope in the Chapter 1, a study on the theory and basic principle is done to fully understand the project. All necessary theory on the distribution network reconfiguration (DNR), voltage stability index (VSI), genetic algorithm (GA) and improved genetic algorithm (IGA) are included in this sub-chapter of Chapter 2. All these theories and basic principles are applied in the project.

2.1.1 Electrical power system

Basically, electrical power system in Malaysia can be divided into three main parts which are generation, transmission and distribution. Each part plays an important role to supply power to the consumers. Figure 2.1 shows the electrical power system.

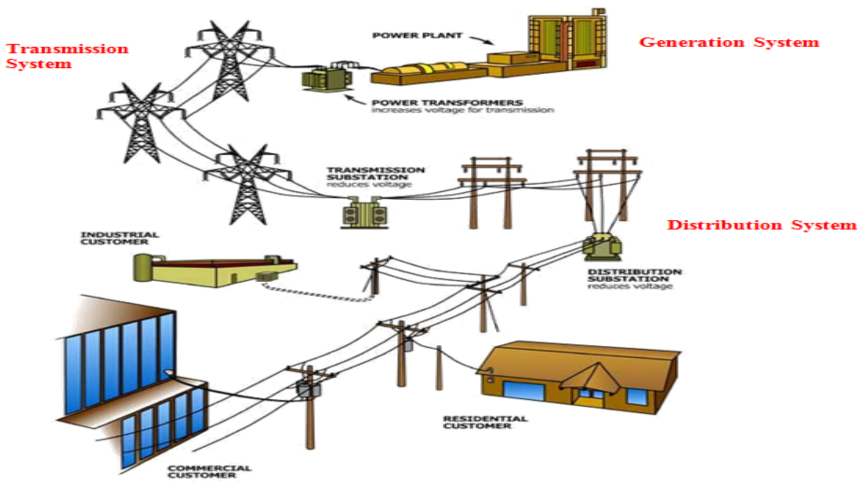

Figure 2.1: Electrical power system [2]

Generation system consists of generating plants which is the first link in the chain in providing electricity to the consumers. Electrical energy is generated by the conversion of energy available in various forms. The generation system must ensure that the electricity generated must be enough to meet the customers' demand. After the electricity is generated, it then moves to the transmission subsystem.

Transmission system transmits the electricity from the generating plants over long distances to local service areas. In order to compensate for power losses during power mismatch, the voltage in the transmission line is stepped up. The transmission voltages as stated in Tenga Nasional Berhad (TNB) are normally 132kV, 275kV and 500kV.

Lastly, the power transmitted is stepped down by using transformer to the distribution system. The main purpose of distribution system is to distribute and also supply the power to individual consumer premises. The distribution of power with low voltage level is done for different consumer. Normally, the distribution voltages in Malaysia are 11kV, 22kV and 33kV.

2.1.2 Network security and operation

The terms reliability and security is used interchangeably for power systems. In [2], power system security can be described as the ability to maintain the flow of the electricity from the generators to the customers especially during disturbed conditions. Since disturbances in power system can be small or large; localized or widespread, it is desirable to plan suitable measures to improve power system security and increase voltage stability margins. According [3], the measures of power system security are the amounts, duration and frequency of customer outages. The outages can be represented in probabilistic terms that can be reliable.

However, when unpredictable equipment failures or sudden increment in customers' demands occur, the entire security of power systems cannot be totally guaranteed. This possibly causes severe impacts on power systems security such as the increment in power losses and also decrement in voltage stability of power system. Power system needs to operationally secure with minimal probability of blackouts to maintain the stability of the voltage. Thus, to overcome the impact on power systems security, distribution network reconfiguration (DNR) is introduced.

2.1.3 Distribution of Network Reconfiguration (DNR)

The function of distribution system is to supply the consumers without any longer interruption during the outage condition. Relays will detect the faulted areas during fault occurs in the system and disconnect the network by opening the circuit breakers. Power becomes unavailable to the loads in certain areas and the power utilities should re-energize the loads as quickly as possible. The re-energizing procedure is known as service restoration or network reconfiguration. Basically the networks are configured radially to increase the efficiency of the protective systems. Other than that, the purposes of network reconfiguration are to reduce power losses and eventually improve the reliability of power supply by changing the status of existing sectionalizing switches and ties. In order to optimize the network system, the process of selection of the switches is involved in the network reconfiguration that determines the best combination set of switches to be opened. The execution of the process of the selection should satisfy the requirement of optimization and satisfying the operating constraints [1, 4]:

1. The radiality arrangement of the configuration should be maintained.
2. Feeder capacity should not be exceeded which can lead to loss minimization.
3. Deviation of voltage profile should be minimized.

In network reconfiguration for loss reduction, the solution involves a search over relevant radial configurations. A variety of approaches of the network reconfiguration problem are previously surveyed. The artificial intelligence-based methodologies such as Genetic Algorithm (GA), Artificial Bee Colony (ABC), Partial Swarm Optimization (PSO) and Improved Genetic Algorithm (IGA) evolutionary technique have increasingly used for the distribution system reconfiguration problem [14, 15].

2.1.4 Voltage Stability Index

In [5], voltage stability is stated as the characteristic for a power system to remain in a state of equilibrium at normal operating conditions and restore an acceptable state of equilibrium after an occurrence of disturbance. So, it becomes one of the major concerns for electric utilities nowadays. This is because the power system is operated under increasingly stressed conditions and hence causes the load become heavy. Other than that, voltage stability is considered as an important factor in power system and planning since voltage instability would lead to system collapse.

Voltage collapse is the process by which the voltage instability leads to the loss of voltage in a significant part of the system. Referring to [6], several important contributing factors to voltage collapse are stressed power systems, inadequate fast reactive power resources, load characteristics, effect of tap-changing transformers and unexpected (and/or unwanted) relay operation. Thus, it is essential in power system planning and secure operation to predict the voltage collapse.

To predict or overcome the voltage collapse, an accurate knowledge regarding the voltage collapse can be obtained by voltage stability analysis. According to [7], voltage stability index (VSI) is numerical solution that helps operator to monitor how close the system is to collapse. The function of voltage stability index (VSI) is to give important information about the proximity of voltage instability in power system and identification of the most sensitive node of the system. In distribution network, the node having instability voltage is more prone to voltage collapse and leads to total blackout to the whole system. The most sensitive node is one that would exhibit one of the following situations [8, 9]:

1. Highest critical point
2. Lowest reactive power margin.
3. Greatest reactive power deficiency
4. Highest % change in voltage.

2.1.5 Genetic Algorithm (GA)

Genetic algorithms (GA) are known as a search algorithms based on mechanics of nature and natural genetics. Genetic algorithm works by combining the solution evaluation with randomized, structured exchanges of information between solutions to obtain optimality. Due to restrictions on solution space are not made during the process, Genetic algorithms (GA) are considered to be robust methods. This algorithm is able to exploit historical information structures from previous solution guesses in an attempt to increase performance of future solutions [10]. Genetic algorithm (GA) tends to develop a group of initial poorly generated solutions via selection, crossover and mutation techniques to a set of acceptable solutions through successive generations. In the course of genetic evolution, more fit specimens are given greater opportunities to reproduce; this selection pressure is counterbalanced by mutation and crossover operation.

Since the topology of a distribution network can be uniquely defined by the statuses of all available tie and sectionalizing switches, a solution to the restoration problem is encoded as a function of the controllable switch states of the network. The number of switches in the network is equal to the length of the binary string. One bit with a value '1' or '0' is representing each switch state corresponding to 'close' or 'open' respectively. The population of the strings is randomly generated such that the number of sectionalizing switches is represented by the number of '1' and the number of the tie switches is represented by the number of '0's [11]. All the strings are in radial since they are represented by the prufer number encoding algorithm. The conventional termination of the genetic algorithm (GA) is applied after a pre-specified number of generations. Lastly, the quality of the best members of the population is tested against the problem definition after the completion of the number of generations. Genetic algorithm (GA) may be restarted or a fresh search is initiated if no acceptable solutions are found.

2.1.6 Improved Genetic Algorithm (IGA)

The disadvantage of genetic algorithm (GA) is prone to premature convergence and slow convergence problem. The improvement of genetic algorithm (GA) leads to a new method called improved genetic algorithm (IGA). The improvement of genetic algorithm (IGA) consists of the same main idea as the conventional genetic algorithm (GA) but some improving is done either at selection, crossover or mutation [12]. Improvement of genetic algorithm (IGA) able to provide better set of solution with faster computational time.

Two parent strings are selected by using the chromosomes string from the initialization process in the selection process of improved genetic algorithm (IGA). There is possibility that both parents have the same characteristic in the chromosomes string since the similar fitness is shared between them. However, the sequences and the position of the chromosomes might be different. This process can be improved by arranging the chromosomes into a group from the best fitness to the least fitness [13].

For crossover operator, two parents from selection process are combining to produce new child with the characteristic from both parents. The child is produced when some gene in both parents is exchange according to the number of crossing point chosen before proceed to the next step. Multi-point point crossover or double point crossover can be implemented to make some improvement rather than used the normal crossover. In [14], double point crossover is introduced instead of the single crossover operator used in genetic algorithm (GA). Double point crossover can be implemented at larger or smaller buses systems. The results obtained are differs based on two terms which is speed and also accuracy. Larger buses system has slower speed of computational time compared to smallest buses system. For the accuracy, larger buses system is more accurate due to the number of switches selected is higher compare to the smallest buses system. When the number of switches selected is higher, the probability of the genes to exchange is increase. Therefore, the lowest power losses can be obtained. The improvement of crossover operator allows a better possibility of the exchange of genetic content between individuals by combining among binaries values of respective parents.

A bit of the child's chromosomes string produces are mutated in mutation operator to produce a new child with a better characteristic compared to the previous stage. This process is responsible to introduce a new characteristic to the population.

2.2 Review of previous related works

Many researches related to power optimization and voltage stability index for distribution system using distribution network reconfiguration method have been done. Methods such as Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO), and Genetic Algorithm (GA) are applied to construct the new configuration network with lowest power losses and stable voltage stability index according to [16, 17].

The reconfiguration of network is one of the solutions in minimizing power losses in the distribution system due to various constraints such as the network radiality, voltage limits and feeder capability limits. Apart from the problem of power losses, voltage stability is also an issue concern if it occurs in the distribution network system. A power system has entered a state of voltage instability when a disturbance causes a progressive and uncontrollable decline in voltage. A quick restoration is required when a fault and voltage instability occurs in the system. Thus, related software such as MatLab can be used to assist the operator. There are a various type of metaheuristic methods can be applied to solve the problem. By referring to [18], artificial bee colony (ABC) is the search ability in the algorithm by presenting neighborhood source production mechanism. This algorithm consists of three groups of bees known as employed bees, onlookers and scouts. However, artificial bee colony (ABC) has a lower convergence speed and easily trapped in local optima when conduct complex multimodal problems. This is due to the search pattern that is good at exploration but poor at exploitation.

Other than artificial bee colony (ABC), Particle Swarm Optimization (PSO) is also one of the commonly method used. In [19] stated that particle swarm optimization (PSO) algorithm is easier to be implemented, less memory required, has ability to reach global optimum solution and also can obtained good solution in a short computing time. However, particle swarm optimization (PSO) also has the lower convergence speed. By referring to [20], genetic algorithm (GA) is another method used to minimizing the power losses and increases the voltage stability in distribution system. Despite that, the full potential of this algorithm in order to find quality solutions is limited for large systems due to some problems related to its coding.

As stated in [21], imperialist competitive algorithm (ICA) is a new motivated global search strategy that used to deal with different optimization tasks. The algorithm starts with initial population named as country. This country is divided into two groups which are imperialist and colonies. When the competition starts, the imperialist begin attempt to gain more colonies. At the end, only one imperialist is remained. In this paper also shows that the end results are compared with genetic algorithm (GA) in terms of speed, accuracy and convergence. When genetic algorithm (GA) is applied, the result showed a better quality of solution in terms of accuracy and convergence compared imperialist competitive algorithm (ICA).

2.3 Summary of review

Currently, many interesting algorithms and solutions have been developed to minimize power losses and to get an optimal value of voltage stability index in distribution system. The solution methods contrast from one application to another. Methods such as Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Imperialist Competitive Algorithm (ICA) are the example of optimization algorithms presently used.

The previous researches proved that heuristic search algorithm is very useful and helpful to improve reliability, and improve the voltage stability index in distribution network system. Genetic algorithm (GA) is commonly used to find the radial configuration to restore the system after a fault occurs. However, by improving the genetic algorithm operator can lead to a better solution. Improved genetic algorithm (IGA) method is proposed in this project to find the best route of network reconfiguration having the lowest power losses and optimal value of voltage stability index. This method is applied at IEEE 16 and IEEE 69 buses network system.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Overall project procedures

MATLAB vr2015b is used to simulate the improved genetic algorithm (IGA) programming for IEEE 16 and IEEE 69 buses system. This project consists of three main stages. There are the literature review, the programming coding and development.

Research study is carried out in the beginning of this project. The literature review and collecting data including the study about the existing method and procedures to be used is performed. Related concept and present problems are identified for this project through the research study. The next stage is to determine the flow of the project programming for this system. There are four parts in the flowchart of the programming which are initialization, fitness, genetic operation and simulation. The initial population is generated randomly to create a huge amount of population which is different from initial population in the initialization process. By using the new population, the fitness inside the chromosome of new population is selected based on the potential of the possible solution. After that, the genetic operation method is implemented through the crossover and mutation to create a new offspring with new genetic chromosome the suitable programming coding is considered to find out the best output that can be reached.

Last stage is the development of the programming coding. In this stage, the coding for the IEEE 16 and IEEE 69 buses system will be run and tested. The coding is continually tested until the desired output could be obtained.

3.2 Principles of the methods or techniques

3.2.1 Genetic Algorithm (GA)

A genetic algorithm (GA) is a set of sequential steps needs to be executed to achieve a task with some of the principles of genetics included in it. The principles in the implementation of genetic algorithm (GA) are the genetic principles natural selection and evolution theory. This algorithm combines the adaptive nature of the natural genetics. The search is carried out through randomized information exchange.

Genetic algorithm (GA) method started with the initialization process. The number of switches (initial of population) is randomly generated in the network reconfiguration from the selected population. The set of search points selected that is used for processing is called as population. The process of fitness takes place where the individual or the chromosomes inside selected population is computed and saved. The chromosomes represent the number of the switches. Fitness of the chromosomes is evaluated according to the value that represents the power losses for each switch. In order to create a new generation with new trait, fitness needs to be changed or improved in the chromosomes of the selected population.

The next stage is the crossover process. The child is produced from the selected parent of the chosen population in this process. The genes of both parents are swapped with each other throughout this process. This creates child with new characteristic inside the chromosomes that occupy all the wanted characteristic and fitness. Through the process of the iteration of number, the process of the crossover is accomplished.

Parent 1	1	1	0	1	0	1	0	1
Parent 2	1	0	0	0	0	1	0	0
	String 1			String 2			String 3	
Child 1	1	1	0	0	0	1	0	1
Child 2	1	0	0	1	0	1	0	0

Figure 3.1: Crossover operation illustration [15]

Mutation process is the last process where the offspring produced in the crossover process is mutated to form new chromosomes genetic. The new chromosomes produced are very different from the parent genetic chromosomes.

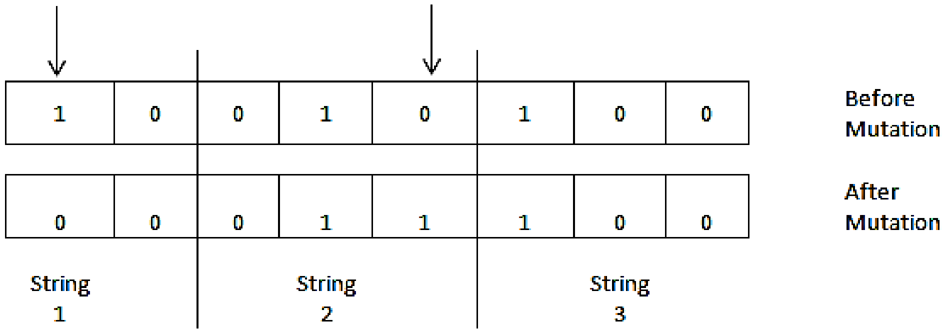

Figure 3.2: Mutation operation illustration [15]

The new children are placed in a new population after going through all the process. This overall process is repeated until it reaches the maximum population. If the last condition is satisfied, the process is stopped. The fitness for each individual in the new population is evaluated and the best solution is selected.

3.2.2 Implementation of Improved Genetic Algorithm (IGA) for power losses and voltage stability index

The improvement of genetic algorithm leads to a new method called improved genetic algorithm (IGA). Improved genetic algorithm (IGA) consists of the same main idea as the genetic algorithm (GA) but some improvement is done either at selection, crossover or mutation.

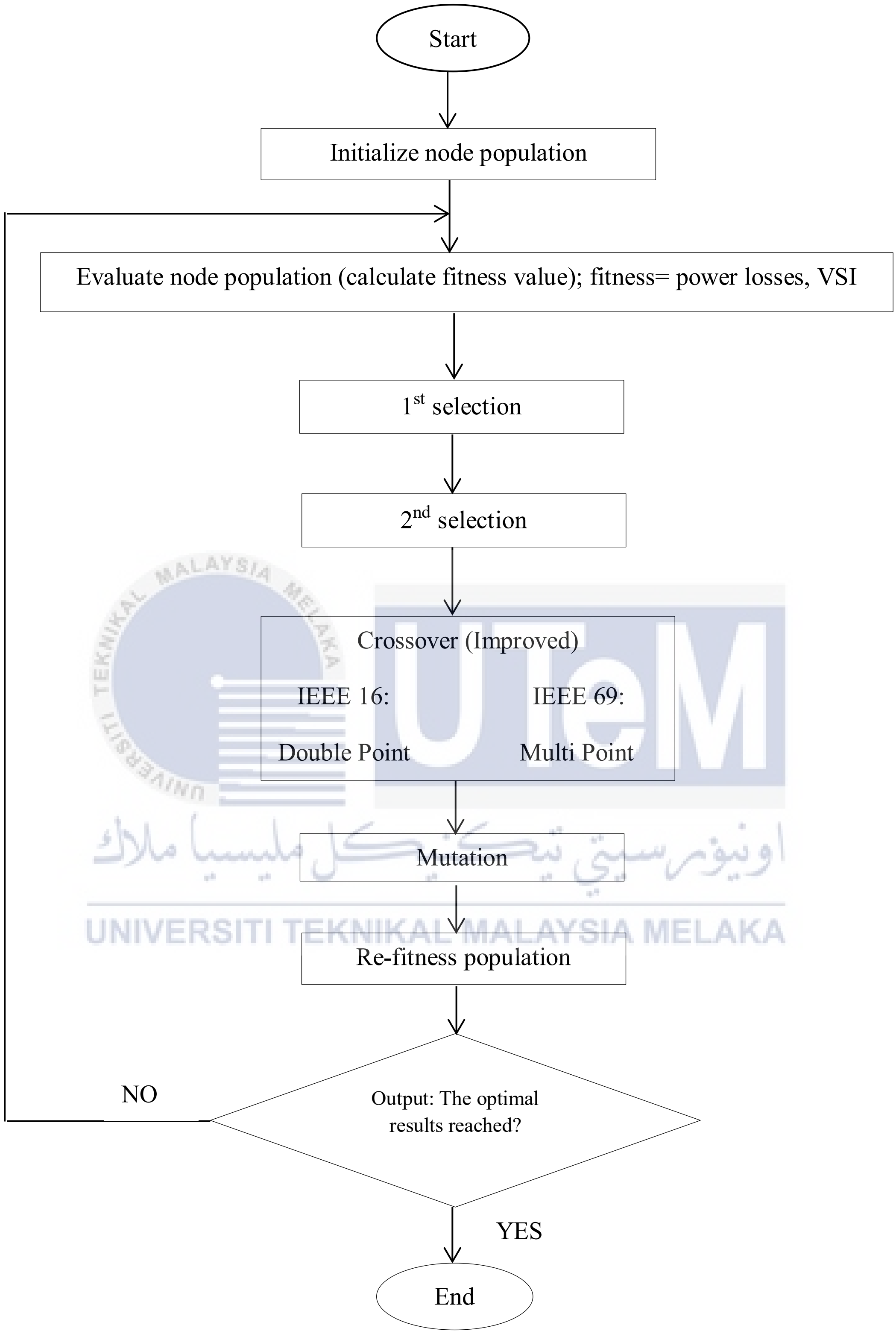

Figure 3.3: Block diagram of improved genetic algorithm (IGA)

For voltage stability index (VSI) implemented using improved genetic algorithm (IGA), the flow is the same as the power losses. However, the equation to calculate the voltage stability index (VSI) is different from the equation of power losses. The equations for power losses and voltage stability index (VSI) are stated below. The steps described the whole processes one by one is shown as following.

Step 1: Initialization

The process starts with the initialization where the selections of the fitness take place. The fitness that represents the power losses is chosen based on the potential and sends to the selection process in the form of the chromosomes string. By using Newton Raphson method, power losses can be calculated as below.

Newton-Raphson Method equation at any given bus of i and j:

$$P_i = \sum_{j=1}^{n} |Y_i| \left|V_j\right| \left|V_{ij}\right| \cos(\theta_{ij} - \delta_i + \delta_j) \neq i \quad (3.1)$$

$$Q_i = -\sum_{j=1}^{n} |Y_i| \left|V_j\right| \left|V_{ij}\right| \cos(\theta_{ij} - \delta_i + \delta_j) \neq i \quad (3.2)$$

Where:

$Vi,$: Voltage magnitude of bus i and j

$\delta i,$: Voltage angle of bus i and j

The equation to define the difference in real power (Pi) and reactive power (Qi):

$$Pi = Psch - Pi \quad (3.3)$$

$$Qi = Qsch - Qi \quad (3.4)$$

Where:

Pi: Specified real power at bus i

Qi: Specified reactive power at bus i

To calculate the power losses:

$$P_{loss} = \sum_{i=1}^{n}\sum_{i=1}^{n} A_{ij}\left(P_iP_j + Q_iQ_j\right) + B_{ij}\left(Q_iP_j - P_iQ_j\right) \tag{3.5}$$

$$Aij = \frac{\text{Rijcos}(\delta i - \delta j)}{ViVj} \tag{3.6}$$

$$Bij = \frac{\text{Rijcos}(\delta i - \delta j)}{ViVj} \tag{3.7}$$

Where:

$Pi,$: Real and reactive power at bus i

$Pj,$: Real and reactive power at bus j

Rij : Line resistance of bus i and j

$Vi,$: Voltage magnitude of bus i and j

$\delta i,$: Voltage angle of bus i and j

For fitness which is voltage stability index (VSI), the proposed voltage stability index (VSI) equation and Newton-Raphson method are used to calculate each bus voltage associated with each chromosome. Figure 3.4 shows the electrical equivalent of radial distribution system.

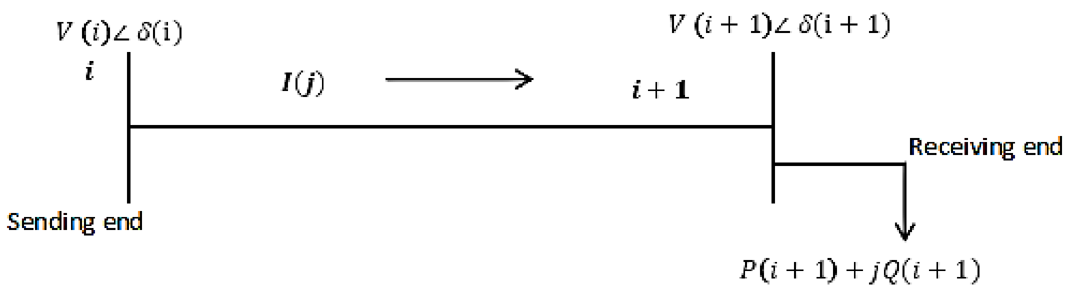

Figure 3.4: Electrical equivalent of two nodes in bus system [6]

The following equation can be written based on the Figure 3.4:

$$I_{(j)} = \frac{V_{(i)} - V_{(i+1)}}{r_{(j)} + jx_{(j)}} \quad (3.8)$$

Where

I(j) = current of branch *j*

V(i)= voltage of node *i*

V(i+1)= voltage of node *i+1*

r(j)= branch resistance

x(j)= branch reactance

j = branch number

i = sending end node

i+1 = receiving end node

From equation (3.8)

$$|V_{(i+1)}|^4 - b_{(j)}|V_{(i+1)}|^2 + c_{(j)} = 0 \quad (3.9)$$

Let,

$$b_{(j)} = \left\{|V_{(i)}|^2 - 2P(i+1)r_{(j)} - 2Q(i+1)x_{(j)}\right\} \quad (3.10)$$

$$c_{(j)} = \{|P^2(i+1)| + Q^2(i+1)\}\{r^2(j) + x^2(j)\} \quad (3.11)$$

Substitutes equation (3.10) and (3.11) into (3.9),

$$SI_{(i+j)} = \left\{|V_{(i)}|^4\right\} - 4.0\{P_{(i+1)}x_{(j)} - Q_{(i+1)}r_{(j)}\}^2 - 4.0\{P_{(i+1)}r_{(j)} - Q_{(i+1)}x_{(j)}\}|V_{(i)}|^2 \quad (3.12)$$

Where

SI(i+1) = voltage stability index of node *i+1*.

$V(i)$= voltage of node i

$V(i+1)$= voltage of node $i+1$

$P(i+1)$= total real power load fed through node $i+1$

$Q(i+1)$= total reactive power load fed through node $i+1$

$r(j)$= branch resistance

$x(j)$= branch reactance

For stable operation of the radial distribution networks, $SI(i+1) \geq 0$. The value of resistance and reactance of the line is not constant. Thus, the voltage stability index acquired is different.

Step 2: Selection

For power losses, two parent strings are selected by using the chromosomes string from the initialization process. There is possibility that both parents have the same characteristic in the chromosomes string since the similar fitness is shared between them. However, the sequences and the position of the chromosomes might be different. This process can be improved by arranging the chromosomes into a group from the best fitness to the least fitness.

For voltage stability index (VSI), the best chromosome that has (minimum or maximum) fitness value is identified and stored. This best fitness will go to the mating pool for producing the next generation.

Step 3: Crossover

In this process, two parents from selection process (set of switches with lowest power losses and maximum voltage stability index) are combined to produce new child with the characteristic from both parents. The child is produced when some segment in both parents is exchange before proceed to the next step. Double point crossover or multi point crossover can be implemented to make some improvement rather than used the normal crossover.

Step 4: Mutation

A bit of the child's chromosomes string produces are mutated to produce a new child with a better characteristic compared to the previous stage. This process is responsible to introduce a new characteristic to the population.

The last step in improved genetic algorithm (IGA) is to make sure that the child produced has minimum power losses and maximum voltage stability index (VSI) compared to the genetic algorithm (GA) method. The process is terminated if the fitness (power losses and voltage stability index) obtained is better than genetic algorithm (GA).

3.2.3 Crossover operator in conventional genetic algorithm (GA)

Crossover operator is very important as it helps in generating new individuals. In conventional genetic algorithm (GA), the type of crossover used is single point crossover. There is only one crossing point is involved in this crossover. Generally, the swapping and shifting of genes occurred when the crossing point is reached. The steps of single point crossover are as shown below.

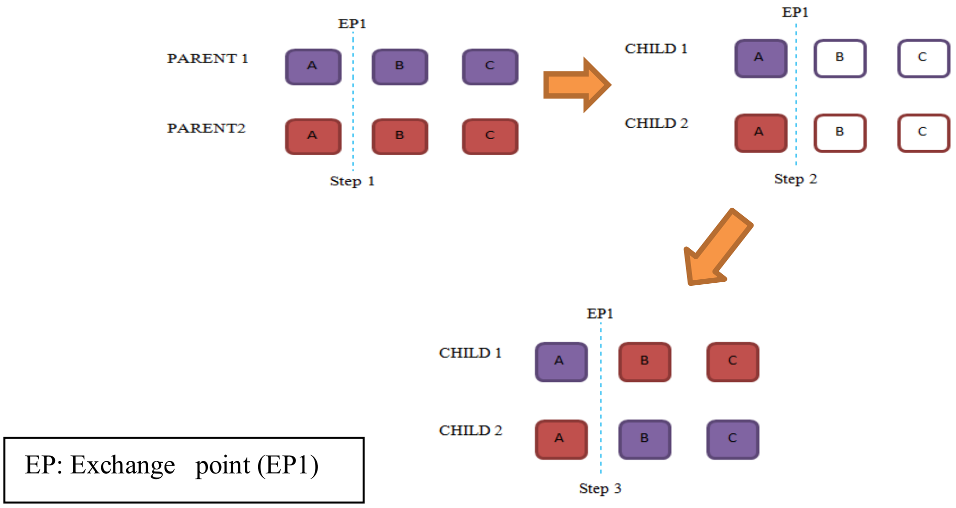

Figure 3.5: Process of Single point crossover

Exchange point is selected as EP1 for Parent 1 and Parent 2. There are three areas in parent chromosomes which is area A, B and C. In Step 2, no swapping of gene in area A occurs for Parent 1 and Parent 2 until EP1 is reached. Hence, Child 1 and Child 2 copied the gene (in area A) of its respective parents. The genes in area B and area C for both parents are swapped with each other after EP1 is reached as shown in Step 3. Child 1 copied the genes (in area B and C) of Parent 2 and Child 2 copied the genes (in area B and C) of Parent 1.

3.2.4 Implementation of improved genetic algorithm (IGA) at crossover operator

The crossover operator is chosen to be improved. It is considered as the best choice since the chances to obtained lowest power losses and stable value of voltage stability index is much higher compared to the single point crossover used in conventional genetic algorithm (GA). This is due to the different number of crossing point selected in the crossover operator. The higher the number of crossing point led to better results obtained. The improved crossover for IEEE 16 buses system is known as Double Point Crossover whereas Multi Point Crossover is used for IEEE 69 buses system. Different types of improved crossover for both buses system are due to the number of switch selection. To make sure that the configuration is in radial, the number of switch selection must be carefully chosen. Based on the simulation done, the number of switch selection for IEEE 16 buses system is three while for IEEE 69 buses system is five. These number of switch selection help to maintain the radiality of the configuration so that there is no looping occurs in the configuration.

3.2.4.1 Double Point Crossover for IEEE 16 buses system

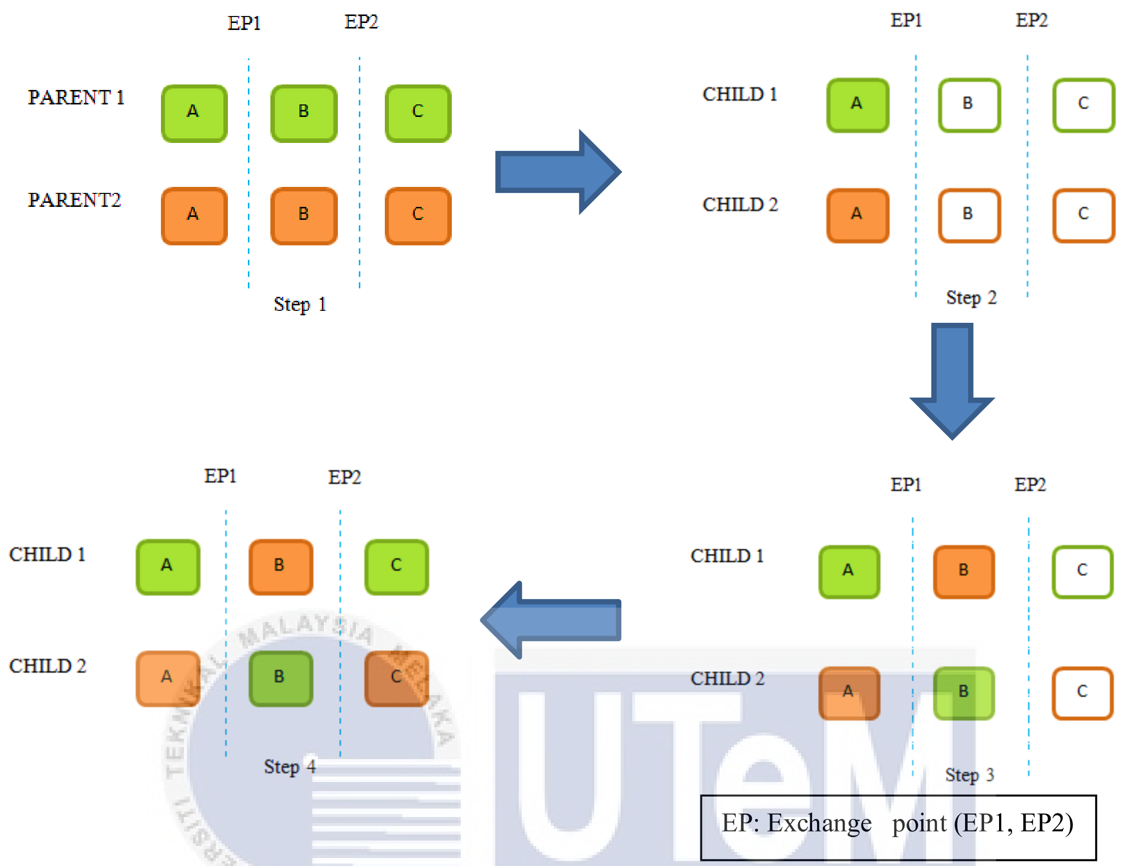

Figure 3.6: Process of Double point crossover

Two exchange points named as EP1 and EP2 are now selected instead of only one exchange point. Both parents' chromosomes are divided into three areas known as area A, B and C shown in Step 1. In Step 2, no swapping of gene in area A for Parent 1 and Parent 2 occurs until EP1 is reached. Therefore, Child 1 and Child 2 copied the first gene (in area A) from its respective parent. After EP1 is reached, the gene involved is in area B for Parent 1 and Parent 2. Swapping of gene occurs and hence Child 1 copied the gene in (area B) of Parent 2 and Child 2 copied the gene (in area B) of Parent 1 as stated in Step 3. No swapping of gene in area C for both parents occurs in Step 4. Child 1 and Child 2 copied the gene (in area C) from its respective parents.

3.2.4.2 Multi point Crossover for IEEE 69 buses system

Instead of only one or two crossing points, now there are three crossing points selected randomly. This is because of the higher number of switch selection for IEEE 69 buses system compared to the IEEE 16 buses system. When there is more crossing points located in both parents, the possibilities to obtain the lowest power losses and stable voltage stability index will be much higher. The processes of multi point crossover are as follows:-

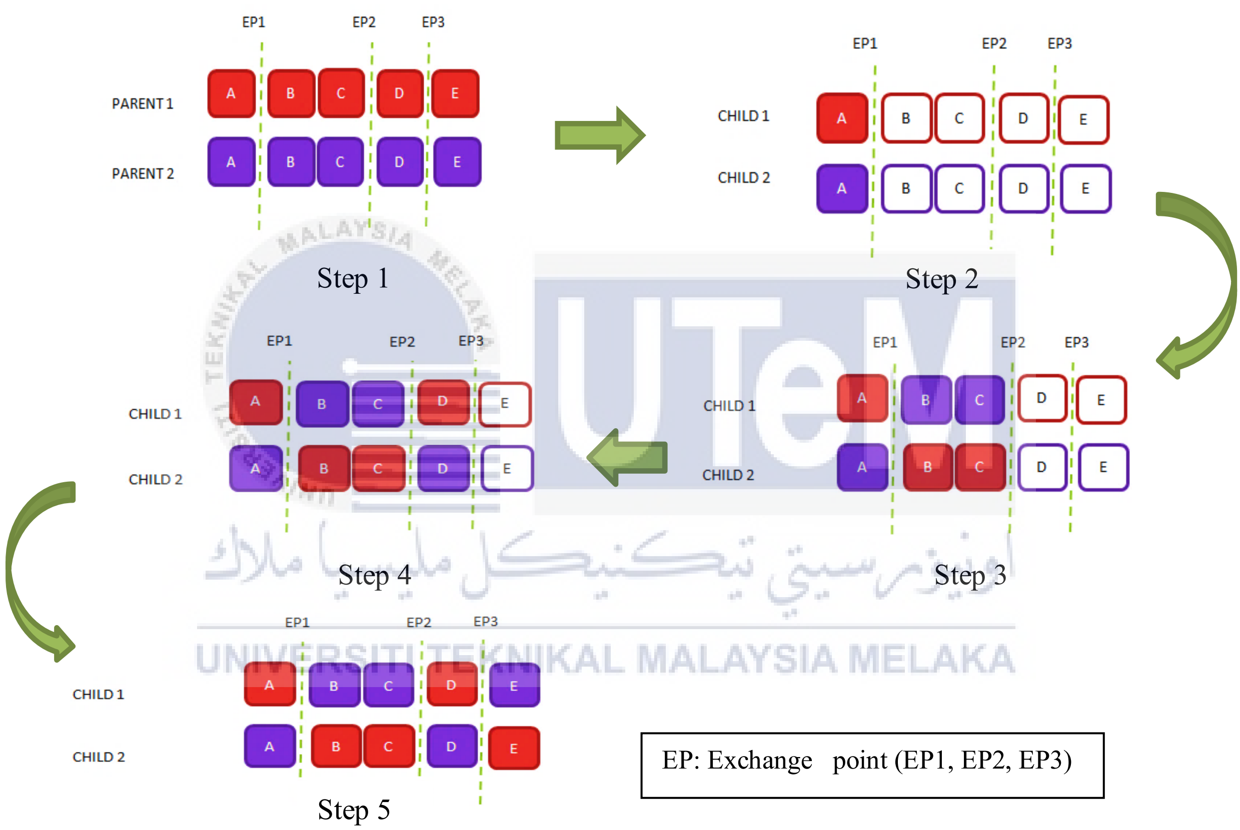

Figure 3.7: Process of Multi point crossover

Three exchange points (EP1, EP2, and EP3) are chosen as stated in Step 1. Both of the parent chromosomes are divided into five areas (A, B, C, D, and E). In Step 2, no swapping of gene occurs in area A for both parents until EP1 is reached. Therefore, Child 1and Child 2 copied the first gene (in area A) of its respective parent. After EP1 is reached, swapping and shifting of the genes occurs in area B and area C for both parents and produced child as shown in Step 3. No swapping of gene occurs in area D for both parents. Child 1 and Child 2 inherited the gene of its own parent. According to step 5, there is swapping process occurs in area E when EP3 is reached. The gene of both parents in area E is swap with each other. Hence, the new child is produced.

3.3 Test Systems

3.3.1 IEEE 16 and IEEE 69 buses

The process of conducting a reconfiguration of a distribution network used an IEEE 16 and IEEE 69 buses network system in radial configuration. The aim of the reconfiguration process is to find a radial network that will minimize the power losses and increase the value of voltage stability index of the distribution system. The simulation of distribution network reconfiguration is conducted using improved genetic algorithm (IGA) method in MATLAB vr2015b. Figure 3.8 and Figure 3.9 below shows the initial configuration of IEEE 16 and IEEE 69 buses system. The normally opened tie switches is closed to transfer the supply from one feeder to another. Meanwhile the normally close sectionalizing switches are opened to restore the radial configuration. The number of open branches must always equal to the number of close tie-switches to make sure that the configuration of the distribution system is still in a radial configuration. Bus data and line data for the system can be referred to Appendix A and B respectively.

The system network of IEEE 16 and IEEE 69 buses are used to undergo system restoration via DNR. Improved genetic algorithm (IGA) for system restoration is implemented instead of genetic algorithm (GA). The parameters below need to be considered when the operation is carried out:-

Table 3.1: Parameters on the improved genetic algorithm (IGA) method

Parameter	Value
Number of population, N	30
Crossover rate, Pc	0.5
Mutation rate, Pm	0.4
Bus and line data	IEEE 16 and IEEE 69 buses
Number of tie switch (initially open switch)	3 (IEEE 16) and 5 (IEEE 69)
Distribution network	132kV

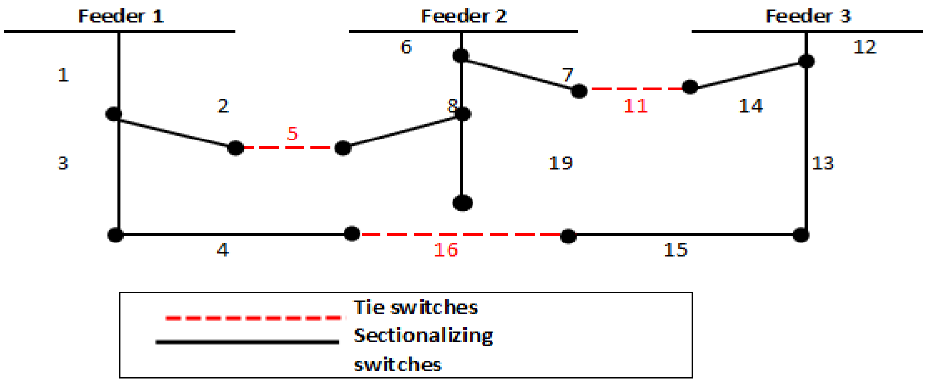

Figure 3.8: Initial configuration of IEEE 16 buses system

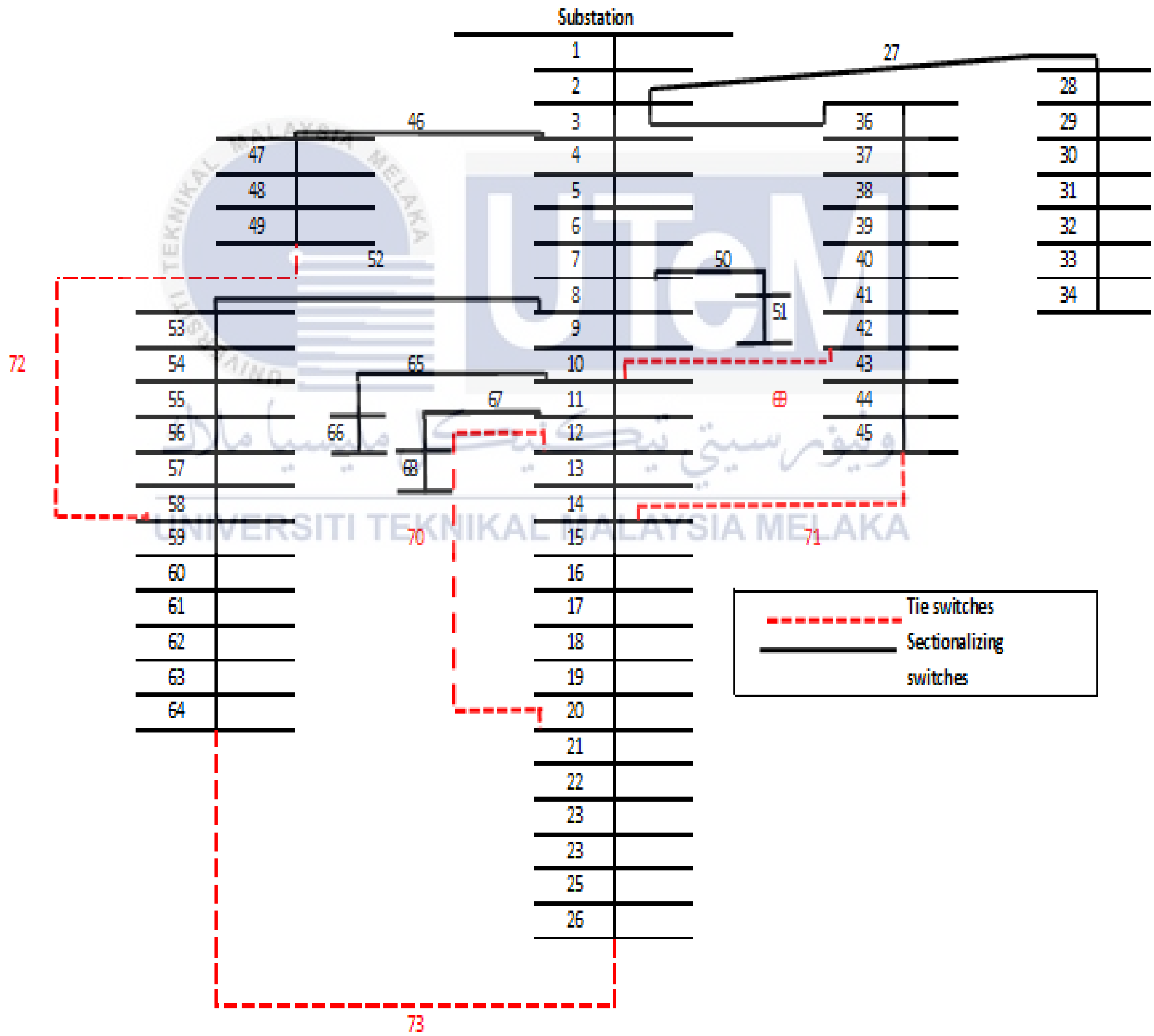

Figure 3.9: Initial configuration of IEEE 69 buses system

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The main objectives of this research are to obtain the maximum reduction of power losses and determine the maximum value of voltage stability index in IEEE 16 and IEEE 69 buses system using DNR. By using MATLAB software, the distribution network is tested. Newton Raphson method is used to attain the power losses and also voltage stability index. There are 3 tie-switches in IEEE 16 buses system whereas for IEEE 69 buses system only used 5 tie-switches and 68 sectionalizing switches. The status of the tie-switches (normally open) and sectionalizing switches (normally closed) is changed based on solution proposed by improved genetic algorithm when the DNR is conducted. At the same time, the radiality of system needs to be maintained. The best combination of switches with lowest power losses and maximum value of voltage stability index by using improved genetic algorithm (IGA) can be determined as the result of the distribution network reconfiguration. Other than that, the results obtained by using improved genetic algorithm (IGA) are compared with genetic algorithm (GA). This is to analyze which method shows the lowest power losses and stable voltage stability index. The results are displayed in tables and graphs for better view of analysis.

4.2 Results and Discussion

Table 4.1 shows the results achieved from the power flow analysis using Newton Raphson method for initial configuration for both systems. The initial power loss for IEEE 16 buses is 511.4 kW, whereas the initial power loss for IEEE 69 buses is 89kW. These results are achieved after simulated the bus and line data. The base power and voltage for the system are set at 100MVA and 132kV respectively. The number of population size approaches in this distribution system is 30. The best results are chosen based on the total power losses and maximum voltage stability index.

Table 4.1: Total power losses for initial configuration

Parameters / Conditions	Initial IEEE 16 buses system	Initial IEEE 69 buses system
Tie- switches	5, 11, 16	69, 70, 71, 72, 73
Total power losses (kW)	511.4	89

According to Table 4.2, there are six best set of switches achieved with lowest value of power losses and stable value of voltage stability index. These results are accomplished from the simulation of IEEE 16 buses system by using improved genetic algorithm (IGA). The switches are in radial configuration. It clearly displays that the best combination of switches is 4, 7, and 8. This is due to the lowest power losses acquired and also highest voltage stability index compared to the others.

Table 4.2: Results for IEEE 16 buses system

Set of Switches	Total Power Losses (kW)	Maximum VSI (p.u)
8,14,15	500.1	0.9186
8,11,13	493.2	0.9210
2,12,7	482.2	0.9267
8, 11, 16	479.3	0.9275
7, 8, 16	466.1	0.9800
4, 7, 8	459.8	0.9950

There are five set of switches obtained as stated in Table 4.3 which are in radial configuration. The best set of switches is 5, 20, 26, 55 and 14. The power losses achieved is 46.1kW which is the lowest power losses whereas the voltage stability index is the highest among the others.

Table 4.3: Results for IEEE 69 buses system

Set of Switches	Total Power Losses (kW)	Maximum VSI (p.u)
8, 54, 22, 12, 19	51.6	0.9748
12, 13, 57, 61, 10	49.7	0.9755
52, 69, 64, 9, 13	49.1	0.9755
55, 10, 15, 73, 69	47.8	0.9763
5, 20, 26, 55, 14	46.1	0.9800

From Table 4.4, the results achieved from the improved genetic algorithm (IGA) are much better than the initial configuration and also genetic algorithm (GA). The total power losses after reconfiguration by using genetic algorithm (GA) for IEEE 16 buses system and IEEE 69 buses system show a total power reduction in rate of 8.86% and 37.1% respectively. As for improved genetic algorithm (IGA), the total power reduction for IEEE 16 buses system and IEEE 69 buses system are 10.1% and 48.2% correspondingly. Therefore, improved genetic algorithm (IGA) method is more suitable in order to solve optimization problems for distribution system compared to genetic algorithm (GA). This is because IGA able to achieve highest percentage reduction of total power losses. When there is increment in percentage reduction of the total power losses, the probability to get lower power losses is higher.

Table 4.4: Comparison of GA and IGA

Parameters/Conditions		Number of switch selection	Open switches	Total power losses (kW)	Total power reduction (kW)	Percentage of reduction (%)
IEEE 16	Initial Configuration	3	5, 11, 16	511.4	-	-
	DNR with GA		7, 8, 16	466.1	45.3	8.86
	DNR with IGA		4, 7, 8	459.8	51.6	10.1
IEEE 69	Initial Configuration	5	69, 70, 72, 73, 71	89.0	-	-
	DNR with GA		10, 12, 13, 57, 61	56.0	33.0	37.1
	DNR with IGA		5, 20, 26, 55, 14	46.1	42.9	48.2

To calculate percentage of reduction of total power losses,

$$Percentage\ of\ reduction\ of\ total\ power\ losses\ (\%) = \frac{Initial\ Configuration - DNR\ with\ GA/IGA}{Initial\ Configuration}\ x\ 100\% \tag{3.13}$$

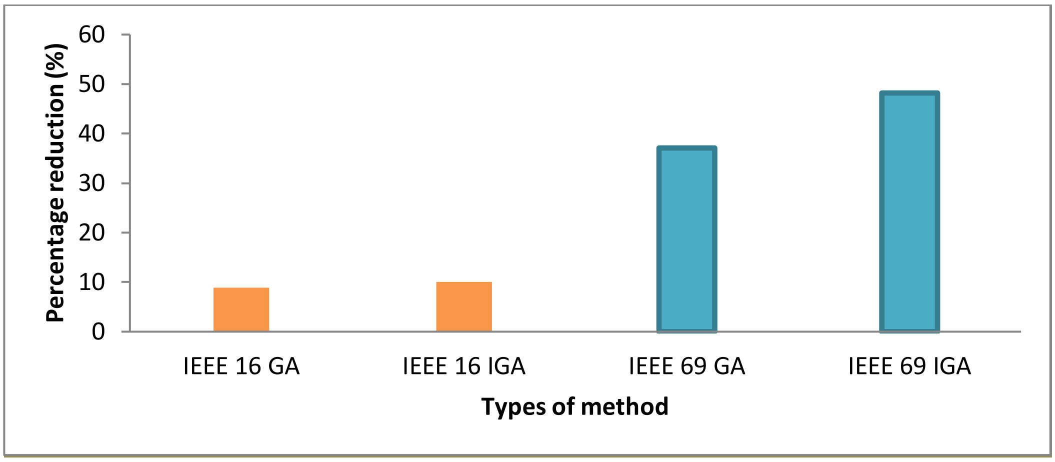

Figure 4.1: Comparison of percentage reduction for both buses system

According to the Figure 4.1, the graph shows an increment in percentage of reduction after the improvement of genetic algorithm (IGA) is done for IEEE 16 buses system and IEEE 69 buses system. This can be concluded that the improvement in crossover operator gives a better result because of the child produced that have new characteristics after exchanging some genes. Thus, this improvement is suitable to be applied for distribution network reconfiguration (DNR) process.

For IEEE 69 buses system, there is comparison between double point crossover [11] and multi-point crossover implemented in the system. Double point crossover used two exchanging points whereas Multi-point crossover used three exchanging points. This exchanging point is the point for the genes of both parent chromosomes to swap between each other and produced new child. Higher number of exchanging point produced better child since the probability for the genes to swap is much higher. Therefore, Multi-point crossover is better methods to implement rather than Double point crossover. The comparison is displayed in Table 4.5 as shown below:-

Table 4.5: Comparison of Double point crossover and Multi-point crossover

Method	IGA (Double Point crossover) [11]	IGA (Multi-point crossover)
No of Switches	8, 54, 22, 12, 19	5, 20, 26, 55, 14
Total Power Losses (kW)	56	46.1
Total Power Losses Reduction (kW)	32.9	42.9
Percentage of Reduction (%)	37	48.2

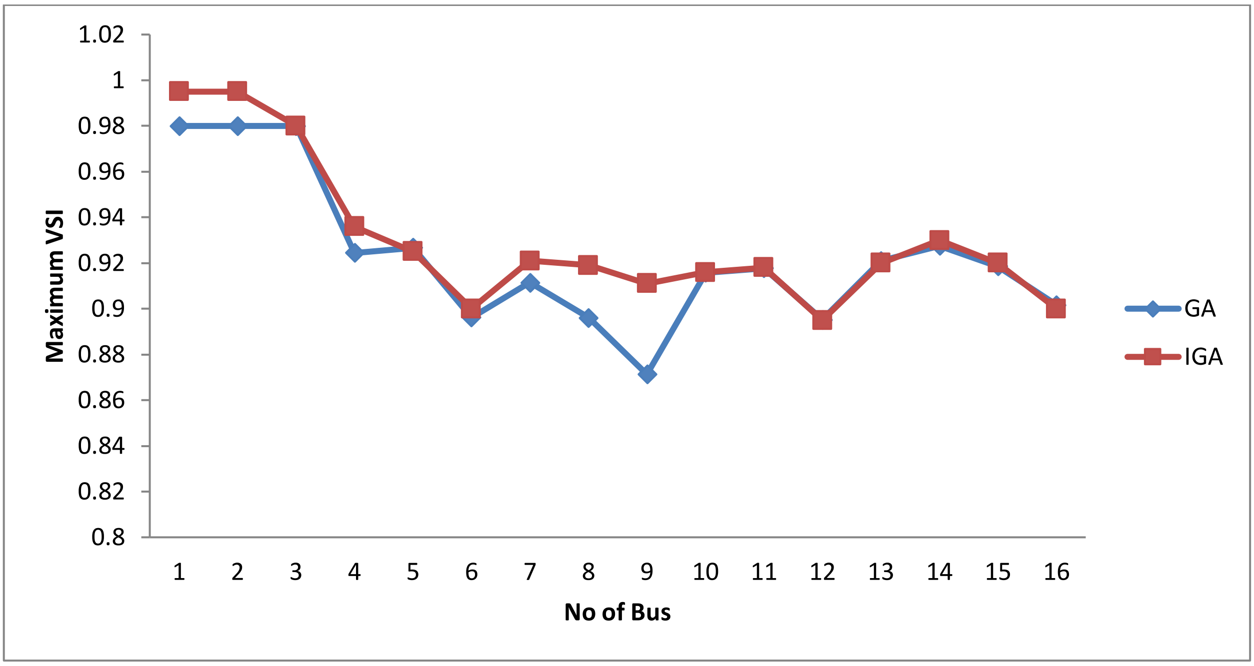

Figure 4.2: Maximum VSI for IEEE 16 buses

Based on Figure 4.2, the maximum voltage stability index (VSI) for each bus in IEEE 16 buses system is recorded. There is an improvement of voltage stability index for each bus in the system. For genetic algorithm (GA), the most stable node with voltage stability of 0.98 pu is at bus 1, 2, and 3 while the most steady node for improved genetic algorithm (IGA) is 0.995 pu at bus 1 and 2. However, the maximum voltage stability index for both algorithms starts to decline from bus 4 to bus 6. From bus 7 to bus 11, the graph of voltage stability index for genetic algorithm (GA) starts to fluctuate compared to the graph of voltage stability index for improved genetic algorithm (IGA) that is more constant. Then, both algorithms have the similar characteristics for bus 12 to bus 16. The most critical node of voltage stability index achieved for genetic algorithm (GA) is at bus 9 which is 0.8713 pu whereas the most critical node for improved genetic algorithm (IGA) is at bus 12 with value of 0.895 pu. For this tested system, the graph of maximum voltage stability index (VSI) using improved genetic algorithm (IGA) is more stable compared to the conventional genetic algorithm (GA). In single crossover used for genetic algorithm (GA), only one gene of both parents is swapped. However, the gene of both parents swapped continuously according to its exchange point when double point crossover is used in the improvement of genetic algorithm. Consequently, the probability of the voltage stability index to increase and stable is much higher where the genes of both parents are frequently swapped.

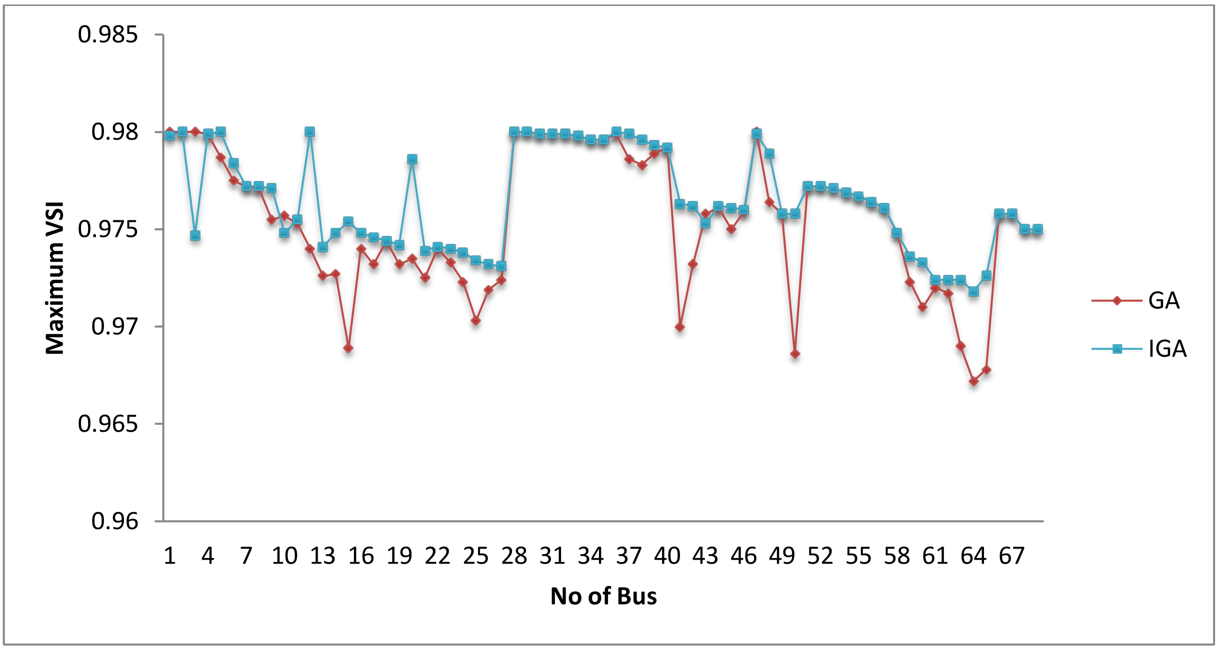

Figure 4.3: Maximum VSI for IEEE 69 buses

By referring to the Figure 4.3, it clearly shows that there is an improvement of maximum voltage stability index for each bus after the improvement of genetic algorithm (IGA) is implemented. For genetic algorithm (GA), the steady node is 0.98 pu at bus 27 and 28 while the most stable nodes acquired for improved genetic algorithm (IGA) is 0.98 pu at bus 2, 10 and 36. The graph for genetic algorithm (GA) and improved genetic algorithm (IGA) starts to fluctuate from bus 4 to bus 26. From bus 29 to bus 40, the graphs for both algorithms are able to maintain constant until it reached bus 50. There is sudden decline from bus 56 to bus 64 for the graph of genetic algorithm (GA) and also improved genetic algorithm (IGA). Both graphs have similar characteristics starts from bus 65 to bus 69. The most critical node achieved for genetic algorithm (GA) is 0.969 pu at bus 63 while the most unstable node acquired for improved genetic algorithm (IGA) is 0.9731 pu at bus 27. Most of the maximum voltage stability index (VSI) recorded using improved genetic algorithm (IGA) are nearly to 1.0 pu compared to the maximum voltage stability index achieved by using conventional genetic algorithm (GA). This is caused by the multi-point crossover used in the implementation of improvement of genetic algorithm (IGA). There are three exchange points in multi-point crossover operator that allow the genes of both parents to swap continuously. Thus, the probability to get the highest voltage stability index is much higher by using IGA compared with GA which only has one exchange point.

4.3 Statistical Analysis

In this part, the effectiveness of the results reached is tested by conducting a statistical analysis. IEEE 16 buses system and IEEE 69 buses system are simulated through 100 iterations by using genetic algorithm (GA) and also improved genetic algorithm (IGA) methods. Figure 4.4 and Figure 4.5 shows the convergence characteristics graph for total power losses whereas Figure 4.6 and Figure 4.7 shows the convergence characteristics graph of maximum voltage stability index (VSI). From the graph, the consistency for algorithms used is identified using standard deviation analysis. A standard deviation close to zero indicates that the data points tend to be very close to convergence value whereas a high standard deviation indicates that the data points are spread out over a wider range of values. The smaller the numbers of standard deviation causes the system to converge earlier.

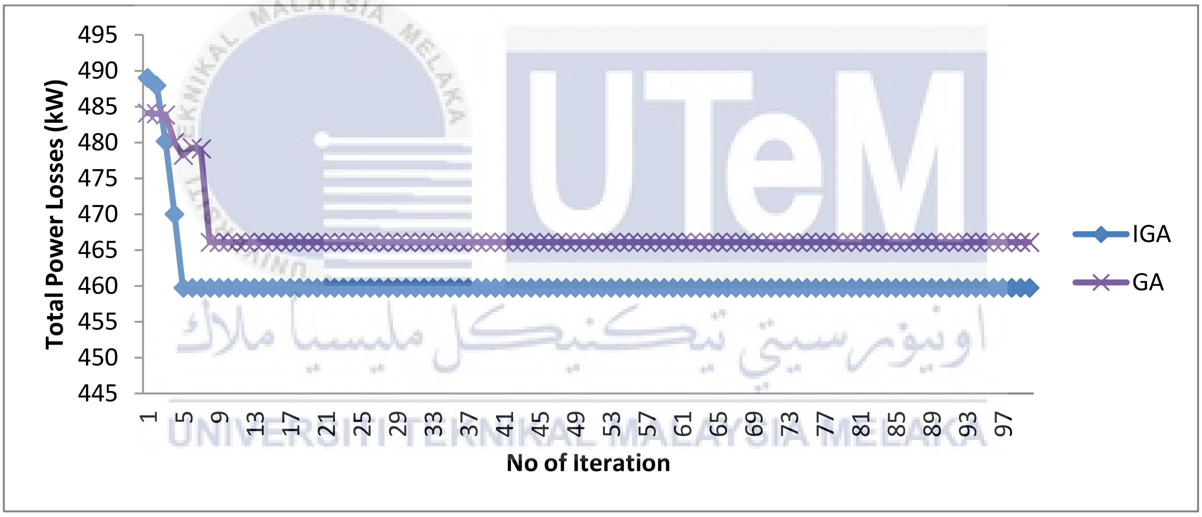

Figure 4.4: Convergence characteristics of total power losses for IEEE 16 buses system

According to Figure 4.4, the system used an improved genetic algorithm (IGA) started to converge earlier compared to genetic algorithm (GA) in IEEE 16 buses system. It converges during 5th iteration compared with genetic algorithm (GA) that begins to converge during 8th iteration.

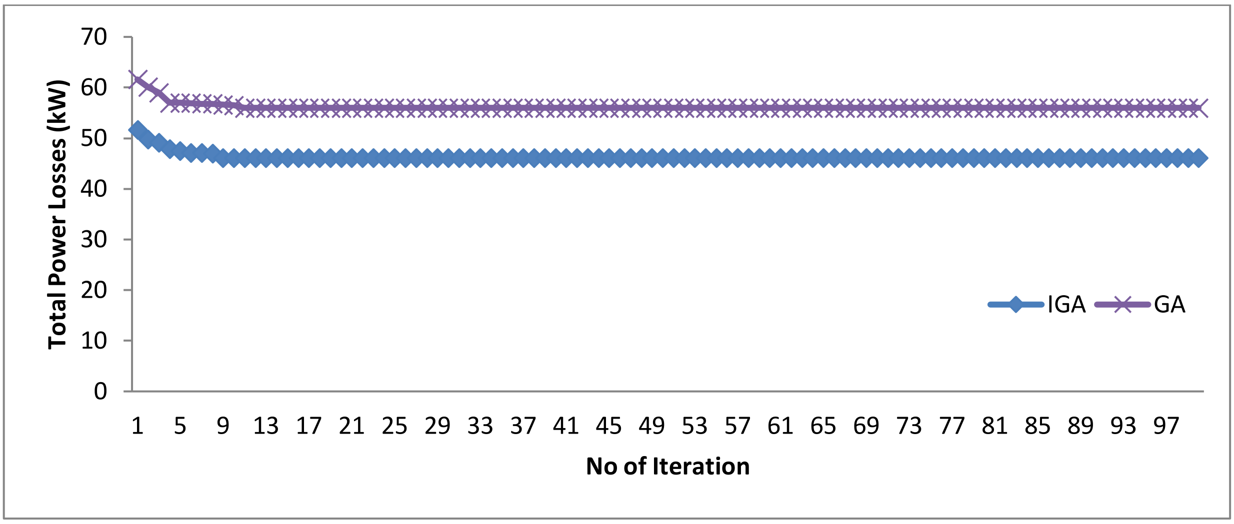

Figure 4.5: Convergence characteristics of total power losses for IEEE 69 buses system

For IEEE 69 buses system, the system converges at 9^{th} iteration for improved genetic algorithm (IGA) method. Meanwhile, the system begins to converge at 11^{th} iteration for genetic algorithm (GA) method as illustrated in Figure 4.5.

Table 4.6 shows the standard deviation for both buses systems. Smaller bus has smaller standard deviation compared to larger buses system. Thus, the smaller system starts to converge earlier. The computational time for IEEE 16 buses system is faster than the computational time of IEEE 69 buses system because the load of the system used is much smaller.

Table 4.6: Standard Deviation for total power losses

Buses	IEEE 16		IEEE 69	
Methods	GA	IGA	GA	IGA
Standard Deviation	0.72	0.70	0.76	0.74

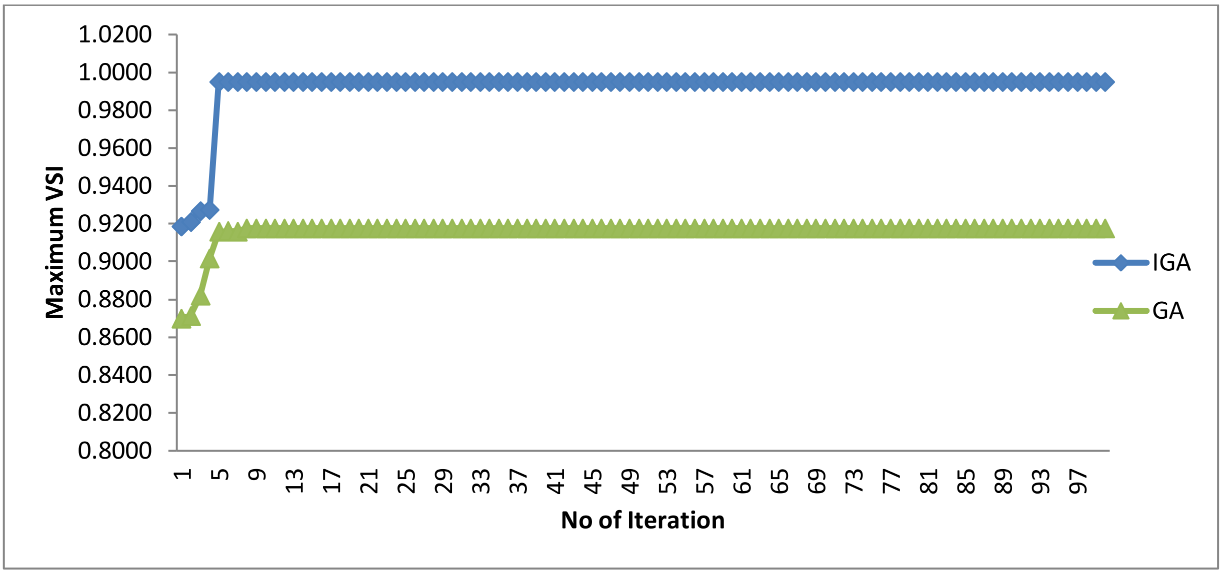

Figure 4.6: Convergence characteristics of maximum VSI for IEEE 16 buses system

By referring to Figure 4.6, the system for IEEE 16 buses begins to converge at 5th iteration when IGA is implemented. In the meantime, the system converges at 8th iteration genetic algorithm (GA) methods.

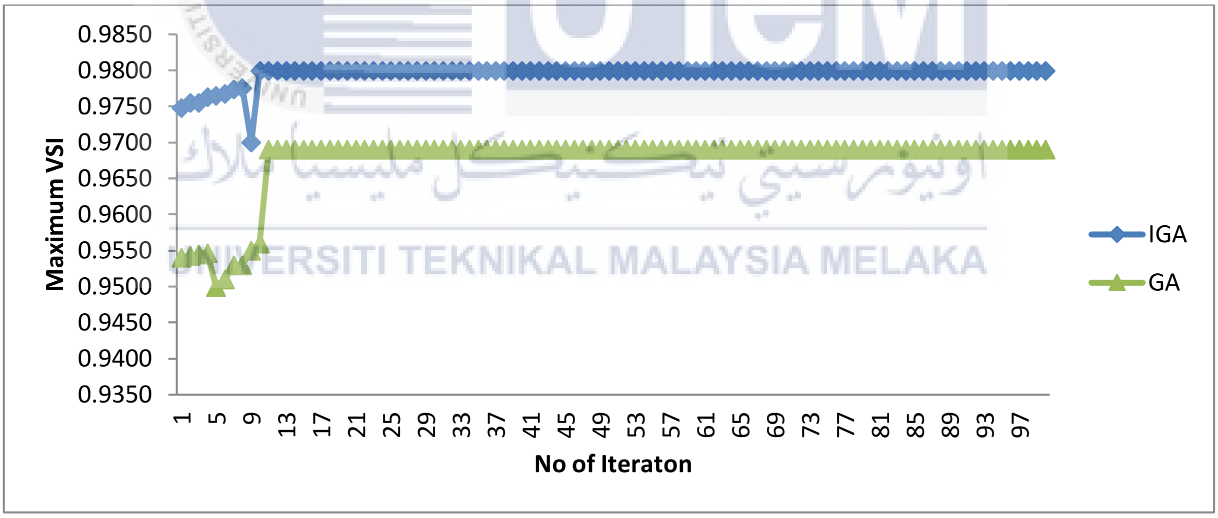

Figure 4.6: Convergence characteristics of maximum VSI for IEEE 69 buses system

For IEEE 69 buses system, the system converges at 12th iteration for genetic algorithm (GA) as displayed in Figure 4.7. When IGA is implemented, the system begins to converge at 10th iteration.

Table 4.7 below shows the standard deviation for both buses system. The system started to converge earlier when smaller buses system is used compared to the larger buses system. The maximum voltage stability index achieved in larger buses system is much higher compared with smaller buses system. However, the computational time is slower than smaller buses system because the standard deviation is bigger. The bigger the standard deviation of the system, the slower the time for the system starts to iterate.

Table 4.7: Standard Deviation for maximum VSI

Buses	IEEE 16		IEEE 69	
Methods	GA	IGA	GA	IGA
Standard Deviation	0.005	0.001	0.08	0.01

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

As a conclusion, there are many types of method can be used to reduce the power losses and improve the voltage stability in distribution system. Distribution network reconfiguration (DNR) is one of the methods used to reconfigure the distribution network. The networks are configured radially to increase the efficiency of the protective systems. DNR is performed by changing the status of the sectionalized and tie switches in the IEEE 16 and IEEE 69 buses system. MATLAB vr2010b is used to simulate the reconfiguration process.

Genetic algorithm (GA) is an example of algorithm that used the computational analogy based on approaching of direct binary. The improvement of genetic algorithm (IGA) is known as the new heuristic tools that improved the conventional genetic algorithm (GA). From the analysis, it shows that IGA method is more efficient and effective than the GA method. The improvement at the crossover operator is successful in producing the lower power losses and higher voltage stability index in reconfiguration network. This implementation of these two methods has given the great impact for the IEEE 16 and IEEE 69 buses distribution reconfiguration system.

5.2 RECOMMENDATION

For future work, the improvement on another two genetic operators such as selection and mutation can be considered. In order to get more convincing solution, the improvement can be done by simultaneously applying multi-point crossover with selection operator or mutation operator. Moreover, selection operator can be improved by implement the Roulette wheel selection or rank selection. Meanwhile mutation operator can be improved by applying the multi-point mutation instead of the normal mutation.

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APPENDIX A

Bus Data

Bus		Voltage		Load	
No	Code	Magnitude	Angle, (X_o)	MW	MVAR
1	1	1	0	0	0
2	0	1	0	0	0
3	0	1	0	0	0
4	0	1	0	2.0	1.6
5	0	1	0	3.0	0.4
6	0	1	0	2.0	-0.4
7	0	1	0	1.5	1.2
8	0	1	0	4.0	2.7
9	0	1	0	5.0	1.8
10	0	1	0	1.0	0.9
11	0	1	0	0.6	-0.5
12	0	1	0	4.5	-1.7
13	0	1	0	1.0	0.9
14	0	1	0	1.0	-1.1
15	0	1	0	1.0	0.9
16	0	1	0	2.1	-0.8

Line Data

Start Bus	End Bus	R (p.u)	X (p.u)
1	4	0.0075	0.1000
4	5	0.0800	0.1100
4	6	0.0900	0.1800
6	7	0.0400	0.0400
2	8	0.1100	0.1100
8	9	0.0800	0.1100
8	10	0.1100	0.1100
9	11	0.1100	0.1100
9	12	0.0800	0.1100
3	13	0.1100	0.1100
13	14	0.0900	0.1200
13	15	0.0800	0.1100
15	16	0.0400	0.0400
5	11	0.0400	0.0400
10	14	0.0400	0.0400
7	16	0.0900	0.1200

APPENDIX B

Bus Data

Bus		Voltage		Load	
No	Code	Magnitude	Angle, (X_o)	MW	MVAR
1	1	1	0	0	0
2	0	1	0	0	0
3	0	1	0	0	0
4	0	1	0	0	0
5	0	1	0	0	0
6	0	1	0	0.026	0.022
7	0	1	0	0.404	0.300
8	0	1	0	0.750	0.540
9	0	1	0	0.300	0.220
10	0	1	0	0.280	0.190
11	0	1	0	1.450	1.040
12	0	1	0	1.450	1.040
13	0	1	0	0.080	0.055
14	0	1	0	0.080	0.055
15	0	1	0	0	0
16	0	1	0	0.455	0.300
17	0	1	0	0.600	0.350
18	0	1	0	0.600	0.350
19	0	1	0	0	0
20	0	1	0	0.010	0.006
21	0	1	0	1.140	0.810
22	0	1	0	0.053	0.035
23	0	1	0	0	0
24	0	1	0	0.280	0.200
25	0	1	0	0	0
26	0	1	0	0.140	0.100
27	0	1	0	0.140	0.100
28	0	1	0	0.260	0.185
29	0	1	0	0.260	0.185
30	0	1	0	0	0
31	0	1	0	0	0
32	0	1	0	0	0
33	0	1	0	0.140	0.100
34	0	1	0	0.195	0.140

35	0	1	0	0.060	0.040
36	0	1	0	0.260	0.186
37	0	1	0	0.260	0.186
38	0	1	0	0	0
39	0	1	0	0.240	0.170
40	0	1	0	0.240	0.170
41	0	1	0	0.012	0.010
42	0	1	0	0	0
43	0	1	0	0.060	0.043
44	0	1	0	0	0
45	0	1	0	0.392	0.263
46	0	1	0	0.392	0.263
47	0	1	0	0	0
48	0	1	0	0.790	0.564
49	0	1	0	3.847	2.745
50	0	1	0	3.847	2.745
51	0	1	0	0.405	0.283
52	0	1	0	0.036	0.027
53	0	1	0	0.043	0.035
54	0	1	0	0.264	0.190
55	0	1	0	0.240	0.172
56	0	1	0	0	0
57	0	1	0	0	0
58	0	1	0	0	0
59	0	1	0	1.000	0.720
60	0	1	0	0	0
61	0	1	0	1.244	8.880
62	0	1	0	0.320	0.230
63	0	1	0	0	0
64	0	1	0	2.270	1.620
65	0	1	0	0.590	0.420
66	0	1	0	0.180	0.130
67	0	1	0	0.190	0.130
68	0	1	0	0.280	0.200
69	0	1	0	0.280	0.200

Line Data

Start Bus	End Bus	R, (p.u)	X, (p.u)
1	2	2.2.8691E-06	6.8870E-06
2	3	2.2.8691E-06	6.8870E-06
3	4	8.60882E-06	2.06112E-05
4	5	0.000144054	0.000168733
5	6	0.002100551	0.001069789
6	7	0.002187213	0.001113981
7	8	0.000529155	0.000269743
8	9	0.000282943	0.000144054
9	10	0.004700413	0.001553604
10	11	0.001074380	0.000355257
11	12	0.004082874	0.001349288
12	13	0.005911387	0.001951331
13	14	0.005991736	0.001980028
14	15	0.006072084	0.002006428
15	16	0.001128329	0.000373049
16	17	0.002148760	0.000710514
17	18	2.69743E-05	9.18274E-06
18	19	0.001880165	0.000621556
19	20	0.001208678	0.000396006
20	21	0.001960514	0.000647957
21	22	8.03489E-05	2.64004E-05
22	23	0.000913108	0.000301882
23	24	0.001987489	0.000657140
24	25	0.004297521	0.001420455
25	26	0.001772842	0.000585973
26	27	0.000994031	0.000328283
3	28	2.52525E-05	6.19835E-05
28	29	0.000367309	0.000898186
29	30	0.002283058	0.000754706
30	31	0.000402893	0.000133150
31	32	0.002014463	0.000665748
32	33	0.004815197	0.001616162
33	34	0.009802571	0.003240358
34	35	0.008459596	0.002796717
3	36	2.52525E-05	6.19835E-05
36	37	0.000367309	0.000898186
37	38	0.000604339	0.000705923
38	39	0.000174472	0.000203742
39	40	1.03306E-05	1.20523E-05
40	41	0.004179867	0.004883494
41	42	0.001779155	0.002079316
42	43	0.000235308	0.000274334
43	44	5.28007E-05	6.65748E-05
44	45	0.000625000	0.000787994
45	46	5.16529E-06	6.88705E-06