

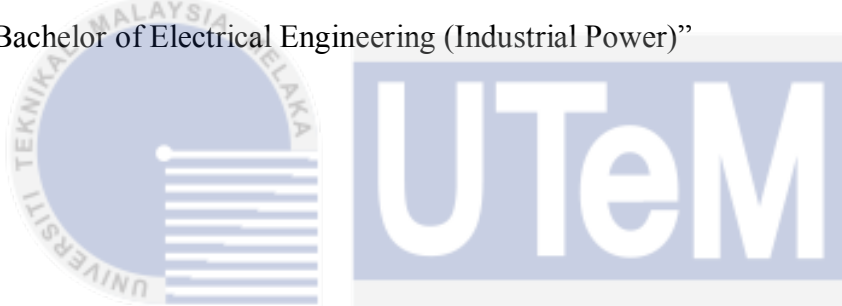
**A COMPARATIVE STUDY OF HYBRIDIZATION
METHOD OF PARTICLE SWARM OPTIMIZATION
(PSO) FAMILY FOR NETWORK RECONFIGURATION**



**BACHELOR OF ELECTRICAL ENGINEERING
(INDUSTRIAL POWER)
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**



“ I hereby declare that I have read through this report entitled “ A Comparative Study of Hybridization Methods of Particle Swarm Optimization (PSO) Family for Network Reconfiguration ” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”



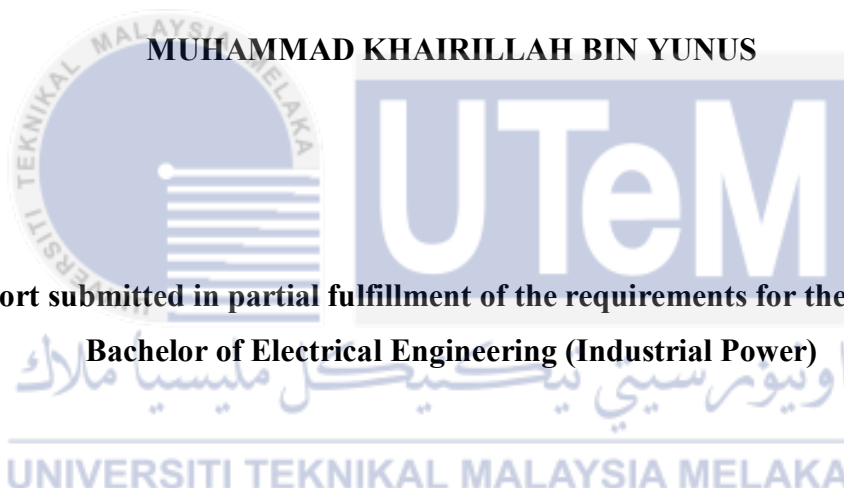
Signature :
اونیورسیتی تکنیکل ملیسیا ملاک

Supervisor's Name :
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Date :

**A COMPARATIVE STUDY OF HYBRIDIZATION METHODS OF PARTICLE
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RECONFIGURATION**

MUHAMMAD KHAIRILLAH BIN YUNUS

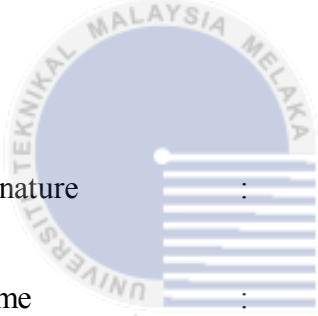


Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

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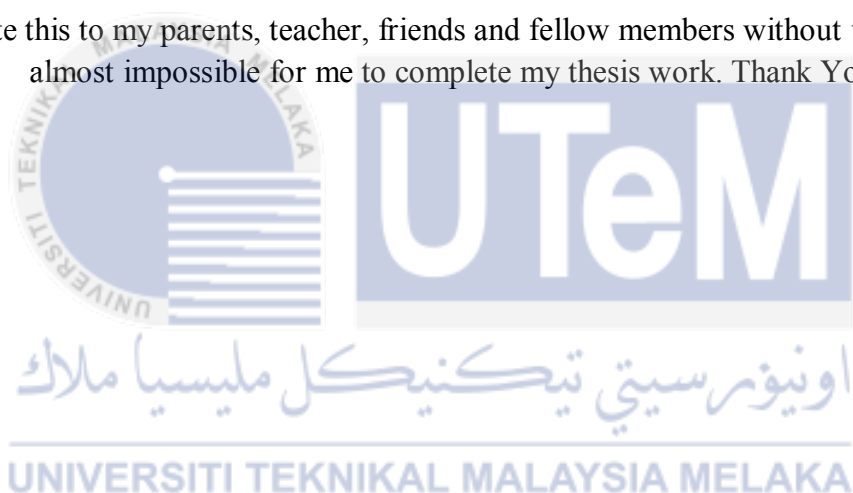
Name :

اونيورسيتي تيكنيكل مليسيا ملاك

Date :

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

I dedicate this to my parents, teacher, friends and fellow members without whom it was almost impossible for me to complete my thesis work. Thank You

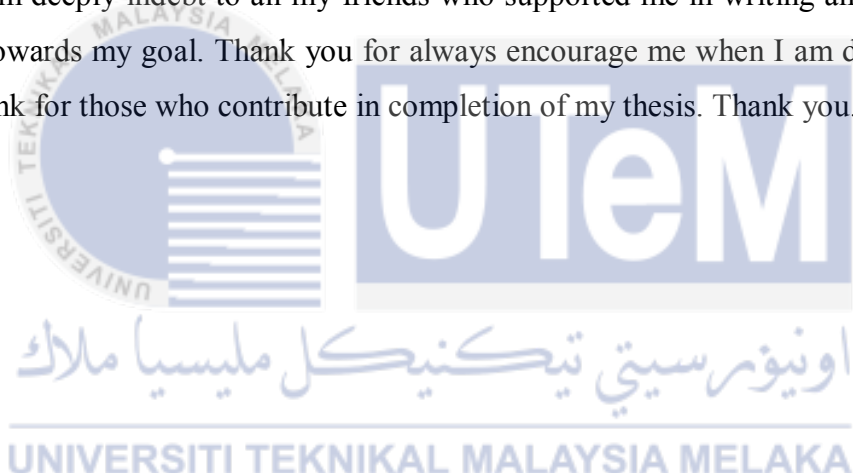


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ABSTARCT

Electric power distribution loss and reliability are major concerns in power system as the demand of electrical energy by customers keep increasing from day to day. Distribution network reconfiguration (DNR) is one of the method that can be applied in the system to minimize the power loss in existing distribution network. This project proposed the comparative study between the meta-heuristics PSO Family that consists of traditional PSO and hybrid PSO ; EPSO and REPSO. The performance on the power loss, computing time and total cost saving has been applied on the algorithm. A comprehensive performance analysis has been applied on IEEE 33 bus distribution system by using the simulation in the MATLAB environment. The proposed technique has been integrated as well as the real power losses along with computation time in the network system offers also been investigated and justified. From this studies, the best PSO Family algorithm that excel in performance of power losses reduction, computation time and total cost save has been determined. Thus, distribution network reconfiguration can certainly be utilized to greatly assist in conserving the expenditure, decreasing the power losses as well as increase the quality and even reliability of electrical power system throughout Malaysia

ABSTRAK

Kehilangan kuasa elektrik di bahagian pengagihan kuasa adalah perkara yang membimbangkan di dalam sistem kuasa kerana permintaan tenaga elektrik yang semakin meningkat oleh pelanggan dari hari ke hari. Konfigurasi semula rangkaian pengedaran adalah salah satu kaedah yang boleh digunakan dalam sistem untuk mengurangkan kehilangan kuasa dalam rangkaian pengedaran yang sedia ada. Projek ini berkaitan kajian perbandingan antara meta-heuristik keluarga PSO yang terdiri daripada PSO tradisional dan PSO hibrid; EPSO dan REPSO. Prestasi pada kehilangan kuasa, masa pengkomputeran dan jumlah penjimatan kos telah dikaji keatas algoritma. Analisis Prestasi komprehensif telah dilaksanakan pada 33 IEEE bus sistem pengagihan dengan menggunakan simulasi dalam persekitaran MATLAB. Teknik yang dicadangkan itu telah dikaji dimana kehilangan kuasa sebenar bersama-sama dengan masa pengiraan dalam sistem rangkaian telah dikenalpasti dan dijustifikasikan. Dari kajian ini, algoritma terbaik dari keluarga PSO yang cemerlang dalam prestasi pengurangan kehilangan kuasa, masa pengiraan dan jumlah kos penjimatan telah ditentukan. Oleh itu, rangkaian pengedaran konfigurasi semula pasti boleh digunakan untuk banyak membantu dalam menjimatkan perbelanjaan operasi, mengurangkan kehilangan kuasa serta meningkatkan kualiti dan juga kebolehpercayaan sistem kuasa elektrik di seluruh Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Electricity distribution companies constantly require improvements in service, and an appropriate reduction in cost of the system. Since the distribution system is the biggest section in power system area, by finding the best optimal method that can reduce the power losses that at the same time influences the cost and crucially also leading to significant energy saving. For the past year, distribution network reconfiguration using the heuristics method had been widely study to minimize the power losses. These studies propose to analyze one of the heuristic methods and compare the hybrid PSO algorithm for distribution network reconfiguration. To verify the effectiveness of the proposed method, comparative studies are conducted between the algorithm to find the most excel PSO Family that efficient in power loss reduction, computed time and cost saving.

1.2 Problem Statements

Distribution system's network carries electricity from the transmission system that delivers it to the consumer. However, distribution section is one of the prime contributors in power loss. Due to that several the heuristics techniques utilized by experts to resolve optimization issue and Particle Swarm Optimization (PSO) is one of the algorithms that applied on the distribution system to reconfigure the network. Many researchers had enhanced the classical PSO algorithm with other heuristics algorithm such as differential evolution (DE) and evolution programming (EP) that produces hybrid PSO which is more powerful and produce more efficient performance to solve optimization problem. However there is lack of research that has been reported in performance of these hybrids PSO family; Particle Swarm Optimization (PSO), Evolutionary Particle Swarm Optimization (EPSO) and Rank Evolutionary Particle Swarm Optimization (REPSO) that contributed the

minimum power loss and best computing time performances. Moreover, the impact of the performances of the PSO Family algorithms on the total cost saves also have not been conducted. Thus, with knowledge about the effectiveness performance of the heuristics algorithms when applied for the distribution network reconfiguration. It will give advantages for improvement of power system efficiency and better financial planning.

1.3 Objective

There are several objectives that have been highlighted in this project. There are:

- a) To analyze the power loss after hybrid method of PSO family applied on network reconfiguration
- b) To compare the performance of computing time between hybrid method of PSO Family
- c) To validate the cost saving after hybrid method of PSO family applied on network reconfiguration in Malaysia.

1.4 Scope

The scope of this paper is mainly focused on comparative studies between PSO, EPSO and REPSO in radial network that contains a group of interconnected radial circuit distribution. Every coding will be carried out by executing MATLAB software simulation along with analyzed upon the 33-bus radial IEEE test system. The Malaysian average selling price [25] were used to analyze the cost saving when the algorithms applied on the network.

1.5 Outline

The inclusive functionality evaluation of the PSO Family (PSO, EPSO and REPSO) methods in discovering the optimum alternative for 33kV bus test system with low power losses as well as computational period and total cost save will be analyzed in this thesis. Essentially, this study is broken down right to several parts in order to provide guidelines along with explain as follows:

Chapter 1 : Introduction

This section specifies motivation to acquire the following research. The determined problem statement, objectives, scope and significances of the research are outlined in this section.

Chapter 2 : Literature Review

This section explains the theory as well as the basic principle and review of previous related work regarding PSO, EPSO and REPSO

Chapter 3 : Research Methodology

In this section, the chapter explains the implementation of the PSO Family algorithm for implementation in distribution network reconfiguration (DNR) in 33Kv IEE test system. In this chapter also defined the mathematical formulation along with constrain that need to be obey in the studies.

Chapter 4 : Results

This segment provides the evaluation of the results obtained through simulation of MATLAB of PSO, EPSO and REPSO in IEEE 33kV bus. The overall investigation of the findings is going to be investigated.

Chapter 5 : Conclusion

This section will summarize the actual finding due to determined objectives along with futurerecommendation

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and basic principle

2.1.1 Types of distribution system

There are three general classification of electrical power distribution system.

2.1.1.1 Radial distribution system

Radial system is the most basic type because the power comes right from a single power source. A generating system supplies power from the substation via radial lines that are extended to the different areas of a community. Radial system is at least efficient in terms of continuous service since there are no back up distribution system connected to the single power source. If any power line opens, one or more loads are disrupted. There is more possibility of power black outs. On the other hand, the radial system is least expensive.

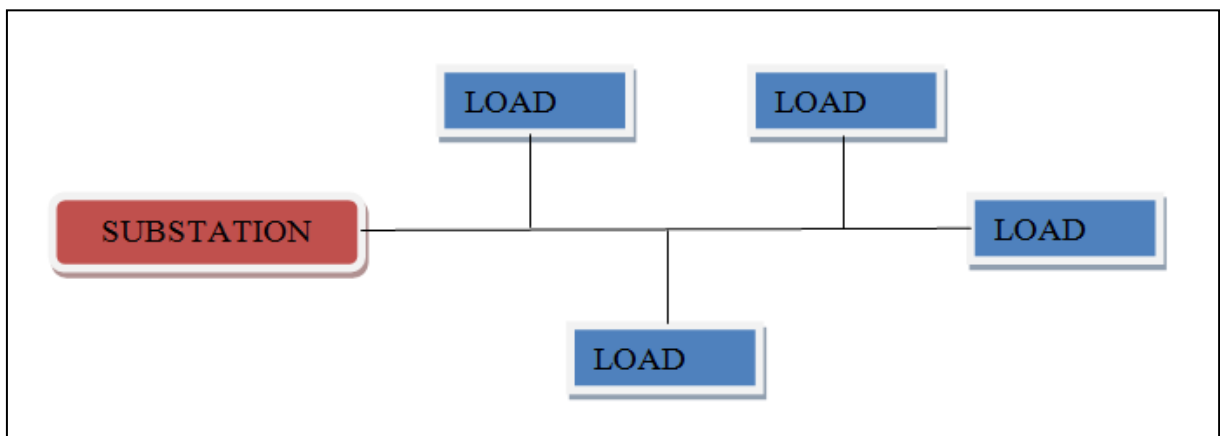


Figure 2.1: Radial Distribution system

2.1.1.2 Loop/ Ring distribution system

Ring distribution systems tend to be utilized in heavily populated areas. The distribution lines encircle the services area. Power is supplied from one or more power sources into substations close to the services area. The power is then distributed through the substations via the radial power lines. When a power line is opened, no disruption to other load occurs. The ring system provides a more continues service than the radial system. Attributed to extra power lines and a greater circuit complexity, the ring system is more expensive.

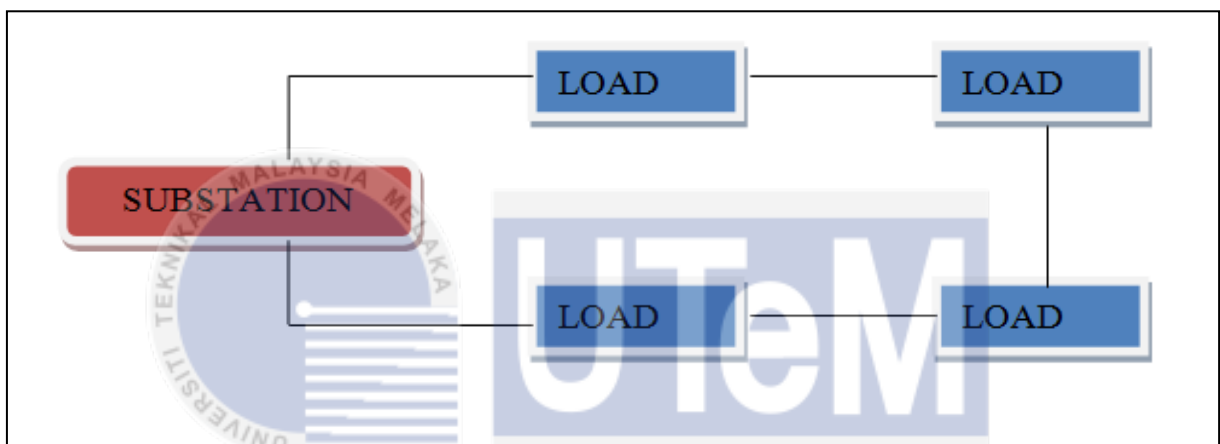


Figure 2.2: Loop / Ring distribution system

2.1.1.3 Mesh / Network distribution system

Network distribution systems are usually a combo of the radial as well as ring systems. They commonly result when one of the other systems is expended. This system is much more complex but it offers quite dependable services to consumers which is where each load is fed by two or more circuit.

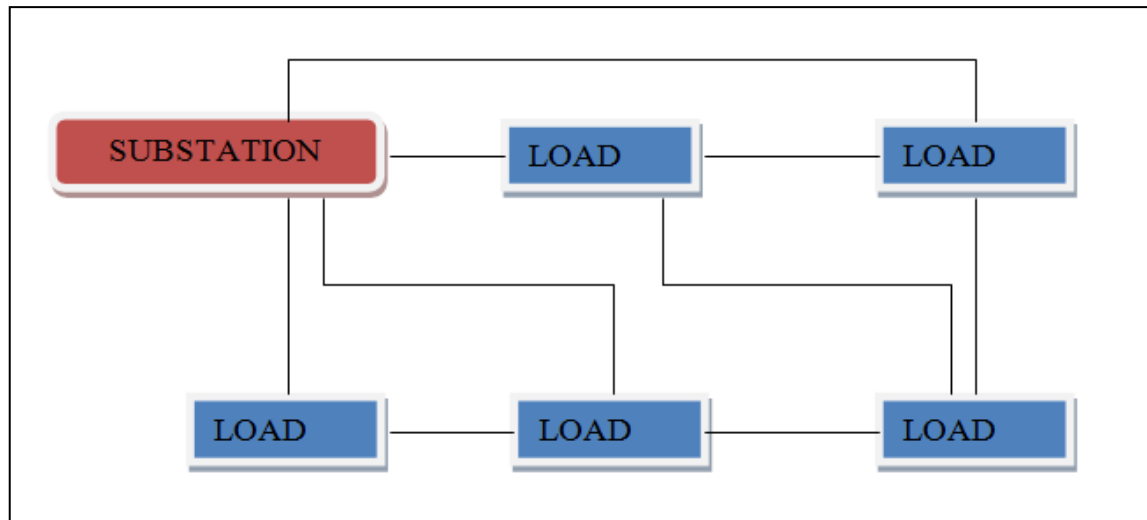


Figure 2.3: Mesh/Network distribution system

2.1.2 Distribution network reconfiguration method

Till today Electric power distribution losses in one of the main concern in power system to reduces as the demand of electrical energy is increasing day by day. The techniques of monitoring systems such local and manual control of capacitor, sectionalizing switches and voltages regulator are generally dealing throughout nearly all of distribution system network [1]. To improve the efficiency of the electrical network, there are several techniques that can be applied in the system and the reconfiguration of distribution network is one of the method [2]. The method is performed by opening the sectionalizing switches that usually closed and closing the tie switches that normally open to maintain the feeder in radial network [3], [4]. The switching action depends on the number of switches. Where, the greater the number of switches, the more available options of reconfiguration. Hence, reconstructing the power lines which connect various buses in a power system. The distribution network that consists of different load characteristics such as domestic and industrial can be configured and can be done from time to time.

There are lot of benefits of network reconfiguration [1]–[5]:

- i. Efficient electric distribution
- ii. Improves voltage stability
- iii. Smoothen the peak demand
- iv. Increase network reliability
- v. Reduce cost instillation of switching equipment
- vi. Minimize the real power losses
- vii. Relieves the overloading of network components and in the feeders
- viii. Balancing system load

2.1.2.1 Switch Connection

Switch connection was installed in primary distribution system for both protection and configuration management purpose. The ‘radiality’ of the network is sustained, with the ability to manipulating the condition for both two types of switch by opening or closing to reduce resistive line losses.

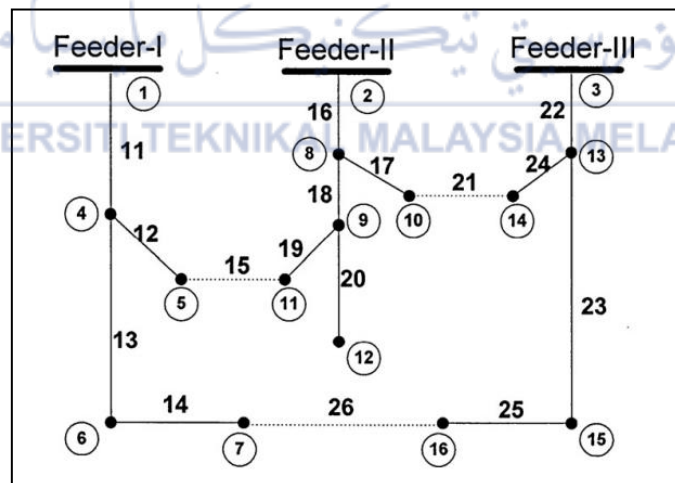


Figure 2.4: 16-Node distribution system [6]

2.1.2.1.1 Closed switches (sectionalizing switches)

The sectionalizing switches are normally closed. Sectionalizing switch need to be opened to sustain the radial composition of the distribution network. For instance, in Fig. 1, whenever the loads of feeder 2 get heavy under normal operating conditions, the sectionalizing switch linking nodes (9 and 10) must be opened up to sustain the radial structure regarding the network.

2.1.2.1.2 Normally open switches (tie switches)

The tie switches are generally normally open. It just closed intended for transferring load to distinct feeders. For illustration, in Fig. 1, whenever the loads of feeder 2 turn out to be heavy under normal operating conditions, the tie switch connecting nodes (5-11) may possibly be closed to transfer the load at bus11 from feeder 2 to feeder 1.

The objective of the reconfiguration is to minimize the distribution losses with turning on/off sectionalizing switches. The reconfiguration problem has the following constrains [6]:

1. Power flow equations.
2. Upper and lower bounds of nodal voltages.
3. Upper and lower bounds of line currents.
4. Feasible conditions in terms of network topology.

2.1.3 Energy loss reduction and cost reduction

One of the main purpose of heuristic method applied to the Distribution Network Reconfiguration applied to the network is to reduce the power loss in the distribution area. Whilst, the power loss has been reduce, the value of the cost saving will increase. Certain studies had been doned in energy loss reduction in Distribution Network Reconfiguration. In [7] , to reduce the operating cost in the real-time operation environment , Liu and W Edwin apply a new feeder reconfiguration algorithm. Operate as series of open/close switching operation, it reduce the resistive losses in primary distribution feeders and at the same time reduce the cost of system operation. The test results prove efficient and robust of the develop algorithm that operate as decision support tool by using production grade software named FRECON.

The studies of reduction of operational cost continues by [8], where there Enhanced Gravitational Search Algorithm (EGSA) for multi-objective distribution feeder reconfiguration considering reliability, loss and operational cost. EGSA algorithm use to reduce processing time, improve quality and avoid from being trapped in local minima. The paper shows the superiority of EGSA obtain better results with respect to the PSO and GA algorithm when tested on 33 and 70 node test system.

Thus, the energy loss reduction analysis on distribution network reconfiguration also had been doned in [9] and [10] where both paper shows the advantageous of heuristic method to obtain the configuration with minimum active energy losse. The IEEE 33-nodes system were used to test the performance of purposed methodology that significant in the area of distribution network design. The energy loss estimation method based on readily available data studies were conducted in [8]. From this studies, it's compare and verify the results of the energy loss estimation from simulation that is important in distribution networks for planning purpose.

2.2 Review of Previous Related Works

Initially, particle swarm optimization (PSO) was presented in 1995 as a brand new heuristic method by Kennedy and Eberhart [11]. However, the original main objective of their research was to graphically simulate the social behaviour of bird flocks as well as fish schools. As the investigation about PSO advanced, they found out that along with certain modifications, their social behavior model can serve as a powerful optimizer. The primary version of PSO was meant to deal with only nonlinear continuous optimization issues. As the research goes on, the PSO had been applied in distribution system reconfiguration implementing an altered particle swarm optimization algorithm [6], where some modification such as using the inertia weight that decrease linearly during the simulation, modification in the number of iterations and the population shows the efficiency of the suggested PSO algorithm. The PSO also had been applied in [12] displays effective approach primarily based on Particle Swarm Optimization (PSO) to determine the switching procedure plan for feeder reconfiguration along with optimum value of DG size concurrently. The primary objective is to minimize the real power losses and enhance the bus voltage profile in the system whilst fulfilling all the distribution constraints. Wardiah Mohd Dahalan and Hazlie Mokhlis demonstrated great enhancement in term of running time, number of iterations to achieve the optimal value of power losses as well as the optimum value of DG sizing. In [13] the modified PSO also known as hierarchical structure poly-particle swarm optimization (HSPPSO) approach using the hierarchical structure principle of control theory is presented. Taking into account the capabilities of distribution network, the possibility of generating feasible solutions is enhanced by adjusting the rule of position updating. The test of proposed method on two typical IEEE testing systems displays that HSPPSO performance is much better than particle swarm optimization (PSO) both on convergence rate as well as accuracy.

Evolutionary Particle Swarm Optimization (EPSO) had been introduced by Miranda and Fonseca (2002) to be implemented in power system [14]. The hybridization Evolutionary Programming (EP) and Particle Swarm Optimization (PSO) had been shown in this paper. The ability of EPSO to dealing with the power system optimization associated with voltage control as well as the actual reduction of the losses within power system had been verified with the ability of the EPSO to locate the particular good solutions within a min-max criterion. The ability of EPSO application to reduce power

losses has been proved in [15], [16]. EPSO also has been discovered by [17] where (EPSO) structured approach for multiple SVCs optimization, in objective to minimize the transmission loss in power system. In this investigation, static var compensator (SVC) is selected as the FACTS device for the optimal installation for compensation requirements due to reported appealing performances of the devices. The research that had been done in [18] verified the effectiveness of EPSO method over the traditional PSO and EP method. The application of EPSO in distribution network reconfiguration for power loss reduction applied by identify the open and closed switching operation plans for feeder network reconfiguration, the network topologies change through On/Off of the sectionalizing tie switches in order to optimize network operation parameter.

Aside from that, in year of 2014, [19] a new hybridization method Rank Evolutionary Particle Swarm Optimization (REPSO) which is the combination of ranking idea in Evolutionary Programming (EP) in conventional PSO in order to obtain quicker solution had been tested on IEEE-33 bus system, verified the superiority of minimization of power loss in distribution network reconfiguration and sizing of distribution generation. The exact ranking idea in REPSO offers remarkable outcome in picking the ideal topologies switches along with faster computational time frame for distribution network optimization. The comparison performance of REPSO with traditional PSO and EPSO had been performed in [20] based on the power losses and the best optimal value shows REPSO is shown to provide the superb effect regarding the total network reconfiguration system.

The comparative studies between three types of particle swarm optimization (PSO, EPSO and REPSO) had been done by J.J.Jamian, H.Mokhlis and M.N.Abdullah in [21] on distributed generator sizing. It shows that both EPSO and REPSO that using execution of EP in PSO permits the whole particles to approach towards the optimal value quicker. The research exposes the fineness of REPSO more than PSO and EPSO. However, the authors do not consider the other objectives such as the detailed process of algorithms when applied on the networks and different from the studies, this comparative study analyze the performance of three types of particle swarm optimization (PSO, EPSO and REPSO) for network reconfiguration that consider the power loss, computation time and operational cost have not been done in any researcher.

2.3 Summary and Discussion of the Review

In this chapter, the background of electrical system and the related information has been discussed. Besides that, the important of reconfiguration to the distribution system as it maintains the reliability of the system by reducing the losses has been discovered. PSO is a type of heuristic method that had been evolves from day by day that can be apply in distribution network reconfiguration to reduce the power losses. From the research that had been done there were still no comparative studies that shows the performances of PSO Family (PSO, EPSO and REPSO) in network distribution reconfiguration for the energy loss reduction and cost reduction improvement.

The main purpose of heuristics method apply in the Distribution Network Reconfiguration is to reduces the amount of the power loss it has been proven from the studies that had been conducted by previous researcher. At the same time, the reduction of power loss also reduce the cost of operation. However there is still no studies that provide the data of total cost of reduction that can be contributed when applying the PSO Family algorithms heuristics method in the DNR.

In next chapter, the PSO is used to make characteristics for switching optimization step. For power flow calculation, the Newton - Raphson method is used in order to get the minimum value of losses. Thus, the next chapter will be looking in depth on the methodology, which was employed in this project.

CHAPTER 3

METHODOLOGY

3.1 Overview

Throughout the preceding studies, the hybridization approaches of PSO family heuristics methods has been presented by numerous research workers to minimize the power losses in the distribution network system. This studies purpose the comparative study performance of hybirdization methods of PSO Family for distribution network reconfiguration that consists of traditional PSO, EPSO and REPSO.

3.2 PSO Family

3.2.1 Particle Swarm Optimization (PSO)

The choreography of a bird flock when they seek for food has inspired Kennedy and Eberhart in 1995 to develop PSO. The birds will move to the food within selected speed and position. P_{best} and G_{best} can be concluded as the movements they have created are primarily based upon their experiences along with their friend's experience. Since it possess individual velocity. While $v_{(i+1)}$ denoted as new velocity and the new position $x_{(i+1)}$ that denoted as new position could be acquired through the function listed below:

$$v_{(i+1)} = \omega V_i + c_1 r_1 (P_{best} - x_i) + c_2 r_2 (G_{best} - x_i) \quad (3.1)$$

$$x_{(i+1)} = v_{(i+1)} + x_i \quad (3.2)$$

Where

ω = inertia weight

c_1 and c_2 = acceleration constant

r_1 and r_2 = random values between 0 and 1

In PSO algorithm:

- i. Initialization - for the randomize population (x)
- ii. REPEAT:
- iii. Calculate the fitness ($f(x)$)
- iv. Calculate the P_{best} and G_{best} for all the population
- v. Find the new velocity for each population
- vi. Adjust the position, X_{new}
- vii. Is the requirement fulfilled? If no, **REPEAT**.
- viii. If yes, **END**

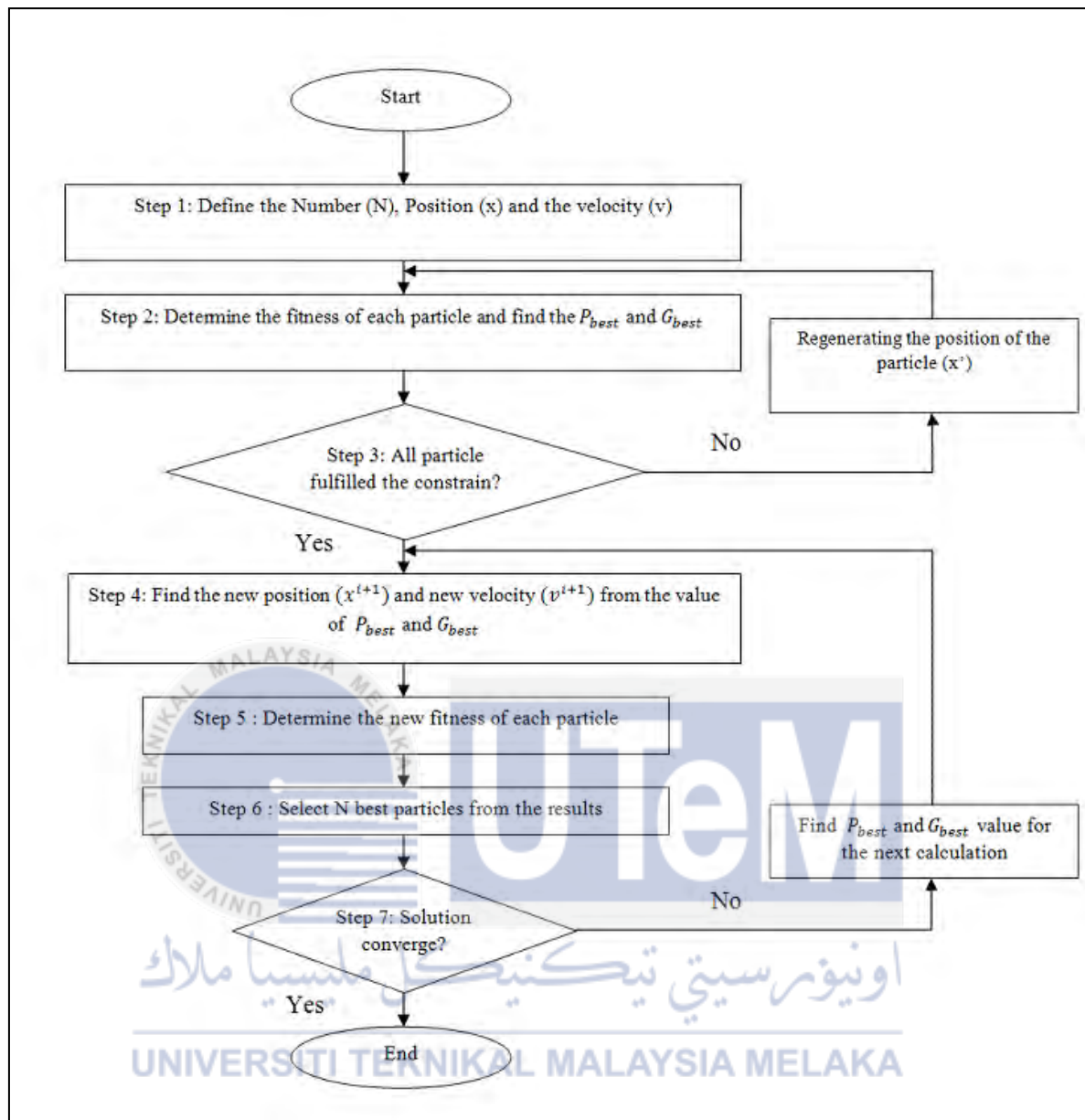


Figure 3.1: The flow chart of the Particle Swarm Optimization

Step 1: Discover the number (N), position (x) and the velocity (v)

Population of N particles is initialized using random position, x and the velocity of each particle is set to zero

Step 2: Find the fitness of each particle and find the P_{best} and G_{best}

Fitness to reduce the power lossess by the generated particle will be tested. On the final phase, the local best P_{best} is established is the present position and at the same time as the objective value of the particle. The global best G_{best} is the best initial particle.

Step 3: Check the constraints

The particle accepted in case the values of the particle and the object if value attain from the particles are inside of the constraints of the system and vise versa. The new particle will be generated and the following step will continuously recurrent if the value obtained is not within the constraints.

Step 4: Locate the new position (x^{i+1}) and new velocity (v^{i+1}) from the value of P_{best} and G_{best}

The new velocity (v^{i+1}) and the new position (x^{i+1}) is calculated by using the equation (3.1) and (3.2) from the values of P_{best} and G_{best} . By using the value of new position, the evaluations of the objectives of all particles is made.

Step 5: Find the new fitness of each particle.

The new fitness is determined from the new position obtained,.

Step 6: Choose N best particles from the results

Through the results the N numbers of position together with the best score is used for the next iteration and regarded as the survival positions. These positions establish as the newest P_{best} . While, the position with the highest score is used as the newest G_{best} .

Step 7: Solution converge

Step 1 to step 7 will repeated to form iteration progression till the convergence is achieved. The optimization seek out process end after the convergence achieved.



3.2.2 Evolutionary Particle Swarm Optimization (EPSO)

The ability of Evolution Programming (EP) for distribution network reconfiguration for power loss configuration had been reported in [22]–[24]. However the result of power loss minimization is not optimal when compared to the traditional PSO method. Evolutionary Particle Swarm Optimization (EPSO) has been unveiled by Miranda [14] merged the evolutionary programming idea to the PSO algorithm to resolve the optimal problem efficiently. Presently there are numerous researches that demonstrated EPSO tend to be efficient and accurate with successful application to the power system as mention in [14]. The efficient of EPSO in distribution network reconfiguration had been reported in [18] where it shown the optimum results that produces lesser power loss compared to the traditional PSO.



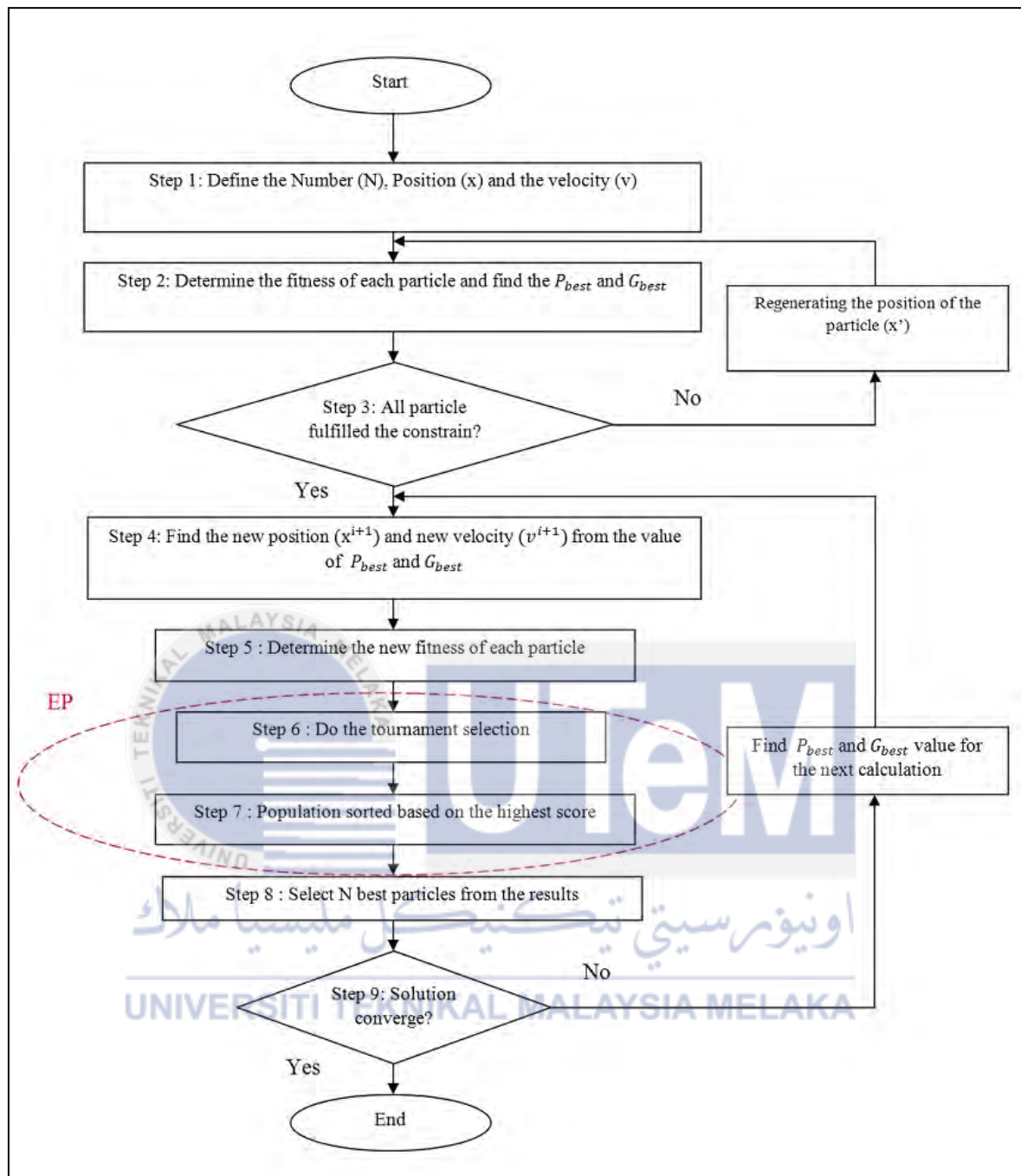


Figure 3.2: The flow chart of the Evolutionary Particle Swarm Optimization Algorithm

Step 1: Discover the number (N), position (x) and the velocity (v)

Population of N particles is initialized using random position, x and the velocity of each particle is set to zero

Step 2: Find the fitness of each particle and find the P_{best} and G_{best}

Fitness to reduce the power loss by the generated particle will be tested. On the final phase, the local best P_{best} is established is the present position and at the same time as the objective value of the particle. The global best G_{best} is the best initial particle.

Step 3: Check the constraints

The particle accepted in case the values of the particle and the object value attain from the particles are inside the constraints of the system and vice versa. The new particle will be generated and the following step will continuously recurrent if the value obtained is not within the constraints.

Step 4: Locate the new position (x^{i+1}) and new velocity (v^{i+1}) from the value of P_{best} and G_{best}

The new velocity (v^{i+1}) and the new position (x^{i+1}) is calculated by using the equation (3.1) and (3.2) from the values of P_{best} and G_{best} . By using the value of new position, the evaluations of the objectives of all particles is made.

Step 5: Find the new fitness of each particle.

The new fitness is determined from the new position obtained. Thus, the contested in tournament between the new fitness based on the new and old position occurs in this step.

Step 6: Do the tournament selection process.

The set of combination among new position and the old position contested in the tournament. It gains the score if the fitness is better. The principle of Evolutionary Programming is involved in this step.

Step 7: Sorting population based on the highest score

The position was sorted from the highest score to the lowest score right after the tournament and selection process is accomplished. The lowest score represent the maximum power losses while the highest score represent the minimum power lossess.

Step 8: Choose N best particles from the results

Through the results the N numbers of position together with the best score is used for the next iteration and regarded as the survival positions. These positions establish as the newest P_{best} . While, the position with the highest score is used as the newest G_{best} .

Step 9: Solution converge

Step 1 to step 9 will repeated to form iteration progression till the convergence is archiebed. The optimization seek out process end after the convergence archiebed.

3.2.3 Rank Evolutionary Particle Swarm Optimization (REPSO)

The application of REPSO in Distribution Network Reconfiguration had been reported in [19], [20] where between the particles in a population, the unfilled position that they left will be exchange by others particles and the best particles will shift to the new position. Through applying principle of combination, ranking as well as selection method in Evolutionary Programming (EP), REPSO make the particle move faster to the optimal solution. Different via EPSO, the strategy of competition/tournament in EP may possibly result in the ‘lucky’ particles to continue to be in the system considering that the particle is going to be compared randomly. Therefore, there will be several probability for those ‘lucky’ particle to stay in the system. As a result , REPSO will overcome this problem as well as produce quicker convergence in comparison to PSO and even EPSO. The circulation process of the unique algorithm is as follow:



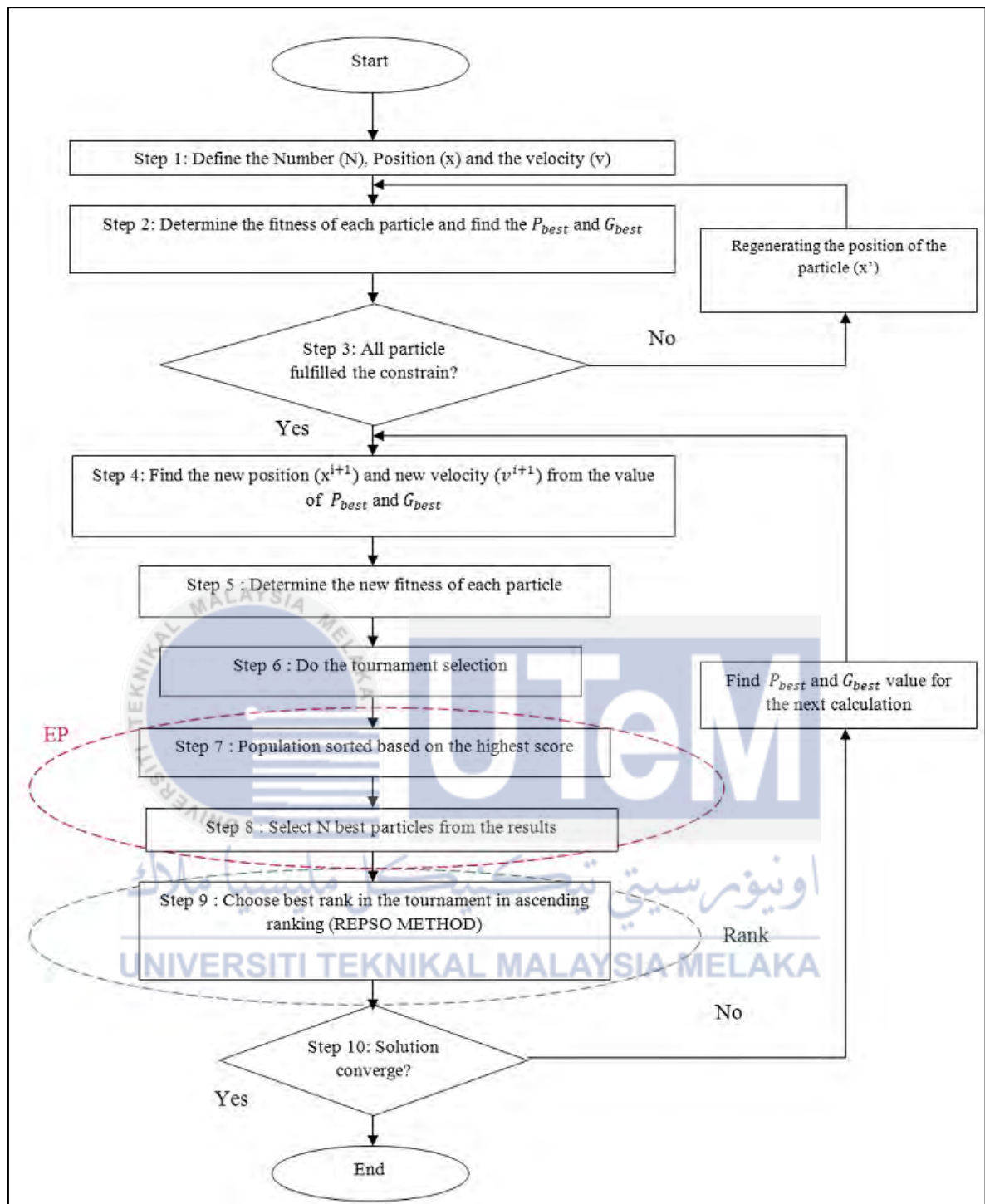


Figure 3.3: The flow chart of the Rank Evolutionary Particle Swarm Optimization

Step 1: Discover the number (N), position (x) and the velocity (v)

Population of N particles is initialized using random position, x and the velocity of each particle is set to zero

Step 2: Find the fitness of each particle and find the P_{best} and G_{best}

Fitness to reduce the power loss by the generated particle will be tested. On the final phase, the local best P_{best} is established is the present position and at the same time as the objective value of the particle. The global best G_{best} is the best initial particle.

Step 3: Check the constraints

The particle accepted in case the values of the particle and the object value attain from the particles are inside of the constraints of the system and vice versa. The new particle will be generated and the following step will continuously recurrent if the value obtained is not within the constraints.

Step 4: Locate the new position (x^{i+1}) and new velocity (v^{i+1}) from the value of P_{best} and G_{best}

The new velocity (v^{i+1}) and the new position (x^{i+1}) is calculated by using the equation (3.1) and (3.2) from the values of P_{best} and G_{best} . By using the value of new position, the evaluations of the objectives of all particles is made.

Step 5: Find the new fitness of each particle.

The new fitness is determined from the new position obtained. Thus, the contested in tournament between the new fitness based on the new and old position occurs in this step.

Step 6: Do the tournament selection process.

The set of combination among new position and the old position contested in the tournament. It gains the score if the fitness is better. The principle of Evolutionary Programming is involved in this step.

Step 7: Sorting population based on the highest score

The position was sorted from the highest score to the lowest score right after the tournament and selection process is accomplished. The lowest score represent the maximum power losses while the highest score represent the minimum power losses.

Step 8: Choose N best particles from the results

Through the results the N numbers of position together with the best score is used for the next iteration and regarded as the survival positions. These positions establish as the newest P_{best} . While, the position with the highest score is used as the newest G_{best} .

Step 9: The best rank in the tournament is chosen

Based on the newest P_{best} and G_{best} , the best rank that won the tournament will be used during the process.

Step 10: Solution converge

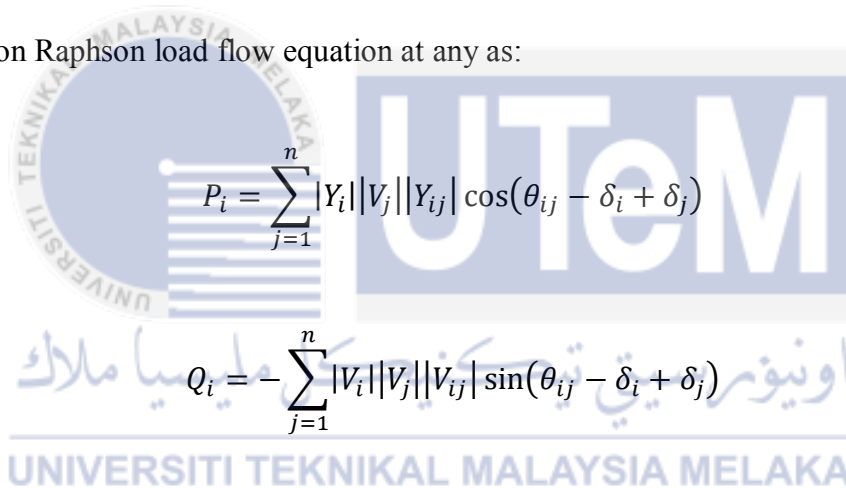
Step 1 to step 9 will repeated to form iteration progression till the convergence is achieved. The optimization seek out process end after the convergence achieved.

3.3 The Formulation and implementation of PSO Family to DNR

3.3.1 Newton-Raphson load flow program

The power flow will be calculated by the Newton-Raphson load flow program. The data for the load bus, load flow Newton-Raphson as well as bus admittance data are referring the 1998 H.Saadat.

The Newton Raphson load flow equation at any as:



$$P_i = \sum_{j=1}^n |Y_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j)$$

$$Q_i = - \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j)$$

Where ,

V_i, V_j = the voltage magnitude of bus i and j respectively

δ_i, δ_j = the voltage angle of bus i and bus j respectively

Y_{ij}, θ_{ij} = the magnitude and angle of Y_{ij} element in the bus admittance matrix respectively

The differences in real power (ΔP_i) and reactive power (ΔQ_i) for the i th bus are:

$$\Delta P_i = P_i^{sp} - P_i$$

$$\Delta Q_i = Q_i^{sp} - Q_i$$

Where P_i^{sp} and Q_i^{sp} are the specified real and reactive power at bus i respectively.

The rectangular Newton-Raphson power flow is expressed as :

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

Power loss can be calculated as in equation:

$$P_{loss} = \sum_{i=1}^n \sum_{j=1}^n A_{ij} (P_i P_j + Q_i Q_j) + B_{ij} (Q_i P_j - P_i Q_j)$$

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

$$B_{ij} = \frac{R_{ij} \sin(\delta_i - \delta_j)}{V_i V_j}$$

- P_i, Q_i = the real and reactive power of bus i
- P_j, Q_j = the real and reactive power of bus j
- R_{ij} = the line resistance between bus i and j
- V_i, V_j = the voltage magnitude of bus i and j
- δ_i, δ_j = the voltage angle of bus i and j

As the data is inserted into the network, the purposed method that consists of traditional PSO, EPSO and REPSO programming has been simulated in MATLAB environment. The 33-bus network data are recorded and analyzed appropriately. The comparability among the conventional results and the simulation results have been done and minimum value of power losses has been validated.

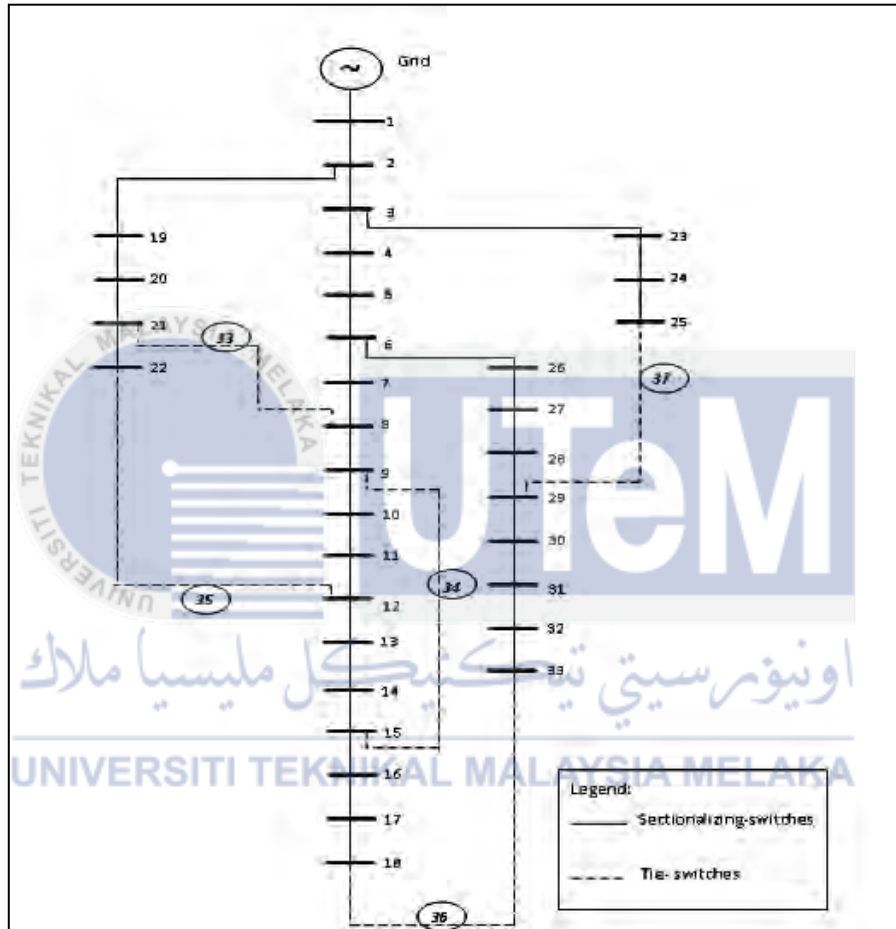


Figure 3.4: The 33-bus radial initial configuration

The mathematical objectives are as follows:

$$\text{Minimize } f_1(x, v) = \sum_{i=1}^n \text{Losses}_i \quad (3.3)$$

Where,

n is the number of branches

x is the continuous control variable

v is the discrete control variable

Losses is the power losses at classified at i branch

During the process of analysis, generally there are some constraints which must be consider . The constraints are:

3.3.2 The voltage constraints

The voltage magnitude in order to sustain the power quality of the system. Too high or too low voltage could cause problems with respect to end user power apparatus damage or instability of power for end users.

$$V_{min} \leq V_{bus} \leq V_{max} \quad (3.4)$$

The particular limits for voltage at each bus is within 1.05 and 0.95 (± 5)

3.3.3 Power flow constraints

Each branch has its own allowable range

$$|I_k| \leq I_k^{max} \in \{1, 2, 3, \dots\}$$

Where I_k^{max} = maximum current capability of branch k

3.3.4 Radial configuration constraints

Consequently, assure the radiality of the network to be preserved, several constraints should be consider as well as to prevent any excessive of current flow thru the system. Several rules need to be implemented for assortment of the switches ; those switches that contribute to a meshed network have to be closed.

3.3.5 Energy Lossess Cost Reduction Analysis

The energy losses that had been obtained were transformed into form of cost by refers the System Average Interruption Duration Index (SAIDI) obtained from [25] for medium voltage which is between 6.6Kv to 33Kv annually. With assumption of the system operates for the whole year. From the SAIDI data the average operation of the system for 1 day in average is calculated as 23.846 Hours.

To obtain the energy loss:

$$Energy (kWh) = Total Power Loss (kW) \times Hour (h)$$

To obtain the loss cost average for one day of operation the values of *Energy (kWh)* obtained were multiple with the average selling price [25] :

$$Total Loss Cost (RM) = Energy (kWh) \times Electricity Average Selling Price \left(\frac{sen}{kWh} \right)$$

3.4 Implementation process of Algorithm

3.4.1 Implementation process of PSO

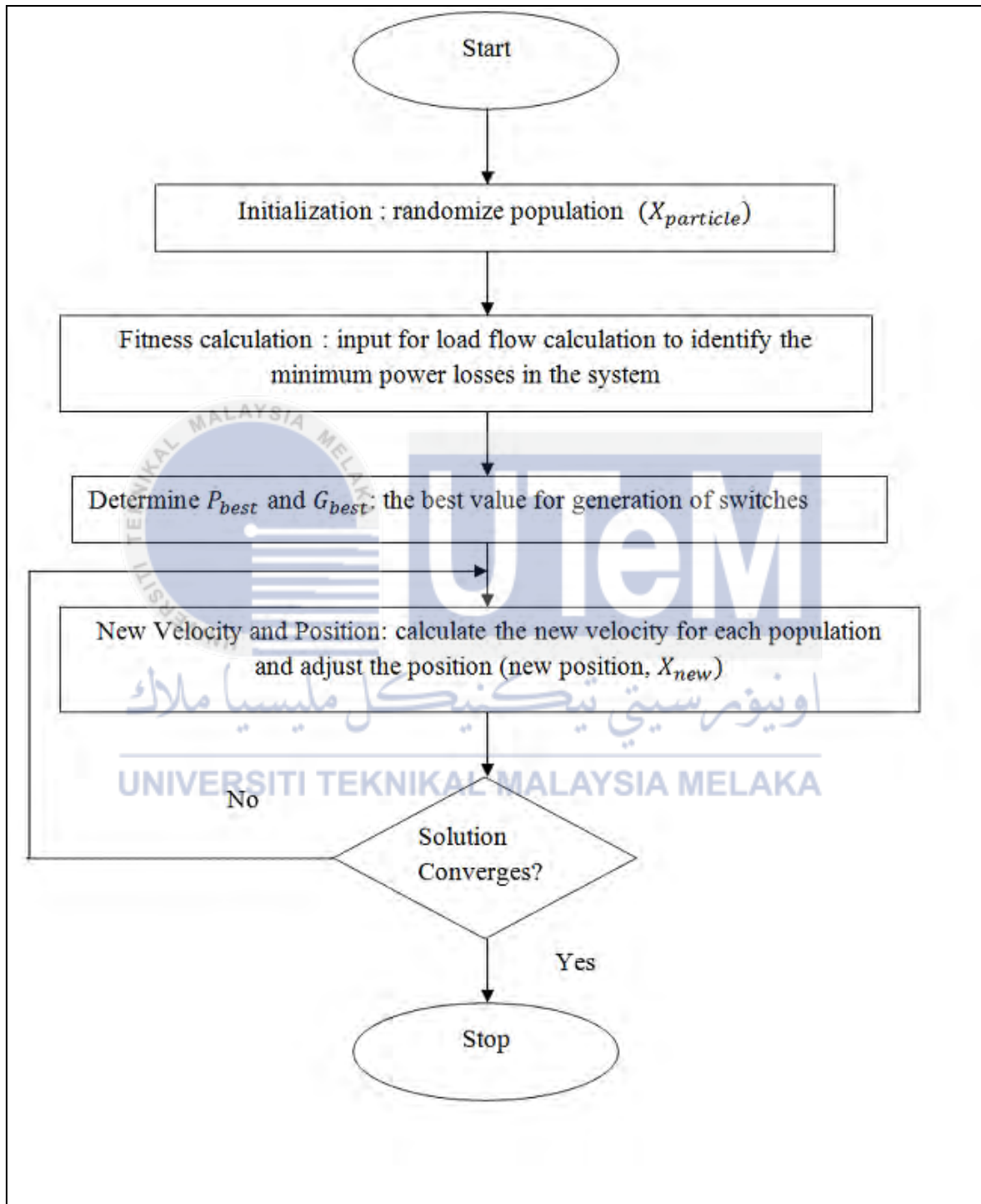


Figure 3.5: Implementation of PSO in Network Reconfiguration

3.4.1.1 Initialization

By using MATLAB software programme, all the input system data which involved that consists of data below are written on the software programme:

1. Network data
2. Buses data
3. Lines data
4. Voltage limit

To find the initialization population, the switches is selected from the set of its original tie switches. Those variables involved will be generated by the system in the program will be generated randomly. While, all the parameters will be utilized in order to calculate the power losses. In the simulation, the particles function as the tie switches and the equation is listed below:

$$X_{particles} = [S_1, S_2, S_3, \dots, S_Y]$$

Where :

y= number of tie switches

On this particular phase, all parameter of PSO that included such as number of particles (N), weighting factor, C_1 and C_2 and the maximum number of iteration are examined. In order to assure the radial network is preserve, generally there are a number of restrictions that must be considered. This is the several important rules that need to be follows for the selection of switches:

Rule 1: All switches that do not belong to any loop are to be closed

Rule 2: All switches are connected to the sources to be closed

Rule 3: All switches contributed to a method need to be closed

3.4.1.2 Fitness Calculation

Fitness calculation is set as the objective of the function. The main objective of this study mainly to optimize the losses in the distribution system. Position, X and velocity, V that act as the variables will randomly generated along with the initial population of particles. The Total power loss will be calculated by using the Newton-Raphson load flow program once all the constraints had been fulfilled.

3.4.1.3 Determine P_{best} and G_{best}

P_{best} and G_{best} parameter represent the generation of the tie-switches and the power losses in the network system a. During the searching process, these parameter values need to be updated and recorded.

3.4.1.4 New Velocity and Position

The particles new velocity and position are kept up to date by applying equation (3.1) and (3.2). The particle velocity represents the switches while the position represents the total power loss of all switches.

3.4.1.5 Convergence Test

New position set which will be tested for convergence obtained from the best position. Right until the convergence is achieved, the procedure may be recurring from step (3.4.1.2) to (3.4.1.4). The optimization process is stopped once the convergence has been achieved.

3.4.2 Implementation process of EPSO

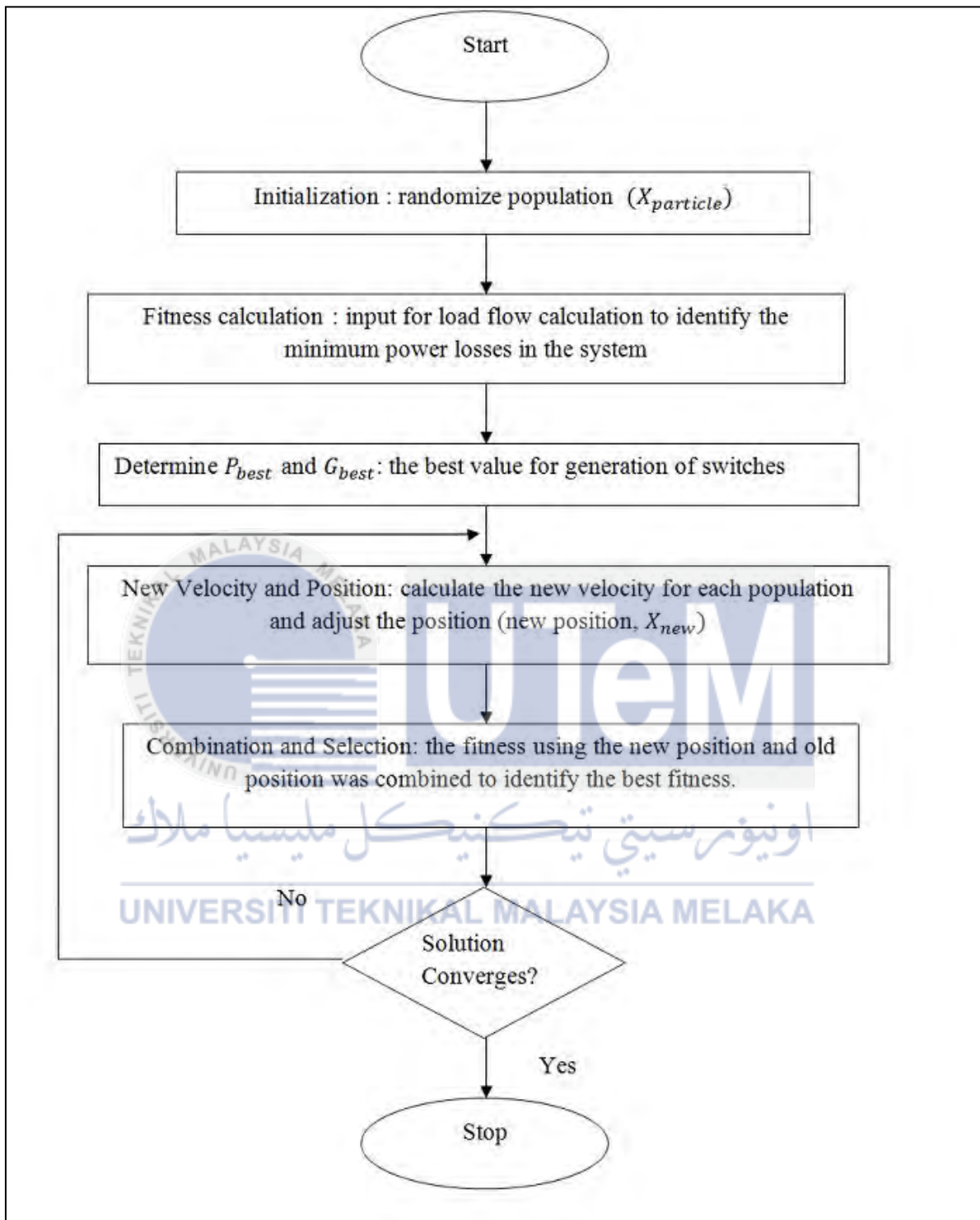


Figure 3.6: Implementation of EPSO in Network Reconfiguration

3.4.2.1 Initialization

By using MATLAB software programme, all the input system data which involved that consists of data below are written on the software programme:

1. Network data
2. Buses data
3. Lines data
4. Voltage limit

To find the initialization population, the switches is selected from the set of its original tie switches. Those variables involved will be generated by the system in the program will be generated randomly. While, all the parameters will be utilized in order to calculate the power losses. In the simulation, the particles function as the tie switches and the equation is listed below:

$$X_{particles} = [S_1, S_2, S_3, \dots, S_Y]$$

Where :

y= number of tie switches

On this particular phase, all parameter of PSO that included such as number of particles (N), weighting factor, C_1 and C_2 and the maximum number of iteration are examined. In order to assure the radial network is preserve, generally there are a number of restrictions that must be considered. This is the several important rules that need to be follows for the selection of switches:

Rule 1: All switches that do not belong to any loop are to be closed

Rule 2: All switches are connected to the sources to be closed

Rule 3: All switches contributed to a method need to be closed

3.4.2.2 Fitness Calculation

Fitness calculation is set as the objective of the function. The main objective of this study mainly to optimize the losses in the distribution system. Position, X and velocity, V that act as the variables will randomly generated along with the initial population of particles. The Total power loss will be calculated by using the Newton-Raphson load flow program once all the constraints had been fulfilled.

3.4.2.3 Determine P_{best} and G_{best}

P_{best} and G_{best} parameter represent the generation of the tie-switches and the power losses in the network system a. During the searching process, these parameter values need to be updated and recorded.

3.4.2.4 New Velocity and Position

The particles new velocity and position are kept up to date by applying equation (3.1) and (3.2). The particle velocity represents the switches while the position represents the total power loss of all switches.

3.4.2.5 Combination and Tournament Selection

After the new position, X_{new} is obtained, the new fitness also known as the power loss was determined. Literally, both the new set location of X_{new} as well as the old set position X will be combined with and contested in a tournament. This tournament is contested randomly where the contender with higher fitness (least total power loss) will gain a higher position. According to power losses in the system, the old set and the new set position were arranged in this method in descending order.

3.4.2.6 Convergence Test

New position set which will be tested for convergence obtain from the best position. Right until the convergence is achieved, the procedure may be recurring from step (3.4.2.2) to (3.4.2.5). The optimization process is stopped once the convergence has been achieved.



3.4.3 Implementation process of REPSO

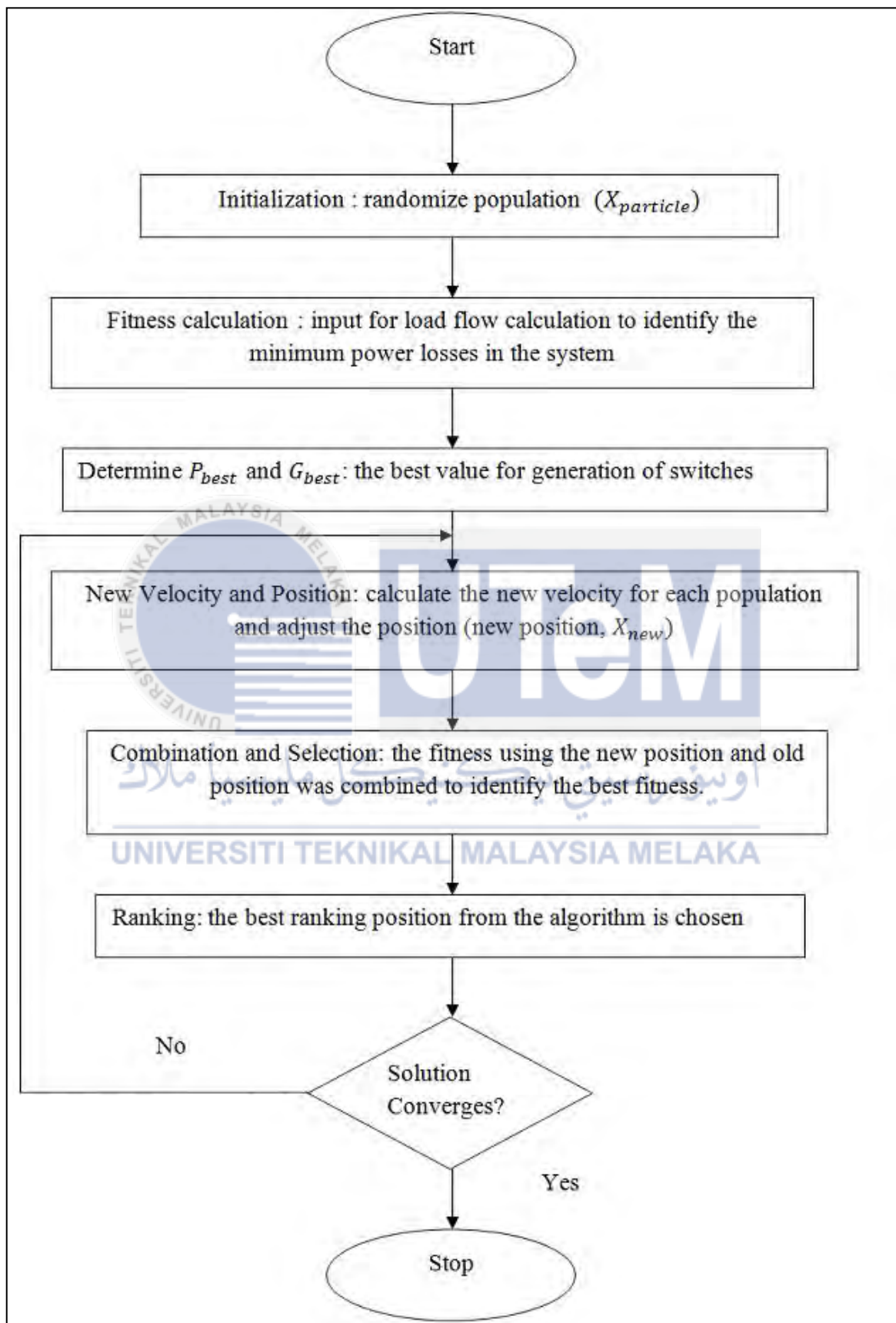


Figure 3.7: Implementation of REPSO in Network Reconfiguration

3.4.3.1 Initialization

By using MATLAB software programme, all the input system data which involved that consists of data below are written on the software programme:

1. Network data
2. Buses data
3. Lines data
4. Voltage limit

To find the initialization population, the switches is selected from the set of its original tie switches. Those variables involved will be generated by the system in the program will be generated randomly. While, all the parameters will be utilized in order to calculate the power losses. In the simulation, the particles function as the tie switches and the equation is listed below:

$$X_{particles} = [S_1, S_2, S_3, \dots, S_Y]$$

Where :

y= number of tie switches

On this particular phase, all parameter of PSO that included such as number of particles (N), weighting factor, C_1 and C_2 and the maximum number of iteration are examined. In order to assure the radial network is preserve, generally there are a number of restrictions that must be considered. This is the several important rules that need to be follows for the selection of switches:

Rule 1: All switches that do not belong to any loop are to be closed

Rule 2: All switches are connected to the sources to be closed

Rule 3: All switches contributed to a method need to be closed

3.4.3.2 Fitness Calculation

Fitness calculation is set as the objective of the function. The main objective of this study mainly to optimize the losses in the distribution system. Position, X and velocity, V that act as the variables will randomly generated along with the initial population of particles. The Total power loss will be calculated by using the Newton-Raphson load flow program once all the constraints had been fulfilled.

3.4.3.3 Determine P_{best} and G_{best}

P_{best} and G_{best} parameter represent the generation of the tie-switches and the power losses in the network system a. During the searching process, these parameter values need to be updated and recorded.

3.4.3.4 New Velocity and Position

The particles new velocity and position are kept up to date by applying equation (3.1) and (3.2). The particle velocity represents the switches while the position represents the total power loss of all switches.

3.4.3.5 Combination and Tournament Selection

After the new position, X_{new} is obtained, the new fitness also known as the power loss was determined. Literally, both the new set location of X_{new} as well as the old set position X will be combined with and contested in a tournament. This tournament is contested randomly where the contender with higher fitness (least total power loss) will gain a higher position. According to power losses in the system, the old set and the new set position were arranged in this method in descending order.

3.4.3.6 Ranking position

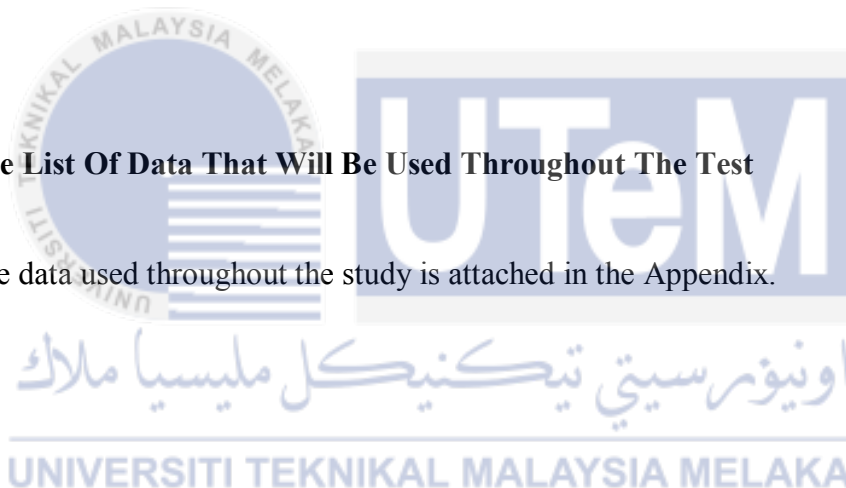
The best ranking position is chosen based on the least value of power losses sorted and obtain from the combination of the old and new set of the position. Hence, the highest rank will chosen to be applied to assist minimizing the power losses.

3.4.3.7 Convergence Test

New position set which will be tested for convergence obtain from the best position. Right until the convergence is achieved, the procedure may be recurring from step (3.4.3.2) to (3.4.3.6). The optimization process is stopped once the convergence has been achieved.

3.4.4 The List Of Data That Will Be Used Throughout The Test

The data used throughout the study is attached in the Appendix.



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

By using MATLAB (version 2012b) package in windows based computer, the CPU is installed with 6.0GB of Ram while the processor used Intel® Core Duo. The optimization programming of PSO Family algorithm that applied on 33-bus IEEE system has been written in the software. Hence, the result from the simulation has justified to find the optimal solution for power losses in the system by determining which tie-switches is needed to be open while maintaining the radial constraints. In this section, the implementation of PSO, EPSO and REPSO algorithms to find the optimal solution for reducing the power loss had been implemented in 33kV bus. From the results obtain, comparative studies on the power losses and computing time will be discussed.

4.2 Project Achievements

The simulation initial 33kV IEEE bus before and after optimization with PSO, EPSO and REPSO algorithm operate in the MATLAB for more than 100 times and 15 best results that obey the constraint and show the lowest power loss were taken. Thus, the results are recorded and tabulated as in the next sub-section accordingly .

4.2.1 Results For 33kV IEEE Test System

The PSO, EPSO and REPSO algorithm is execute in the MATLAB software for more than 1 times and the 15 best results are taken for the analysis. The overall network consists of 33 loads, with five initial tie-switches which will be opened at 33, 34, 35, 36

and 37. The five switches reconfiguration the known as S1, S2, S3, S4 and S5 are randomly generated during initialization.

Table 4.1: Power losses after reconfiguration with PSO algorithm

No of simulation	Open Switches	Total Power Losses (kW)	The computational Time (s)
1.	33 11 32 34 28	120.7	30.42
2.	33 34 10 35 26	200.4	36.84
3.	11 33 26 34 35	173.8	35.37
4.	17 18 33 5 7	151.6	5.63
5.	33 7 8 4 27	170.5	3.27
6.	17 33 9 34 28	155.3	31.26
7.	9 33 17 8 28	236.4	21.00
8.	33 9 31 32 28	121.5	7.55
9.	27 11 33 12 7	208.4	21.20
10.	33 34 35 6 9	175.5	3.62
11.	28 17 33 8 14	190.5	29.46
12.	33 28 32 11 34	120.7	28.32
13.	14 26 7 10 33	175.9	30.39
14.	33 12 34 10 27	199.4	19.69
15.	33 34 28 32 11	160.7	28.88

Table 4.2: Power losses after reconfiguration with EPSO algorithm

No of simulation	Open Switches	Total Power Losses (kW)	The computational Time (s)
1.	33 6 14 28 34	146.1	34.52
2.	11 33 34 32 28	130.7	21.22
3.	33 28 34 8 17	155.8	30.55
4.	29 4 27 33 15	196.2	2.85
5.	9 28 33 14 32	121.3	26.85
6.	33 34 27 11 32	142.8	27.02
7.	27 33 34 35 13	158.5	21.60
8.	30 31 10 17 5	130.1	3.18
9.	13 9 26 6 33	219.1	26.17
10.	14 33 9 28 32	121.3	34.46
11.	8 14 28 17 33	175.5	22.85
12.	5 27 17 25 7	136.0	4.23
13.	33 12 34 35 29	150.7	9.99
14.	5 21 24 6 7	136.6	2.73
15.	12 28 33 32 34	190.7	13.57

Table 4.3: Power losses after reconfiguration with REPSO algorithm

No of simulation	Open Switches	Total Power Losses (kW)	The computational Time (s)
1.	32 12 33 29 34	120.7	12.51
2.	5 15 6 4 33	124.8	2.88
3.	9 33 34 28 17	125.3	25.68
4.	33 10 11 4 12	113.8	4.31
5.	6 13 10 27 17	122.8	4.89
6.	6 31 33 17 25	128.9	3.62
7.	27 18 26 8 33	137.3	4.88
8.	14 7 11 25 33	157.9	29.26
9.	9 25 7 33 13	150.4	20.86
10.	9 17 33 28 34	129.3	11.59
11.	33 28 32 9 14	121.3	15.98
12.	33 28 34 17 9	105.3	34.30
13.	28 7 31 33 22	122.3	14.17
14.	7 21 12 28 17	112.2	4.36
15.	33 14 27 34 8	127.5	19.02

4.2.1.1 Power Losses Reduction

The results obtained total power losses are recorded and tabulated into tables 4.1, 4.2 and 4.3. Only the best fifteen values of power losses for each algorithm simulation is included in the tables.

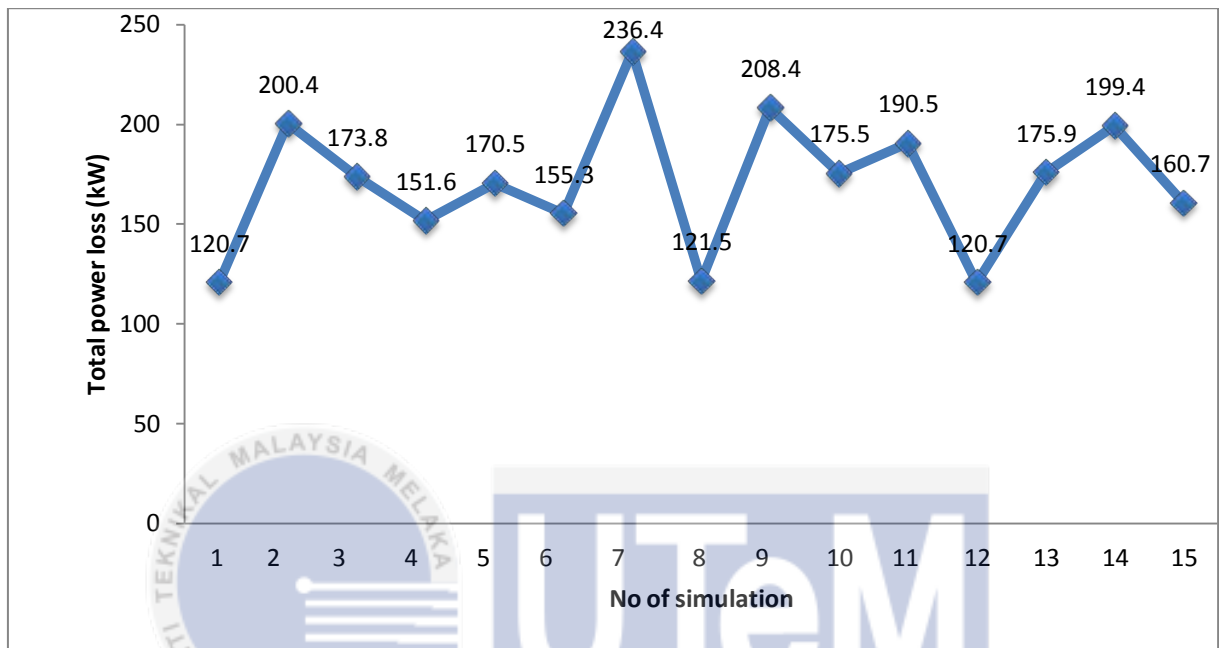


Figure 4.1: No of simulation versus the total power losses for PSO

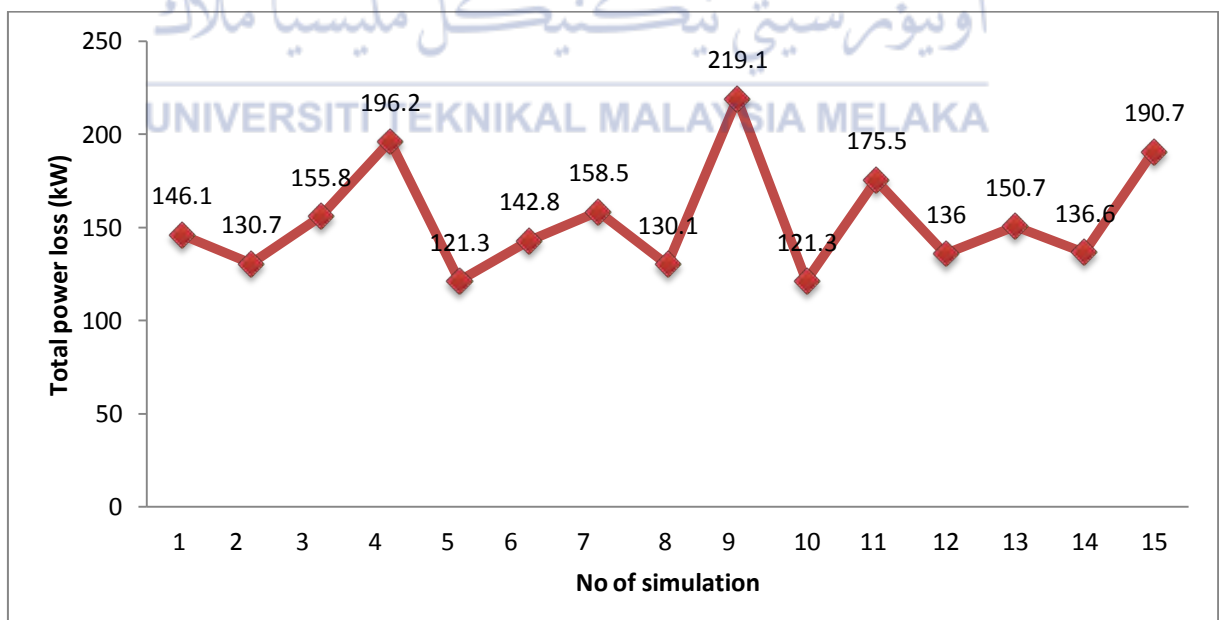


Figure 4.2: No of simulation versus the total power losses for EPSO

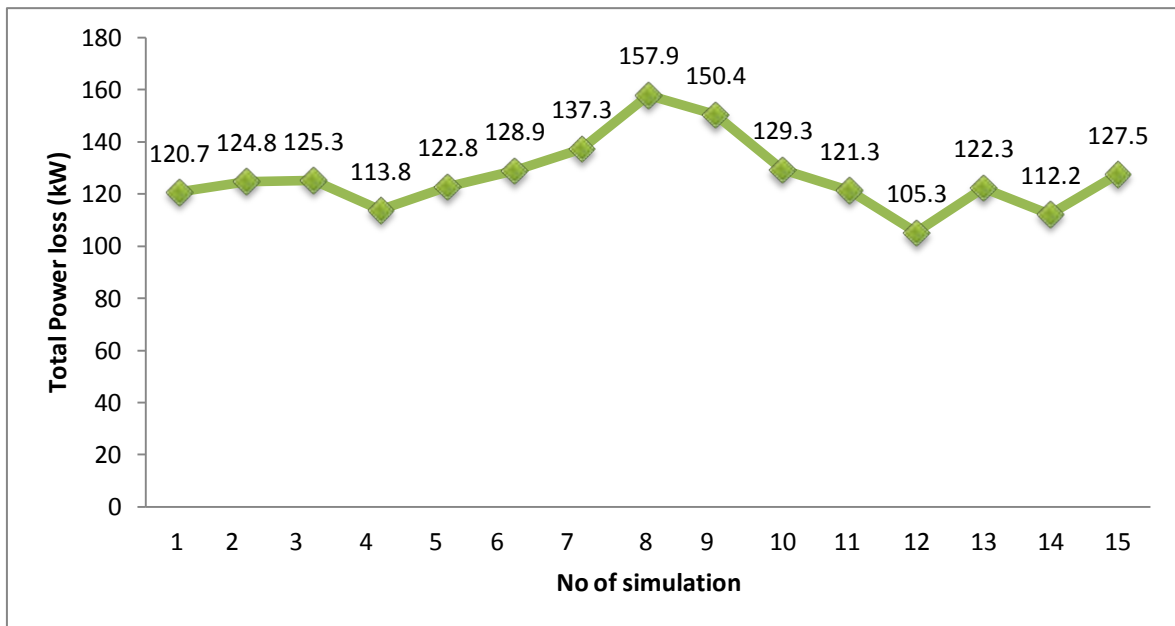


Figure 4.3: No of simulation versus the total power losses for REPSO

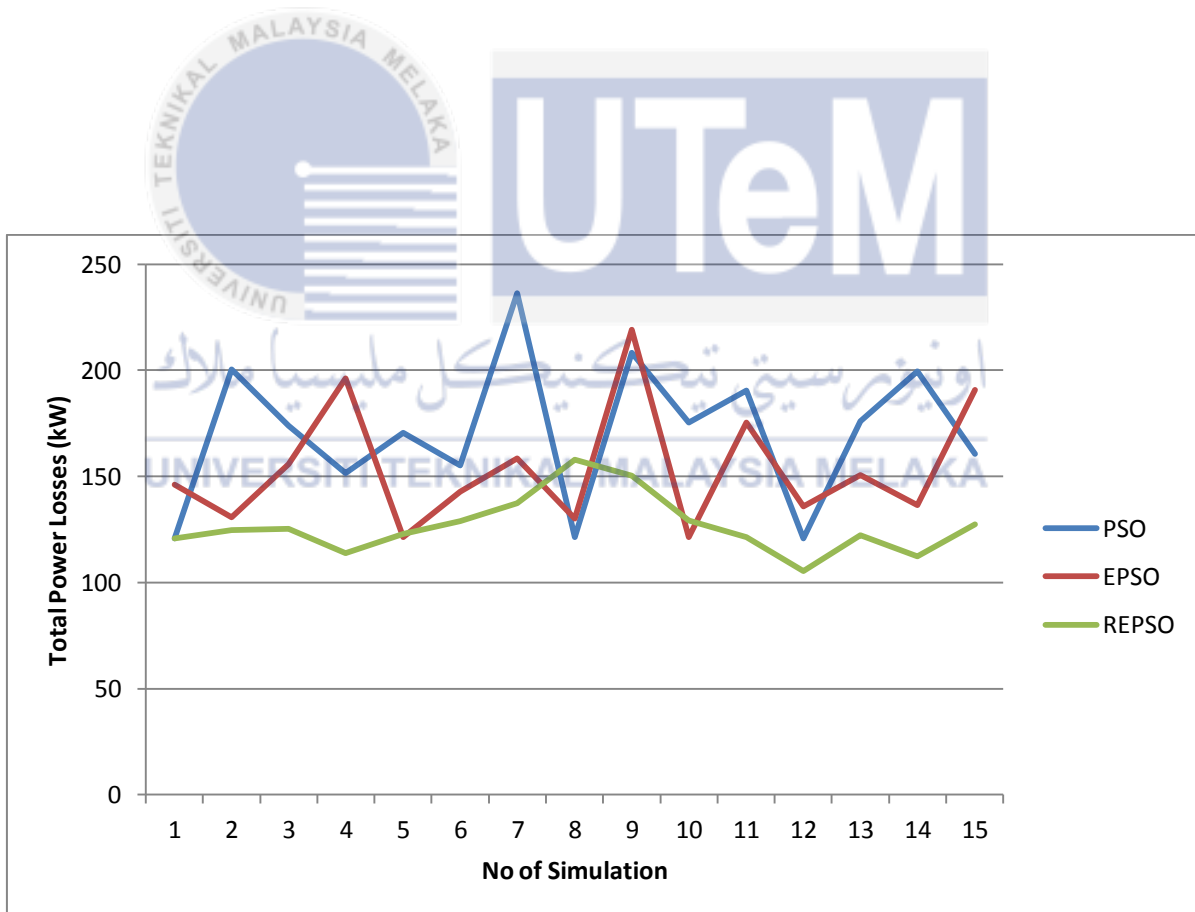


Figure 4.4: No of simulation versus the total power losses for PSO, EPSO and REPSO algorithm

Tables 4.1, 4.2 and 4.3 shows the results of the power losses and the computational time that had been taken based on the sectionalizing switches to be opened while maintaining the radial constraints.

Table 4.4: The statistical analysis of power loss for three cases

Algorithms	Mean Power Losses / kW	Standard Derivation / σ
PSO	170.75	33.83
EPSO	154.09	29.19
REPSO	126.25	13.60

While in Figure 4.4 all the performances of PSO Family are drawn in the graph to show the difference of the algorithm when applied to the 33kV system to minimize the losses. Thus, from the 15 best results obtained. The mean value of the power loss were calculated and the closest values of power losses to the mean values were taken as the best results for comparison. From the statistical analysis of power loss for three cases it shows that REPSO provide lower mean power loss and lower standard derivation.

Table 4.5: The analysis results for 33-bus test system for three cases

Parameters	Case 1: Original initial network	Case 2: After reconfiguration using PSO	Case 3: After reconfiguration using EPSO	Case 4: After reconfiguration with REPSO algorithm.
Switch to be opened.	33,34,35,36,37	14,26,7,10,33	27,33,34,35,13	9,17,33,28,34
Total power loss (kW)	202.7	175.90	158.5	125.30
Loss Reduction (kW)	-	26.80	44.20	77.40
Percentage of Loss Reduction (%)	-	13.22	21.81	38.18
Computational time (s)	-	30.39	21.60	11.59

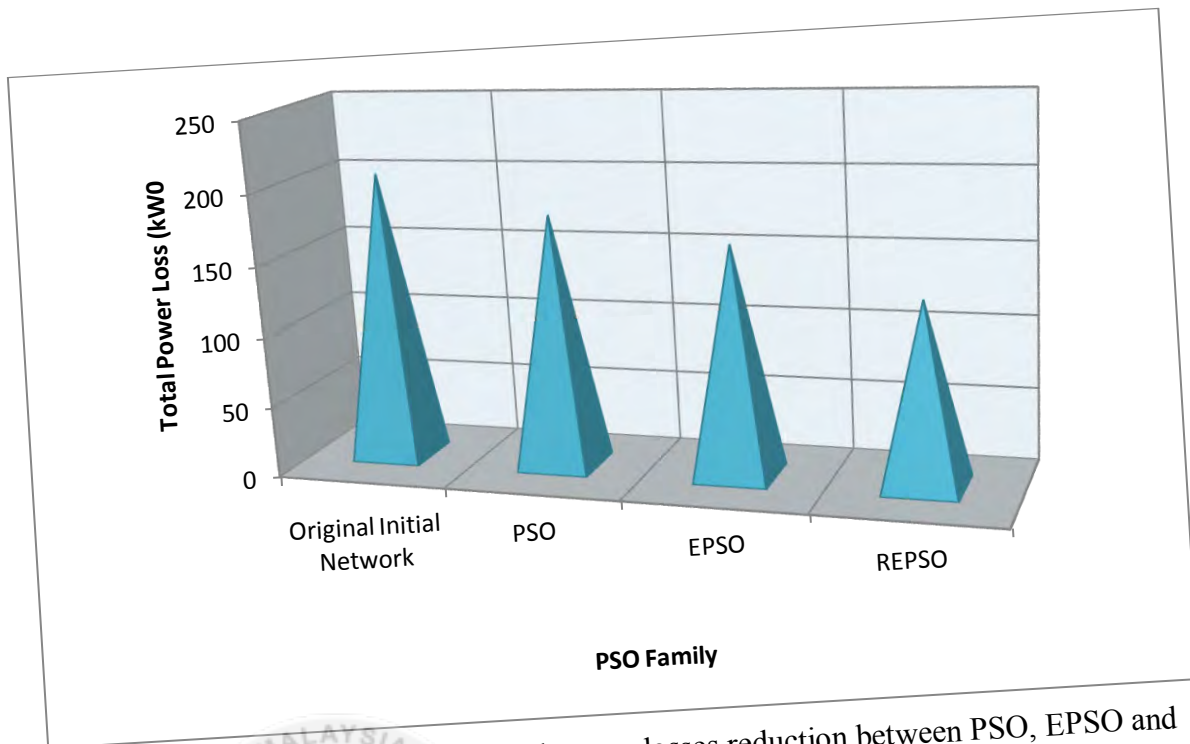


Figure 4.5 : The comparison of total power losses reduction between PSO, EPSO and REPSO algorithm

Table 4.4 shows the results for four cases consists of original initial network that maintain its radial configuration with the open tie line, PSO algorithm, EPSO algorithm and REPSO algorithm. From the result that had been obtain, it shows the minimization of power losses in distribution system when applied with PSO Family algorithms. For case 2, the traditional PSO the power loss reduce by 26kW which is 13.22% lesser than the initial losses followed by EPSO that reduce by 44.2kW that 21.81 lesser than initial and REPSO that shows superior optimization on the system that reduce the power losses by 77.4kW which is 38.18% more than the initial losses. The REPSO algorithm also monopolies the computation times for all three PSO family when it recorded shorter times that is 11.59s followed by EPSO; 21.60 s and PSO; 30.39s correspondently.

4.2.1.2 Convergence Time

The results obtained for computational times are recorded and tabulated into tables 4.1, 4.2 and 4.3. Only the best fifteen result is included in the tables.

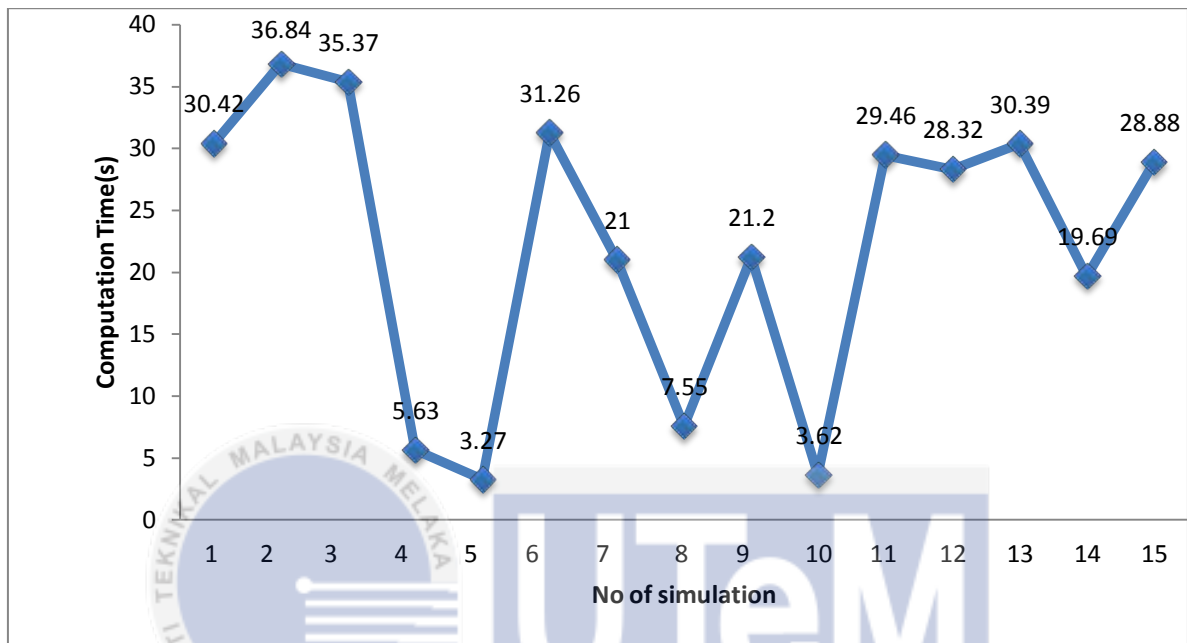


Figure 4.6: Number of simulation versus the computation time for PSO algorithm

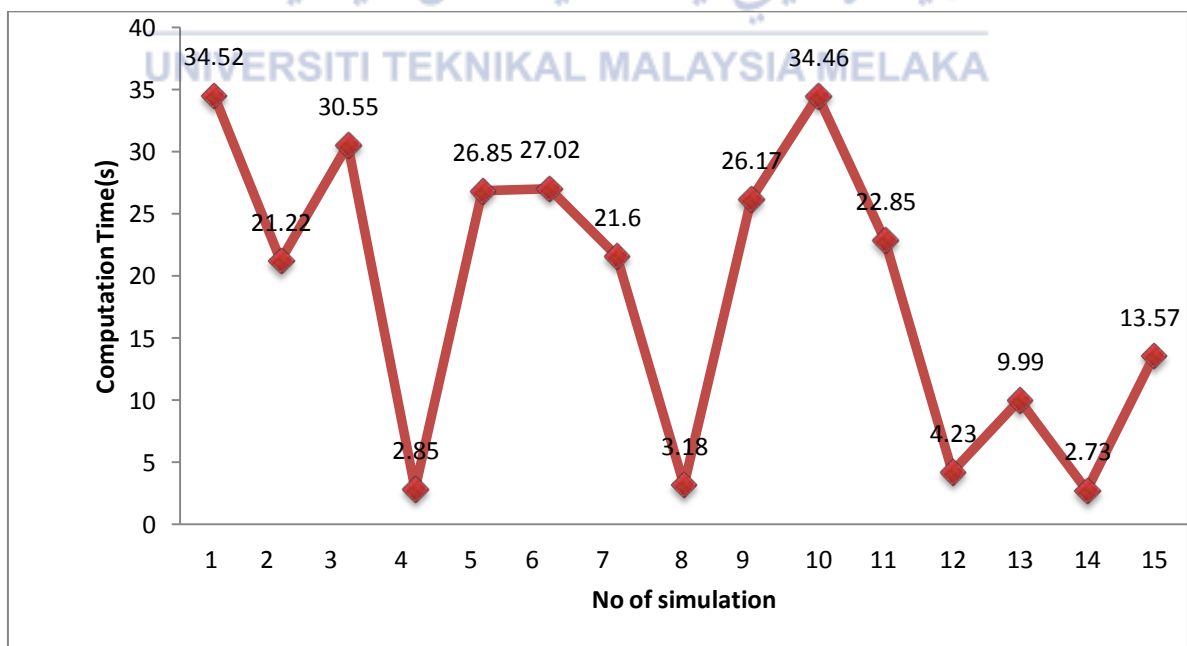


Figure 4.7: Number of simulation versus the computation time for EPSO algorithm

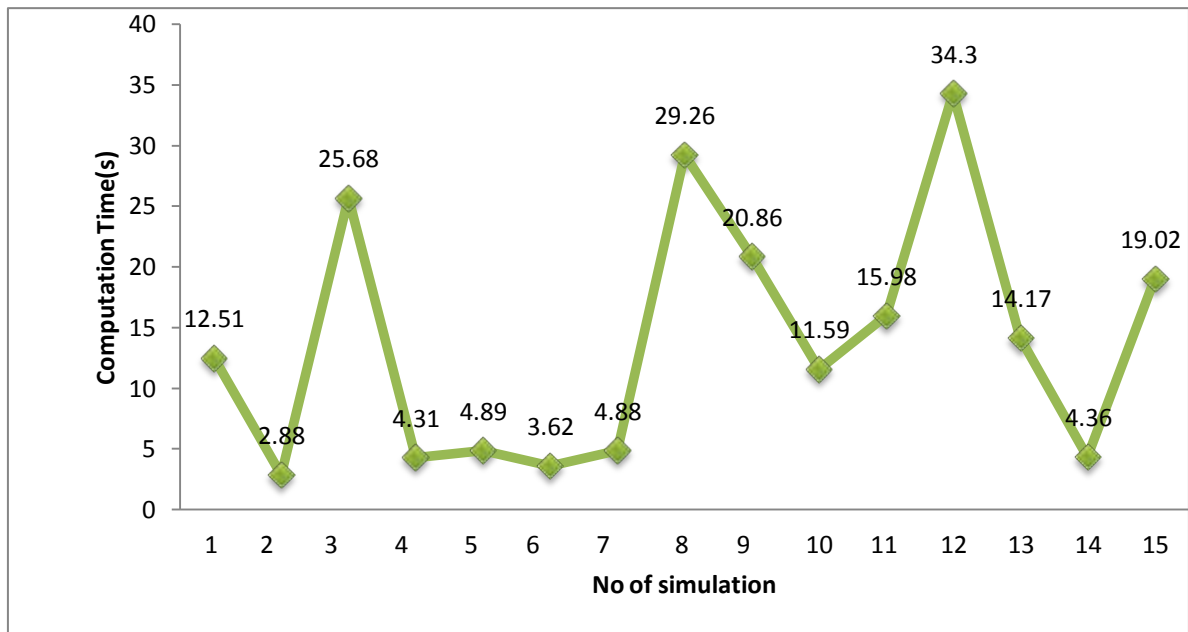


Figure 4.8: Number of simulation versus computation time for REPSO algorithm

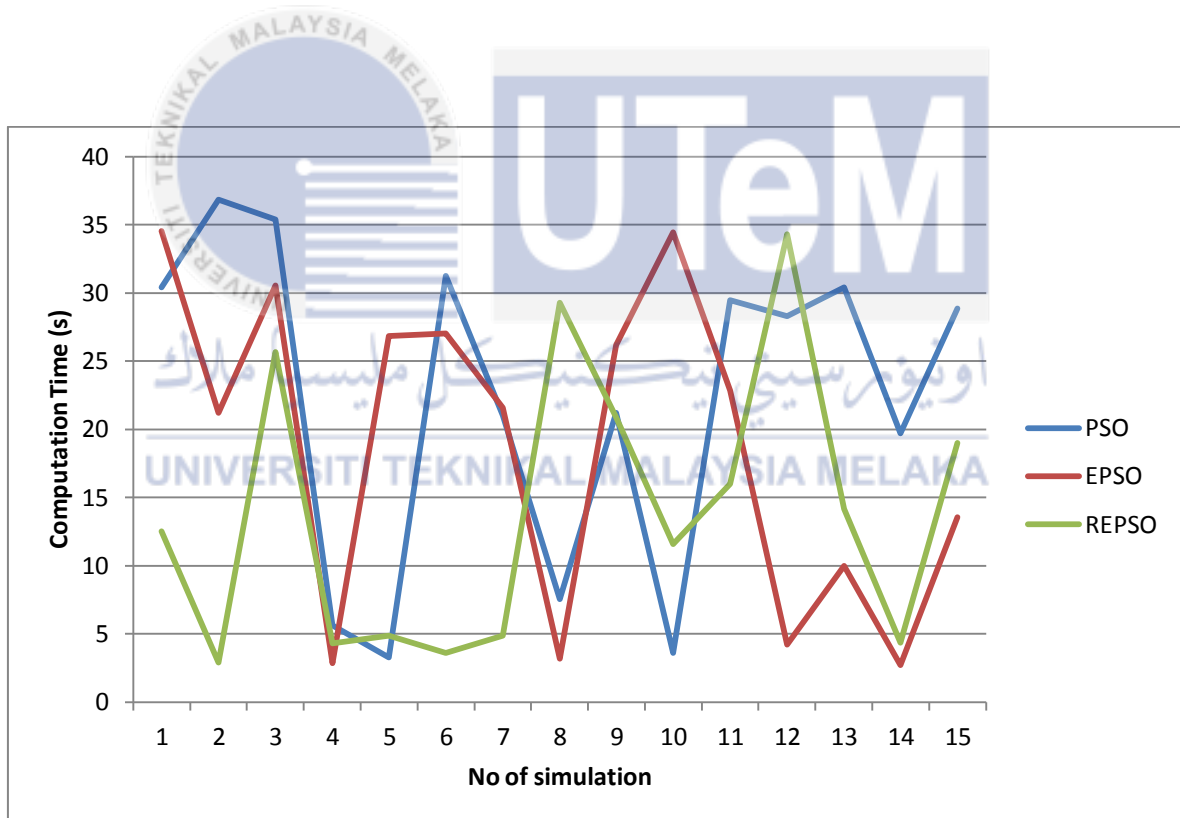


Figure 4.9: Number of simulation versus the computation time for PSO, EPSO and REPSO algorithm

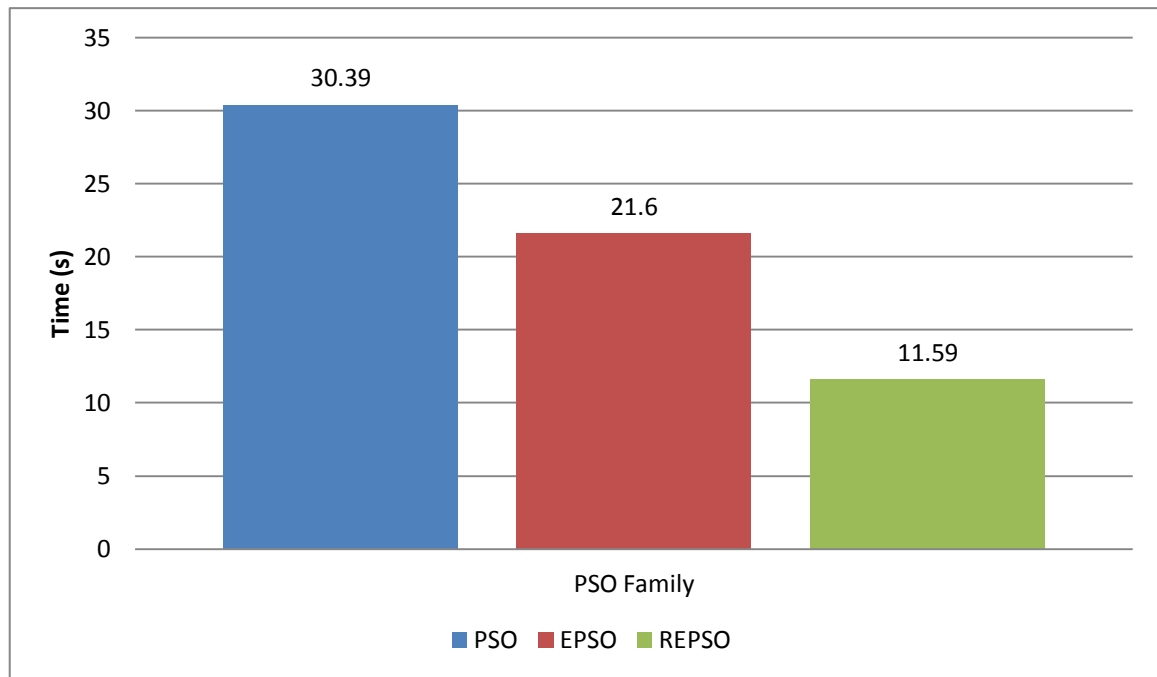


Figure 4.10: The convergence time between PSO, EPSO and REPSO

4.2.1.3 The 33-Bus Test System and Simulation Results

The algorithm of PSO, EPSO and REPSO are tested in 33-bus radial IEEE test system. The sectionalizing switch of both algorithm are obtained. The following Figure shows the 33-bus initial configuration while Figure , and show the 33-bus reconfiguration with PSO, EPSO and REPSO algorithm when applied to network. The sectionalizing switch of each configuration are shown by the dotted line that symbolize the switch that had been opened.

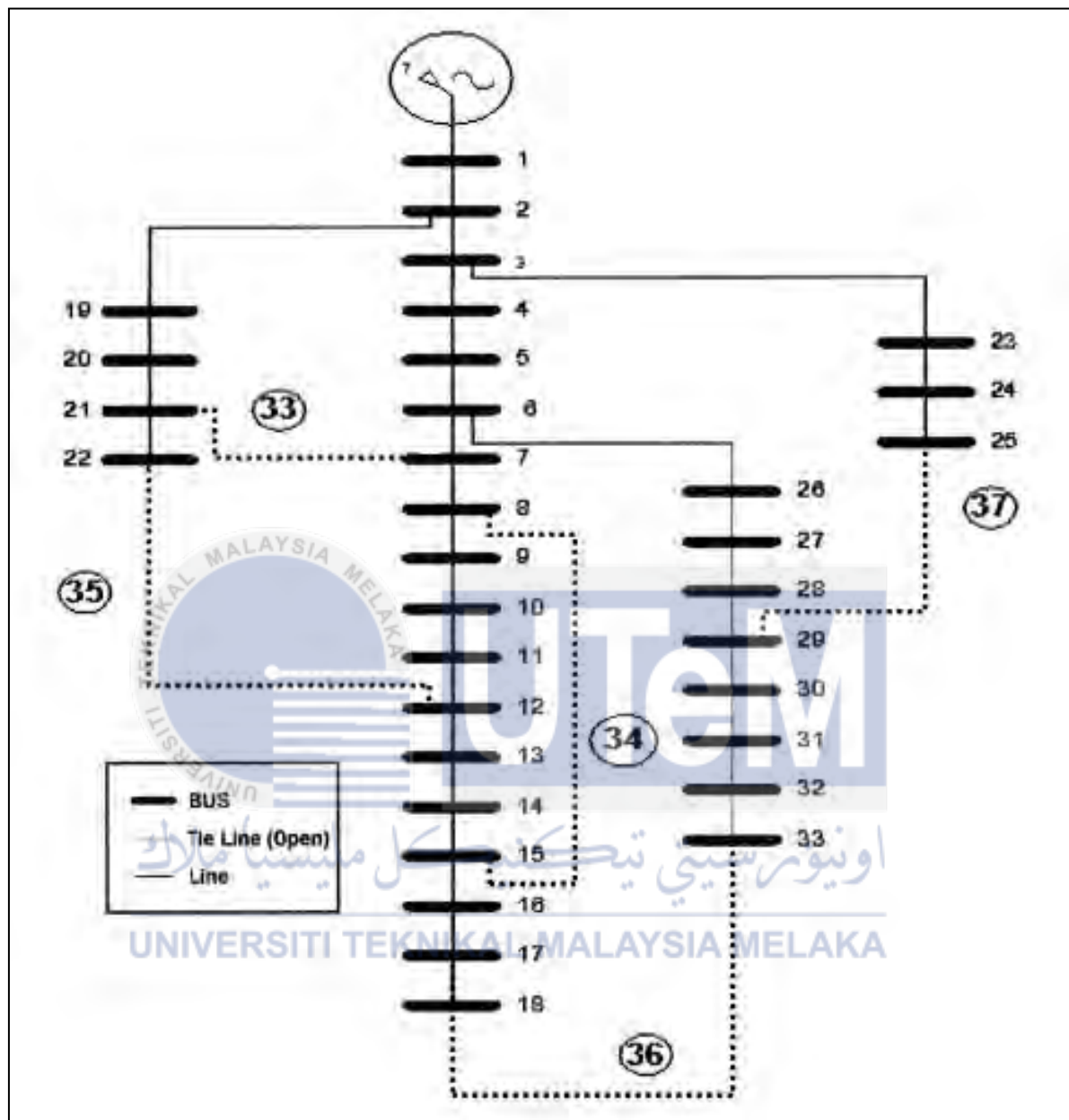


Figure 4.11: The initial 33-bus radial IEEE test system configuration

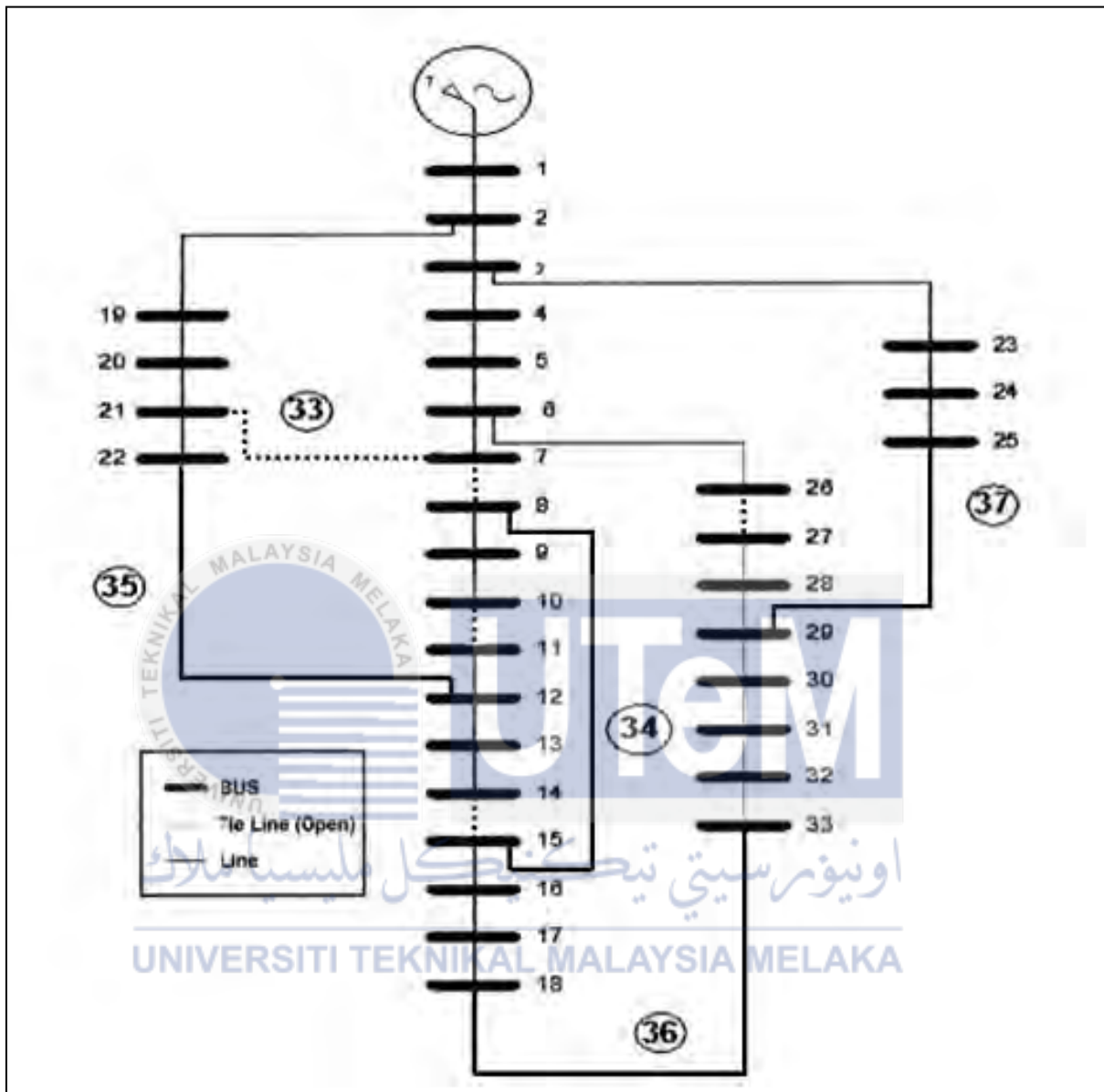


Figure 4.12: The 33-bus radial IEEE test system radial after reconfiguration with PSO

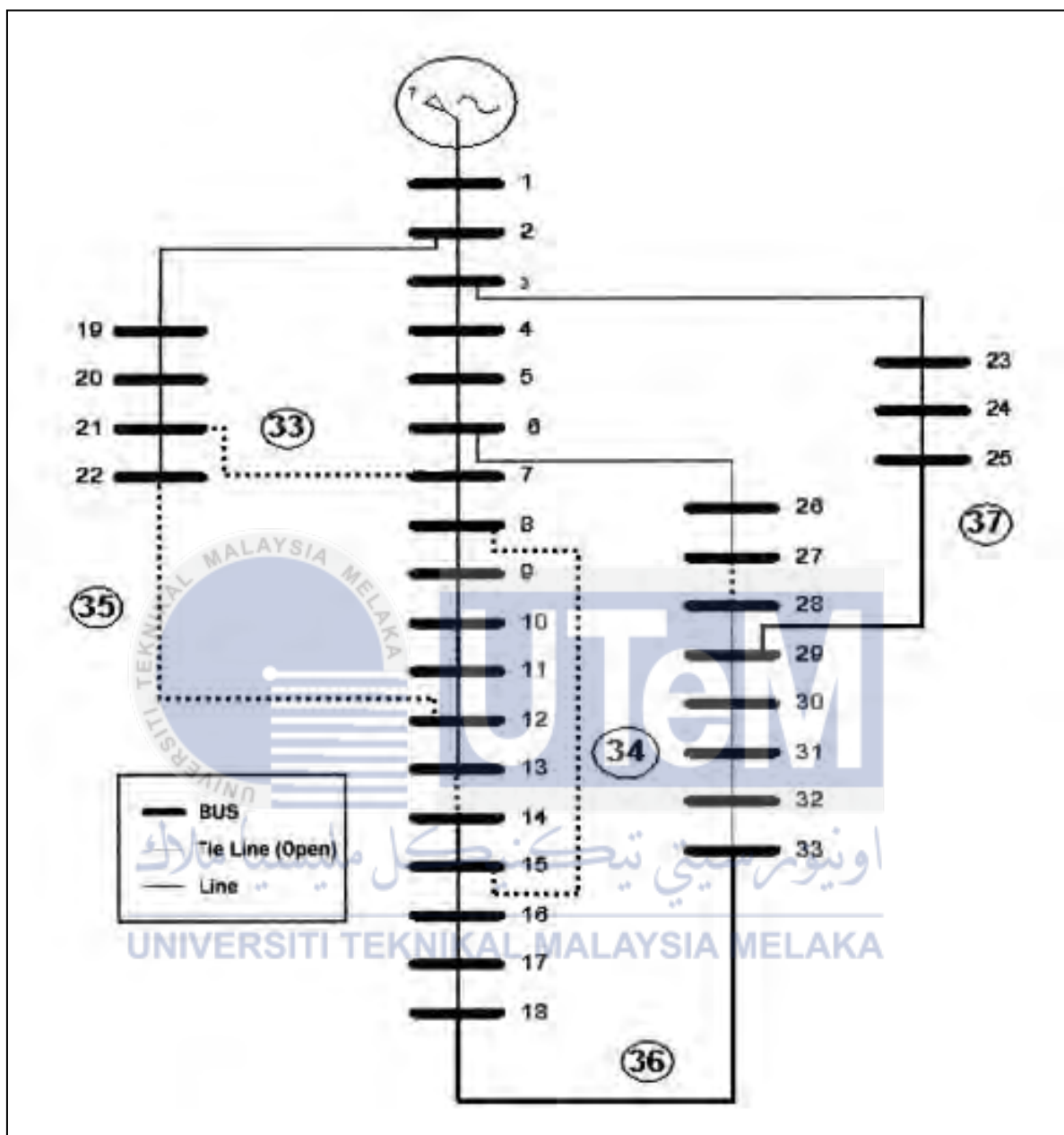


Figure 4.13: The 33-bus radial IEEE test system radial after reconfiguration with EPSON

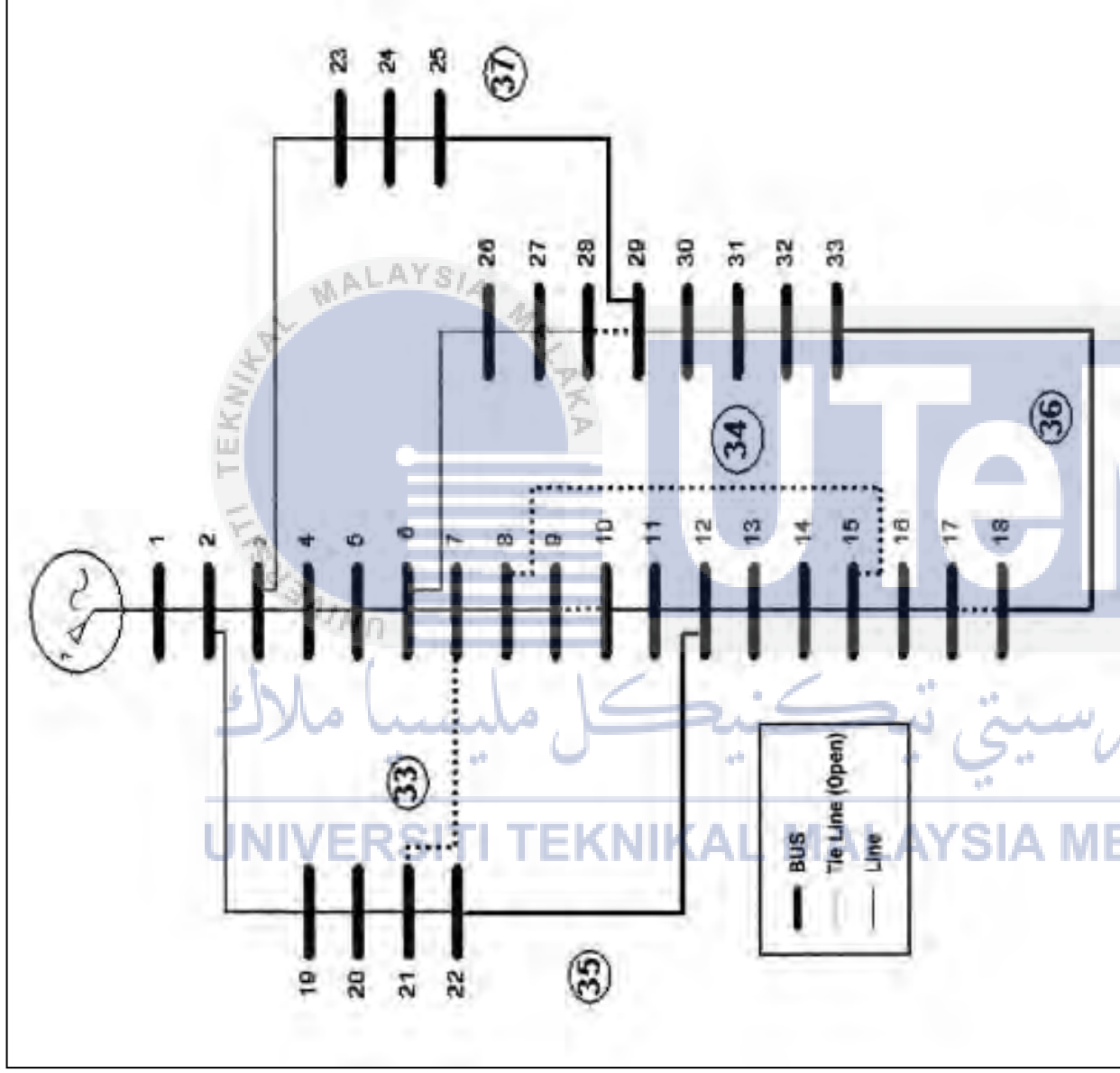


Figure 4.14: The 33-bus radial IEEE test system radial after reconfiguration with REPSO

4.2.1.4 Energy Lossess Reduction

4.2.1.4.1 The System Average Interruption Duration Index (SAIDI)

The **System Average Interruption Duration Index (SAIDI)** is commonly used as a reliability indicator by electric power utilities. SAIDI is the average outage duration for each customer served. The 2013 SAIDI data were taken for the total cost save calculation.

Table 4.6: Average SAIDI data for Malaysian Peninsular Area [25]

Company	SAIDI (Minute)					
	2008	2009	2010	2011	2012	2013
Tenaga Nasional Berhad , TNB (Medium Voltage: 33kV)	68.31	56.72	88.1	63.25	49.30	56.20

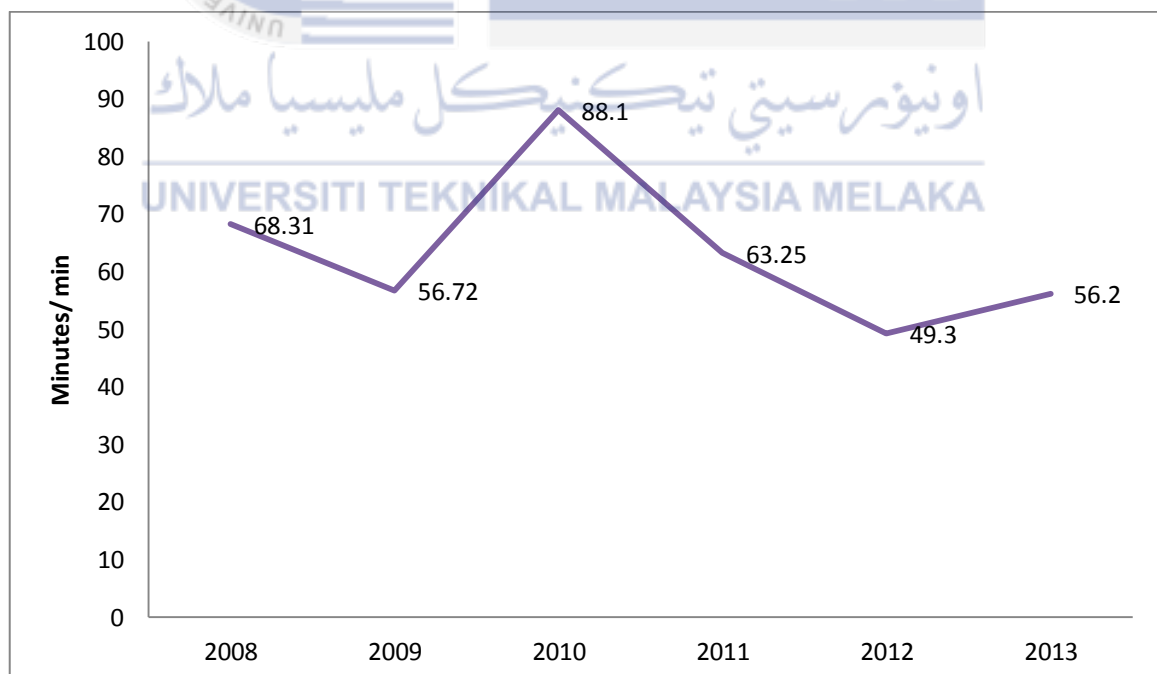


Figure 4.15: Average SAIDI data for Malaysian Peninsular Area

4.2.1.5 Total Cost Save

Table 4.7 : The electricity average selling [25]

Area	Electricity Average Selling Price / sen/kWh
Peninsular Malaysia	33.8

Table 4.8: Total Cost loss for one day for Peninsular Malaysia

Algorithm	Original Network	PSO	EPSO	REPSO
Total Power Loss (kW)	202.7	175.9	158.5	125.3
Energy (kWh)	4 833.58	4 194.51	3 779.59	2 987.90
Total loss Cost for one day (RM)	1 633.75	1 417.74	1 275.47	1 009.91

Table 4.9: Total cost loss per month

Month	Per month cost loss / RM			
	Original Network	PSO	EPSO	REPSO
January	50 646.25	43 949.94	39 539.57	31 307.21
February	45 745.00	39 696.72	35 713.16	28 277.48
March	50 646.25	43 949.94	39 539.57	31 307.21
April	49 012.50	42 532.20	38 264.10	30 297.30
May	50 646.25	43 949.94	39 539.57	31 307.21
June	49 012.50	42 532.20	38 264.10	30 297.30
July	50 646.25	43 949.94	39 539.57	31 307.21
August	50 646.25	43 949.94	39 539.57	31 307.21
September	49 012.50	42 532.20	38 264.10	30 297.30
October	50 646.25	43 949.94	39 539.57	31 307.21
November	49 012.50	42 532.20	38 264.10	30 297.30
December	50 646.25	43 949.94	39 539.57	31 307.21
Total	596, 318.75	517, 475.10	465, 546.55	368, 617.15

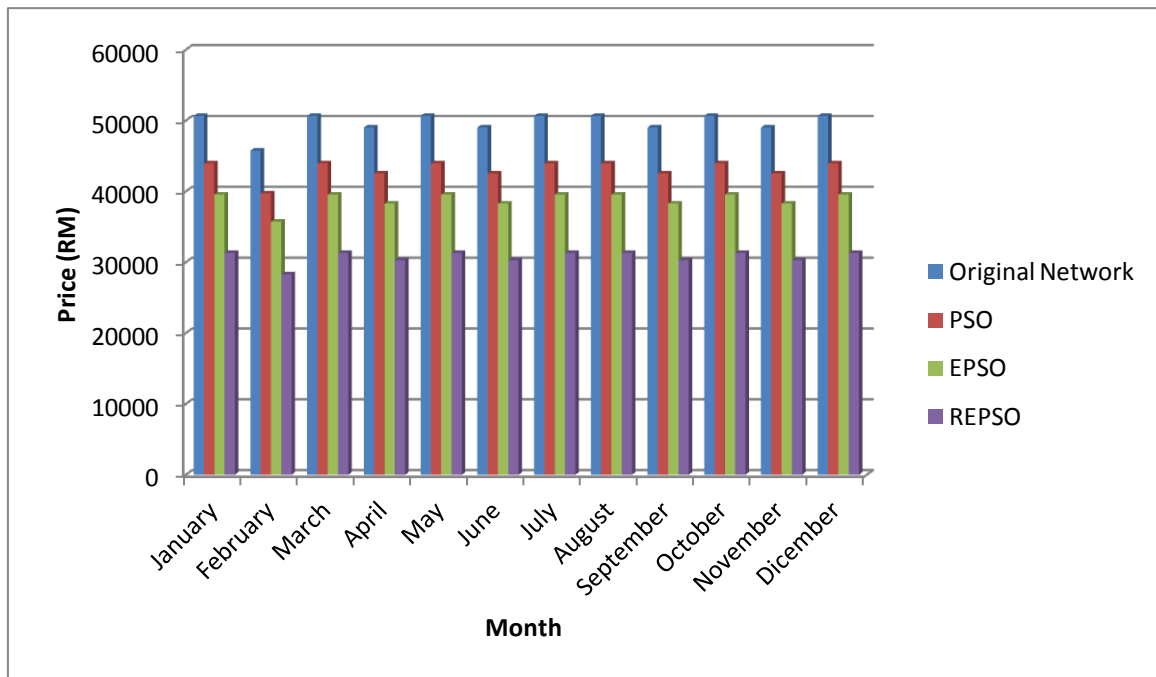


Figure 4.16: Total cost loss divided by month with original network and PSO Family algorithm apply on the 33-bus radial IEEE test system

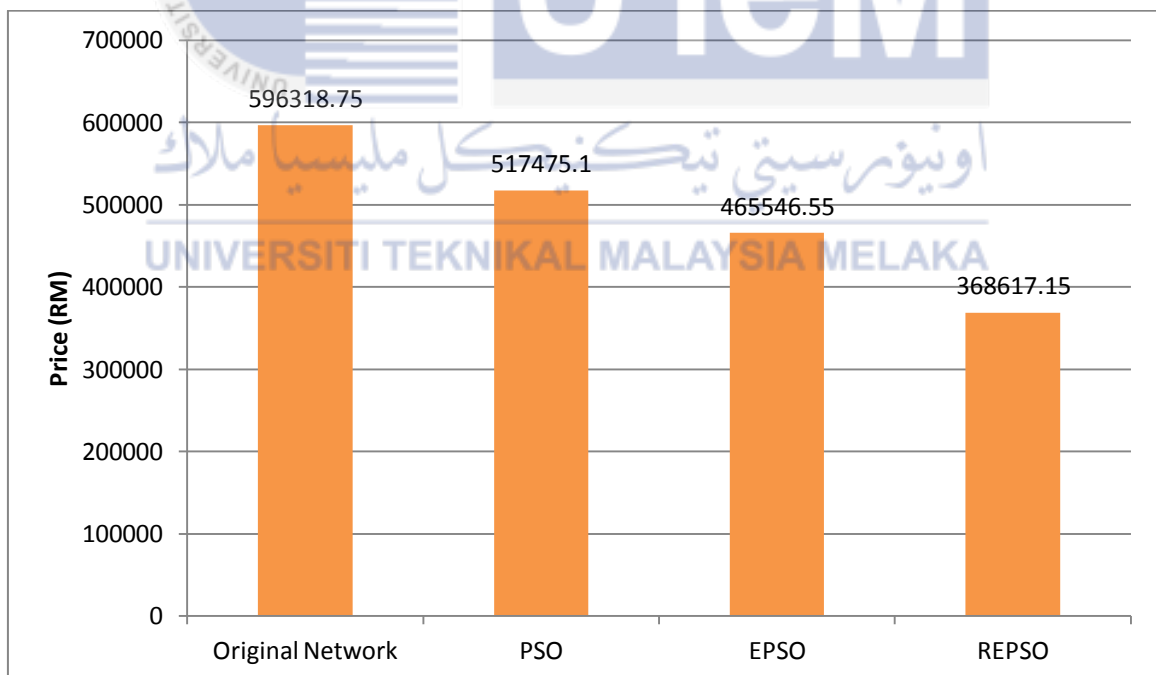


Figure 4.17: Total annual cost operation with original network and PSO Family algorithm apply on the 33-bus radial IEEE test system

Table 4.10: Total cost save when PSO Family algorithm apply on the network

Algorithm	PSO	EPSO	REPSO
Total Cost Save (RM)	78,843.65	130,772.2	227,701.6

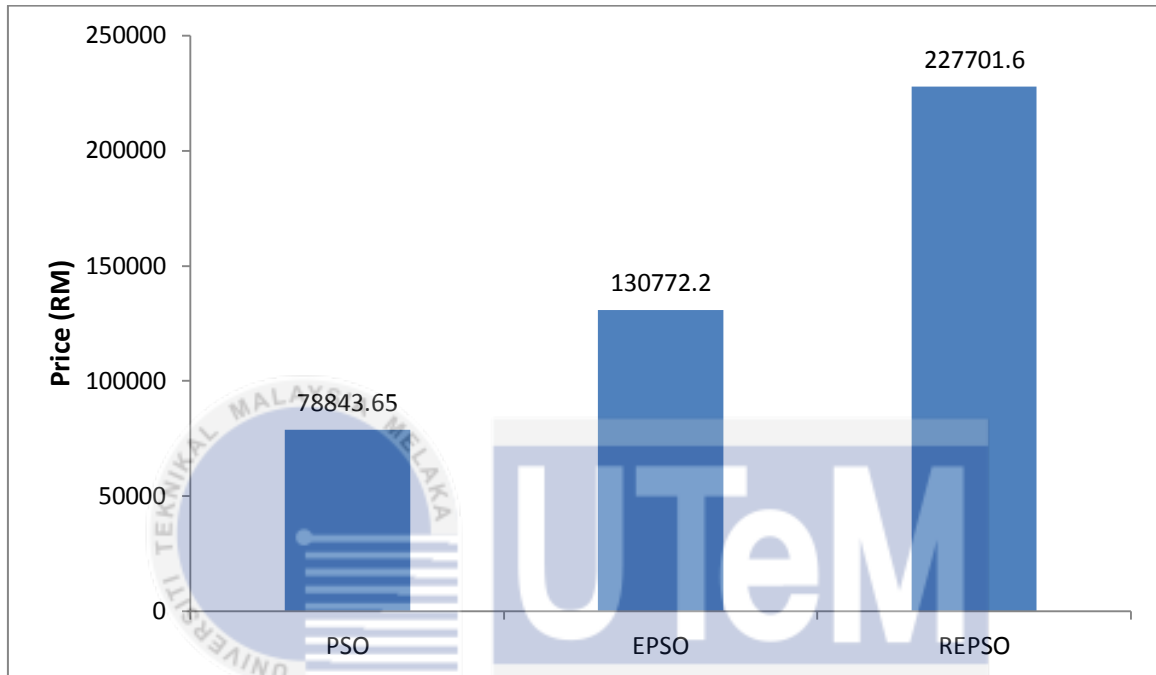


Figure 4.18: Total cost save when PSO Family algorithm apply on 33-bus radial IEEE test system

From the result that had been obtained from the simulation of the power loss. It has been proven the greater amount of power loss reduction contributed to higher total cost save. The data obtained from the SAIDI, total power losses and average selling price had been merged in the calculation of best total cost save stated that when applying REPSO on the systems save RM 227, 701.6, followed by EPSO that save RM 130, 772.2 and PSO that save RM 78, 843.65.

4.2.2 Evaluation of Information

The most obvious finding to emerge from this study is that by using the Particle Swarm Optimization (PSO) [11] application on distribution network reconfiguration the power losses has been minimized when compared with the original initial network of 33-bus radial IEEE test system. The PSO that used the concept of bird flocks to identify the switching operation plan for feeder reconfiguration has been proved efficient contributing to minimization of power losses is consistent with literature [6] whereas from this studies shows the power loss has been reduces by 13.22% . Hence the advantages of PSO to find the optimize solution can be enhanced with the hybridization heuristic method such as Evolutionary Programming (EP) and Differential Evolution (DE). These results performances were contradicted by the experiments in [22]–[24] when combining the both EP and PSO to create EPSO that solve the optimal problem effieciently compared with the traditional PSO where our findings revealed that the performances of EPSO in distribution network reconfiguration contribute 21.81% dimunation of power loss and 9.09s faster computing time compared with the traditional PSO. The above finding is consistent with the study in [18]. The enhancement of the traditional PSO is due to the usage of EP that use the sorted tournament selection between the new and old position occurances to find the best fitness has been integrated in the EPSO algorithm. Where only the particle with best fitness from the result will be choosen as the best position . These positions have been used as the newest P_{best} while the position with the highest score is used as the newest G_{best} . Thus, the different and hybridization of the algorithm shows the improvement of the results in this studies when compared with traditional PSO.

Table 4.11: The performance analysis on the 33 bus systems by using PSO, GA, EP EPSO and REPSO by previous researcher.

Parameter	Switch to be opened	Total power losses (kW)	Loss reduction (kW)	Convergence Time (s)
Case 1: Original initial network	33, 34, 35, 36, 37	202.7	-	-
Case 2: After reconfiguration using PSO[12]	7, 10, 14, 28, 31	126.5	76.2	18.0
Case 3: After reconfiguration using GA [26]	7, 9, 14, 32, 37	137.0	65.7	24.0
Case 3 : After reconfiguration using EP [27][28]	7, 9, 14, 32, 37	139.5	63.2	13.9
Case : After reconfiguration using EPSO[20]	14, 33, 17, 26, 8	131.1	71.6	13.62
Case : after reconfiguration using REPSO[29]	32, 28, 11, 33, 34	120.7	82	9.0

Rank Evolutionary Particle Swarm Optimization (REPSO) is another hybrid PSO that use the concept of EP which is combination, ranking and selection technique. The correlation between EPSO and REPSO is interesting because REPSO is a algorithm that use the application of ranking between the particles that won the tournament. It provides evidence that make the particle move faster to the optimal solution, that is just 9.97s .The finding of superiority of REPSO among PSO and EPSO in reduction of power loss in 33kV is consistent with the study in [18] which is 38.18% reduction of power losses. Thus by referring the Table 4.11which is the research that had been conducted by previous researcher. It justified the result that had been obtained which verify the performance of REPSO when compared with other heuristics technique.

Thus, since the values of total power loss reduction is directly proportional to the total cost saved. REPSO also shown the better performance in the cost saving area if applied in the networks.

4.2.3 Conclusion and Recommendation

The following conclusion can be drawn from the present results, it can be summarized that REPSO minimize the total power losses in shortest time in 33-bus radial IEEE test system followed by EPSO and PSO. REPSO is also able to reduce power losses to 125.3kW with time frame of 11.59s AND and give the best total annual RM 227, 701.60 annual cost save when applied on the 33-bus radial IEEE test system. The summarization of using the algorithms can be seen in table below.

Table 4.12: The summarization of analysis results for 33-bus radial IEEE test system

Algorithm	Total Power Losses (kW)	Computation Time (s)	Total Annual Cost Save (RM)
PSO	175.9	30.39	78, 843.65
EPSO	158.5	21.60	130, 772.20
REPSO	125.3	11.59	227, 701.60

CHAPTER 5

CONCLUSION

5.1 Conclusion

The main objective of this studies is to compare the performance of hybrid method of PSO Family when applied on network reconfiguration for power loss minimization. By using the Newton Raphson method to calculate the power loss for all buses. Hence , the PSO is adapted with Newton Raphson method to get the optimal configuration for existing distribution system. From the simulation and analysis that had been conducted, it shows the superiority of REPSO compared to other optimization PSO Family which is traditional PSO and EPSO in power loss, computation time and total cost save. Without performing any reconfiguration, the power and cost loss in distribution system will be high . Thus, it will affect the reliability of the distribution system. Through distribution network reconfiguration, these problem can be solved in order it helps in improving power system performance and distribution network for planning purpose.

5.2 Recommendation

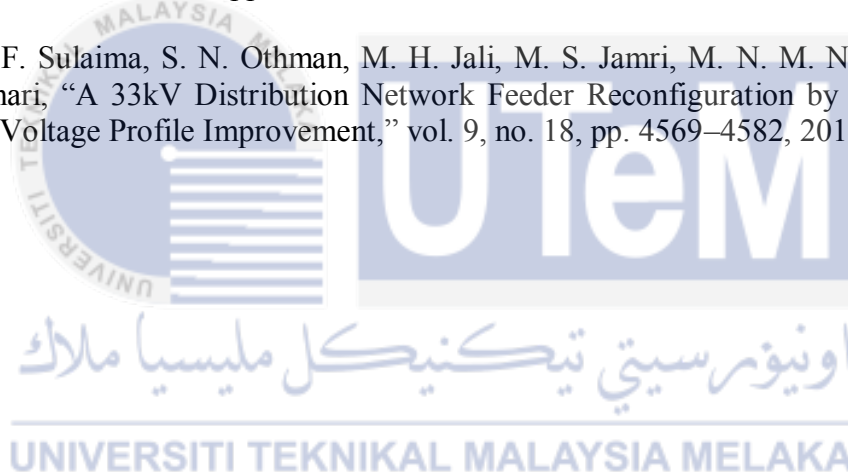
Parameter such as voltage profile, voltage stability, number of iteration to archives convergence and others parameter that can be benchmarks for performance between PSO, EPSO and REPSO algorithms when applied in the other distribution system such as 11Kv and 69Kv can be compare and analyze for future research. The power engineer should try to applies the algorithms in the real distribution network to optimize the performance and reduce power losses at the same time operation cost, therefore the distribution system would be more efficient and reliable.

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APPENDICES A

The 33- bus data

```

clc
clear
%BASEMVA = 100      BASEVOLT = 132      ERROR TOL = 1E-004
basemva = 100;
basevoltage = 132;
ep = 1E-004;
maxiter=10;
accuracy=0.0001;

```

```

busdata1= [
1 1 1 0 0 0 0 0 0 0 0 0
2 0 1 0 0 1 0.6 0 0 0 0 0
3 0 1 0 0 0 0.9 0.4 0 0 0 0
4 0 1 0 0 0 1.2 0.8 0 0 0 0
5 0 1 0 0 0 0.6 0.3 0 0 0 0
6 0 1 0 0 0 0.6 0.2 0 0 0 0
7 0 1 0 0 0 2 1 0 0 0 0
8 0 1 0 0 0 2 1 0 0 0 0
9 0 1 0 0 0 0.6 0.2 0 0 0 0
10 0 1 0 0 0 0.6 0.2 0 0 0 0
11 0 1 0 0 0 0.45 0.3 0 0 0 0
12 0 1 0 0 0 0.6 0.35 0 0 0 0
13 0 1 0 0 0 0.6 0.35 0 0 0 0
14 0 1 0 0 0 1.2 0.8 0 0 0 0
15 0 1 0 0 0 0.6 0.1 0 0 0 0
16 0 1 0 0 0 0.6 0.2 0 0 0 0
17 0 1 0 0 0 0.6 0.2 0 0 0 0
18 0 1 0 0 0 0.9 0.4 0 0 0 0
19 0 1 0 0 0 0.9 0.4 0 0 0 0
20 0 1 0 0 0 0.9 0.4 0 0 0 0
21 0 1 0 0 0 0.9 0.4 0 0 0 0
22 0 1 0 0 0 0.9 0.4 0 0 0 0
23 0 1 0 0 0 0.9 0.5 0 0 0 0
24 0 1 0 0 0 4.2 2 0 0 0 0
25 0 1 0 0 0 4.2 2 0 0 0 0
26 0 1 0 0 0 0.6 0.25 0 0 0 0
27 0 1 0 0 0 0.6 0.25 0 0 0 0
28 0 1 0 0 0 0.6 0.2 0 0 0 0
29 0 1 0 0 0 1.2 0.7 0 0 0 0
30 0 1 0 0 0 2 6 0 0 0 0
31 0 1 0 0 0 1.5 0.7 0 0 0 0
32 0 1 0 0 0 2.1 1 0 0 0 0
33 0 1 0 0 0 0.6 0.4 0 0 0 0 ];

```

```

%
%      Bus bus      R      X      1/2 B      = 1 for lines
%      nl  nr      p.u.    p.u.    p.u.    > 1 or < 1 tr.
tap at bus nl
linedata1=[
1 2 0.000529155 0.000356061 0 1
2 3 0.002829431 0.00190303 0 1
3 4 0.002101125 0.001412121 0 1
4 5 0.002187213 0.001470455 0 1
5 6 0.004700413 0.005356061 0 1

```

6	7	0.00107438	0.004687879	0	1
7	8	0.004083448	0.001781061	0	1
8	9	0.005910813	0.005606061	0	1
9	10	0.005991736	0.005606061	0	1
10	11	0.001128903	0.000493182	0	1
11	12	0.00214876	0.000983333	0	1
12	13	0.008425161	0.008749242	0	1
13	14	0.003108356	0.005400758	0	1
14	15	0.003391299	0.003984848	0	1
15	16	0.004282599	0.000303030	0	1
16	17	0.007397268	0.013037879	0	1
17	18	0.004201102	0.004347727	0	1
2	19	0.00094123	0.001185606	0	1
19	20	0.00863292	0.010268939	0	1
20	21	0.002350207	0.003624242	0	1
21	22	0.004068526	0.007100758	0	1
3	23	0.002589532	0.002336364	0	1
23	24	0.005153811	0.005371970	0	1
24	25	0.005141758	0.005356818	0	1
6	26	0.001165634	0.000783333	0	1
26	27	0.001631084	0.001096212	0	1
27	28	0.00607725	0.007074242	0	1
28	29	0.004616047	0.005307576	0	1
29	30	0.002912075	0.001958333	0	1
30	31	0.00559286	0.007294697	0	1
31	32	0.001782025	0.002741667	0	1
32	33	0.001957645	0.004016667	0	1
8	21	0.0114800	0.0114800	0	1
9	15	0.0114800	0.0114800	0	1
12	22	0.0114800	0.0114800	0	1
18	33	0.0028696	0.0028696	0	1
25	29	0.0028696	0.0028696	0	1]

اونيورسيتي تیکنیکل ملیسيا ملاک

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPENDICES B

The line flow and losses

```

SLT = 0;
fprintf('\n')
fprintf('                                Line Flow and Losses \n\n')
fprintf('          --Line--  Power at bus & line flow      --Line loss--\n\n')
fprintf('          from  to      MW      Mvar      MVA      MW      Mvar\n\n')
Transformer\n')
for n = 1:nbus
busprt = 0;
    for L = 1:nbr;
        if busprt == 0
            fprintf('          \n'), fprintf('%6g', n), fprintf('          %9.3f',
P(n)*basemva)
                fprintf('%9.3f', Q(n)*basemva), fprintf('%9.3f\n',
abs(S(n)*basemva))

            busprt = 1;
        else, end
        if nl(L)==n      k = nr(L);
            In = (V(n) - a(L)*V(k))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(n);
            Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);
            Snk = V(n)*conj(In)*basemva;
            Skn = V(k)*conj(Ik)*basemva;
            SL  = Snk + Skn;
            SLT = SLT + SL;
        elseif nr(L)==n      k = nl(L);
            In = (V(n) - V(k)/a(L))*y(L) + Bc(L)*V(n);
            Ik = (V(k) - a(L)*V(n))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(k);
            Snk = V(n)*conj(In)*basemva;
            Skn = V(k)*conj(Ik)*basemva;
            SL  = Snk + Skn;
            SLT = SLT + SL;
        else, end
        if nl(L)==n | nr(L)==n
            fprintf('%12g', k),
            fprintf('%9.3f', real(Snk)), fprintf('%9.3f', imag(Snk))
            fprintf('%9.3f', abs(Snk)),
            fprintf('%9.3f', real(SL)),
                if nl(L) ==n & a(L) ~= 1
                    fprintf('%9.3f', imag(SL)), fprintf('%9.3f\n', a(L))
                else, fprintf('%9.3f\n', imag(SL))
                end
        else, end
    end
end
SLT = SLT/2;
fprintf('          \n'), fprintf('          Total loss\n\n')
fprintf('%9.3f', real(SLT)), fprintf('%9.3f\n', imag(SLT))
clear Ik In SL SLT Skn Snk

```

APPENDICES C

The bus admittance matrix for power flow solution data

```

j=sqrt(-1); i = sqrt(-1);
nl = linedata(:,1); nr = linedata(:,2); R = linedata(:,3);
X = linedata(:,4); Bc = j*linedata(:,5); a = linedata(:, 6);
nbr=length(linedata(:,1)); nbus = max(max(nl), max(nr));
Z = R + j*X; y= ones(nbr,1)./Z;           %branch admittance
for n = 1:nbr
if a(n) <= 0
    a(n) = 1; else end
Ybus=zeros(nbus,nbus);           % initialize Ybus to zero
                                % formation of the off diagonal elements
for k=1:nbr;
    Ybus(nl(k),nr(k))=Ybus(nl(k),nr(k))-y(k)/a(k);
    Ybus(nr(k),nl(k))=Ybus(nl(k),nr(k));
end
                                % formation of the diagonal elements
for n=1:nbus
for k=1:nbr
    if nl(k)==n
        Ybus(n,n) = Ybus(n,n)+y(k)/(a(k)^2) + Bc(k);
    elseif nr(k)==n
        Ybus(n,n) = Ybus(n,n)+y(k) +Bc(k);
    else, end
end
end
clear Pgg

```

APPENDICES D

The Newton-Raphson data

```

ns=0; ng=0; Vm=0; delta=0; yload=0; deltad=0;
nbus = length(busdata(:,1));
kb=[];Vm=[]; delta=[]; Pd=[]; Qd=[]; Pg=[]; Qg=[]; Qmin=[]; Qmax=[]; %
Added (6-8-00)
Pk=[]; P=[]; Qk=[]; Q=[]; S=[]; V=[]; % Added (6-8-00)
for k=1:nbus
n=busdata(k,1);
kb(n)=busdata(k,2); Vm(n)=busdata(k,3); delta(n)=busdata(k, 4);
Pd(n)=busdata(k,5); Qd(n)=busdata(k,6); Pg(n)=busdata(k,7); Qg(n) =
busdata(k,8);
Qmin(n)=busdata(k, 9); Qmax(n)=busdata(k, 10);
Qsh(n)=busdata(k, 11);
    if Vm(n) <= 0
        Vm(n) = 1.0; V(n) = 1 + j*0;
    else delta(n) = pi/180*delta(n);
        V(n) = Vm(n)*(cos(delta(n)) + j*sin(delta(n)));
        P(n)=(Pg(n)-Pd(n))/basemva;
        Q(n)=(Qg(n)-Qd(n)+ Qsh(n))/basemva;
        S(n) = P(n) + j*Q(n);
    end
end
for k=1:nbus
if kb(k) == 1, ns = ns+1; else, end
if kb(k) == 2
    ng = ng+1; else, end
ngs(k) = ng;
nss(k) = ns;
end
Ym=abs(Ybus); t = angle(Ybus);
m=2*nbus-ng-2*ns;
maxerror = 1; converge=1;
iter = 0;
%%% added for parallel lines (Aug. 99)
mline=ones(nbr,1);
for k=1:nbr
    for m=k+1:nbr
        if ((nl(k)==nl(m)) && (nr(k)==nr(m)));
            mline(m)=2;
        elseif ((nl(k)==nr(m)) && (nr(k)==nl(m)));
            mline(m)=2;
        else, end
    end
end
%%% end of statements for parallel lines (Aug. 99)

% Start of iterations
clear A DC J DX
while maxerror >= accuracy && iter <= maxiter % Test for max. power
mismatch
for ii=1:m
for k=1:m
    A(ii,k)=0; %Initializing Jacobian matrix
end, end
iter = iter+1;
for n=1:nbus
nn=n-nss(n);

```



```

lm=nbus+n-ngs(n)-nss(n)-ns;
J11=0; J22=0; J33=0; J44=0;
for ii=1:nbr
    if mline(ii)==1 % Added to include parallel lines (Aug. 99)
        if nl(ii) == n || nr(ii) == n
            if nl(ii) == n , l = nr(ii); end
            if nr(ii) == n , l = nl(ii); end
            J11=J11+ Vm(n)*Vm(l)*Ym(n,l)*sin(t(n,l)- delta(n) + delta(l));
            J33=J33+ Vm(n)*Vm(l)*Ym(n,l)*cos(t(n,l)- delta(n) + delta(l));
            if kb(n)~=1
                J22=J22+ Vm(l)*Ym(n,l)*cos(t(n,l)- delta(n) + delta(l));
                J44=J44+ Vm(l)*Ym(n,l)*sin(t(n,l)- delta(n) + delta(l));
            else, end
            if kb(n) ~= 1 && kb(l) ~=1
                lk = nbus+l-ngs(l)-nss(l)-ns;
                ll = l -nss(l);
                % off diagonalelements of J1
                A(nn, ll) =-Vm(n)*Vm(l)*Ym(n,l)*sin(t(n,l)- delta(n)
+ delta(l));

                if kb(l) == 0 % off diagonal elements of J2
                    A(nn, lk) =Vm(n)*Ym(n,l)*cos(t(n,l)- delta(n) +
delta(l));end

                if kb(n) == 0 % off diagonal elements of J3
                    A(lm, ll) =-Vm(n)*Vm(l)*Ym(n,l)*cos(t(n,l)-
delta(n)+delta(l)); end
                if kb(n) == 0 && kb(l) == 0 % off diagonal elements
of J4
                    A(lm, lk) =-Vm(n)*Ym(n,l)*sin(t(n,l)- delta(n) +
delta(l));end
                else end
            else , end
        else, end
    end
    Pk = Vm(n)^2*Ym(n,n)*cos(t(n,n))+J33;
    Qk = -Vm(n)^2*Ym(n,n)*sin(t(n,n))-J11;
    if kb(n) == 1
        P(n)=Pk; Q(n) = Qk; end % Swing bus P
    if kb(n) == 2
        Q(n)=Qk;
        if Qmax(n) ~= 0
            Qgc = Q(n)*basemva + Qd(n) - Qsh(n);
            if iter <= 7 % Between the 2th & 6th
iterations
                if iter > 2 % the Mvar of generator buses
are
                    if Qgc < Qmin(n), % tested. If not within limits
Vm(n)
                        Vm(n) = Vm(n) + 0.01; % is changed in steps of 0.01 pu
to
                        elseif Qgc > Qmax(n), % bring the generator Mvar
within
                            Vm(n) = Vm(n) - 0.01;end % the specified limits.
                        else, end
                    else,end
                else,end
            end
        end
    if kb(n) ~= 1
        A(nn,nn) = J11; %diagonal elements of J1
        DC(nn) = P(n)-Pk;
    end
    if kb(n) == 0

```

```

A(nn,lm) = 2*Vm(n)*Ym(n,n)*cos(t(n,n))+J22; %diagonal elements of
J2
A(lm,nn)= J33; %diagonal elements of J3
A(lm,lm) =-2*Vm(n)*Ym(n,n)*sin(t(n,n))-J44; %diagonal of elements
of J4
DC(lm) = Q(n)-Qk;
end
end
DX=A\DC';
for n=1:nbus
    nn=n-nss(n);
    lm=nbus+n-ngs(n)-nss(n)-ns;
    if kb(n) ~= 1
        delta(n) = delta(n)+DX(nn); end
    if kb(n) == 0
        Vm(n)=Vm(n)+DX(lm); end
end
maxerror=max(abs(DC));
if iter == maxiter && maxerror > accuracy
% fprintf('\nWARNING: Iterative solution did not converged after ')
% fprintf('%g', iter), fprintf(' iterations.\n\n')
% fprintf('Press Enter to terminate the iterations and print the
results \n')
    converge = 0;
% pause,
else,
end

end

if converge ~= 1
    tech= ('
else,
    tech=('
Method');
end
V = Vm.*cos(delta)+j*Vm.*sin(delta);
deltad=180/pi*delta;
i=sqrt(-1);
k=0;
for n = 1:nbus
    if kb(n) == 1
        k=k+1;
        S(n)= P(n)+j*Q(n);
        Pg(n) = P(n)*basemva + Pd(n);
        Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
        Pgg(k)=Pg(n);
        Qgg(k)=Qg(n); %june 97
    elseif kb(n) ==2
        k=k+1;
        S(n)=P(n)+j*Q(n);
        Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
        Pgg(k)=Pg(n);
        Qgg(k)=Qg(n); % June 1997
    end
yload(n) = (Pd(n)- j*Qd(n)+j*Qsh(n))/(basemva*Vm(n)^2);
end
busdata(:,3)=Vm'; busdata(:,4)=deltad';
Pgt = sum(Pg); Qgt = sum(Qg); Pdt = sum(Pd); Qdt = sum(Qd); Qsht =
sum(Qsh);

```

APPENDICES E

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