AN OPTIMAL APPROACH FOR PLACEMENT OF DISTRIBUTED GENERATION IN RADIAL DISTRIBUTION SYSTEM CONSIDERING LOAD VARIATION

MOHD NAZRI BIN ABD HALIM

A report submitted in partial fulfillment of the requirements for the degree of electrical engineering

Faculty Of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2018

DECLARATION

“I hereby declared that I have read through this report entitle ‘An Optimal Approach for Placement of Distributed Generation in Radial Distribution System Considering Load Variation’’’

Signature : ___________________________

Name : Dr Aida Fazliana Bin Abdul Kadir

Date : ___________________________

DECLARATION

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in this reference"

Signature :____________________________

Name : Mohd Nazri Bin Abd Halim

Date :____________________________

To my beloved mother and father

ACKNOWLEDGEMENT

First and foremost, thanks to Allah for giving me this great opportunity to live in this world and giving me this healthy body that enables to gain the knowledge, experience and able to finish this project. Therefore, I consider myself as a very lucky individual as I was provided with an opportunity to be a part of it. I am also grateful for having a chance to meet so many wonderful people and professional who led me through this final year project.

Secondly, bearing in mind previous I am using this opportunity to express my deepest gratitude and thanks to the Dr Aida Fazliana binti Abdul Kadir for his patience guidance and enthusiastic encouragement throughout the duration of this project. The supervision and patient guidance that he gave truly help the progression and smoothness of my final year report. The support and hard work are much appreciated indeed. Her is the one of the best and good lecturer that I ever met in UTeM.

Next, I express my deepest to my family and friend for giving moral support, provide advice and guidance needed also their prayer, I feel this is a very big contribution for me. I perceive this opportunity as a big milestone in my career development. I will strive to use gained skill and knowledge in the best possible way and I will continue to work on their improvement to attain desired career objectives.

ABSTRACT

Distributed generation (DG) devices can be advantageously placed in power systems for minimizing real power losses, grid reinforcement, improving bus voltages and efficiency of distribution system. One of the real concerns identified with the distributed generation (DG) is the effect on system stability because of the interaction amongst generators and load characteristic. It is shown that load in distribution system will affect significantly the optimal placement and sizing of DGs in distribution system. Load increase and vice versa the voltage profile will drop below tolerable limit along distribution feeders. Multi-objective function is generated to minimize the total power loss, average total voltage harmonic distortion and voltage deviation improvement in the distribution system. Six different load levels in percentage of load have been considered in this study. The improved gravitational search algorithm (IGSA) is proposed as an optimization technique and its performance is compared with other optimization techniques such as particle swarm optimization (PSO) and gravitational search algorithm (GSA). The Newton-Raphson load flow algorithm from MATPOWER was simulate in MATLAB to solve the proposed multi-objective. This method is tested on the 69-bus and 33-bus distribution system with six case studies. The result will illustrate the losses minimization, average voltage deviation improvement and average total harmonic distortion in the distribution system when load variation was considering by placement of DGs unit in distribution system. Data analysis and result obtain can be used to other else as a reference when related with optimal approach for placement DGs in distribution generation in radial network considering load variation.

ABSTRAK

Peranti generasi yang diagihkan (DG) boleh digunakan secara optimal dalam sistem kuasa untuk meminimumkan kehilangan kuasa sebenar, meningkatkan voltan bas dan kecekapan sistem pengedaran. Salah satu kebimbangan sebenar yang dikenalpasti dengan penghasilan pengagihan (DG) adalah kesan ke atas kestabilan sistem kerana interaksi di antara penjana dan ciri beban. Telah ditunjukkan bahawa model beban perbezaan dapat memberi kesan dengan ketara penempatan yang optimum dan saiz DG dalam sistem pengedaran. Beban dalam sistem pengedaran akan menjejaskan penempatan yang optimum dan saiz DGs. Beban meningkat dan sebaliknya menyebabkan profil voltan akan jatuh di bawah had yang boleh diterima di sepanjang pengumpan pengedaran. Fungsi multi-objektif dijana untuk mengurangkan jumlah kehilangan kuasa, purata voltan harmonik total voltan dan sisihan voltan dalam sistem pengedaran. Enam tahap beban yang berbeza dalam peratusan beban telah dipertimbangkan dalam kajian ini. Algoritma carian graviti yang lebih baik (IGSA) dicadangkan sebagai teknik pengoptimuman dan prestasinya dibandingkan dengan teknik pengoptimuman lain seperti pengoptimuman swarm partikel (PSO) dan algoritma carian graviti (GSA). Algoritma aliran beban Newton-Raphson dari MATPOWER adalah mensimulasikan dalam MATLAB untuk menyelesaikan pelbagai objektif yang dicadangkan. Kaedah ini diuji pada 69-bus dan sistem pengedaran 33-bus dengan enam kajian kes. Hasilnya akan menggambarkan penurunan kehilangan, peningkatan voltan dan jumlah keseluruhan penyelarasan harmonik dalam sistem pengedaran apabila variasi beban dugunakan oleh penempatan unit DGs dalam sistem pengedaran. analisis Data dan keputusan diperoleh boleh digunakan untuk orang lain sebagai rujukan apabila berkaitan dengan pendekatan optimum untuk penempatan DGs dalam penjanaan pengedaran dalam rangkaian radial berkaitan dengan variasi beban.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE

LIST OF TABLES

LIST OF FIGURES

TABLE	TITLE	PAGE

LIST OF ABBREVIATIONS

DG	-	Distribution Generation
THD	-	Total Harmonic Distortion
IGSA	-	Improved Gravitational Search Algorithm
PSO	-	Particle Swarm Optimization
GSA	-	Gravitational Search Algorithm
MATLAB	-	Matrix Laboratory
PV	-	Photovoltaic
DER	-	Distributed Energy Resources
GA	-	Genetic Algorithm
Fyp	-	Final Year Project
IJEEAS	-	International Journal of Electrical Engineering and Applied Science

CHAPTER 1

INTRODUCTION

1.1 Introduction

Distributed generation can be said as technologies that generate electricity at or near where it will be used with using renewable energy to produce electricity. DG may provide as single structure for a residential and business, but also can be section of a micro grid, DG usually applied in industrial facilities, military base to provided power supply, or a large university. In other term ,DG could be “electric power generation within distribution networks or on the customer side of the network” [1]. Usually in Malaysia, DG technologies that available is solar photovoltaic while other technologies in DGs are wind power, biomass and solar thermal systems. People want the energy that purifier and has less impact to the surroundings. They tend to pick DG as main electricity supply due to the fact that DG can generate electricity with renewable source rather than fossil fuel and, accepted through many countries due to reduction in gasses emission is major criteria that lead for DGs implementation [2]. Provided peak load demand, minimizes branch current loadings, voltage profile and reduces losses can be improves with better placement and sizing od DG [3]. Allocation and sizing of DG power in inappropriate way toward the distribution network leads to power quality issues, increasing power losses, unstable power system, and rising operational cost [23]. The maximum potential benefits achieve from DGs relies upon on how optimal and placement of the installation on the network system. Details research about the effect load level varying in DG planning is investigating to get on how load effect locations and size of the DGs.

1.2 Research Motivation

Nowadays, electricity demand is very encouraging due to the expansion of the population and the improvement of technology that requires higher electricity by customer. Power system management has been facing major changing in power generation sector during the past decades. Power system company has trying to find the best way and solution to provided energy which is sufficient for customer and avoid many unwanted problems in power system such as losses in system, voltage stability, total harmonic distortion (THD) problem etc. Consequently, meeting of small generation has growth and cause rise of demand in DG utilization. The presence of DGs in the distribution system may result some advantages such as improved of power quality, voltage stability and reduction of the system but with inappropriate installation of DGs with improper design could either cause positive and negative impact. However, it must be depending on the operational characteristic of the DGs and criteria of the distribution network. Moreover, placement and optimal of DGs is quite important to be investigated for design a reliable power system.

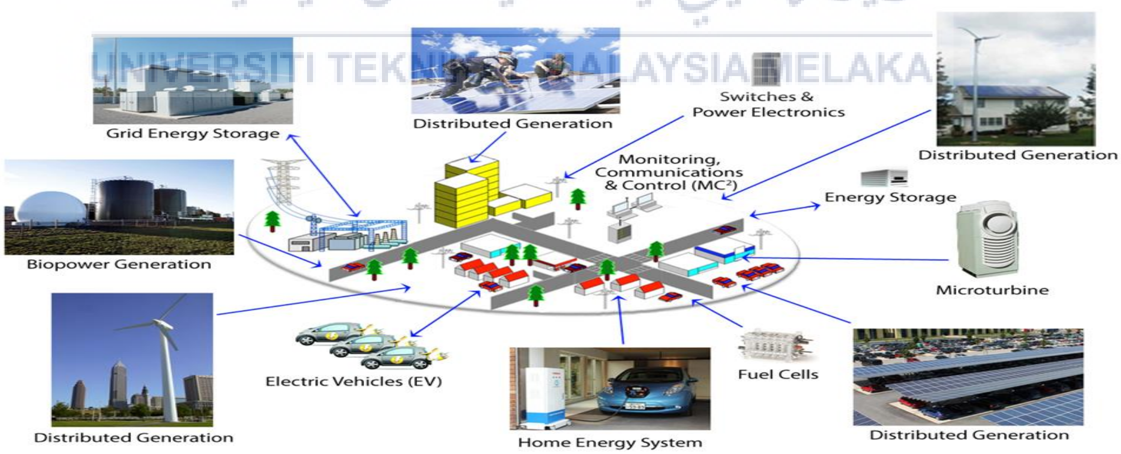

Figure 1.1: Concept of Distribution Generation [21]

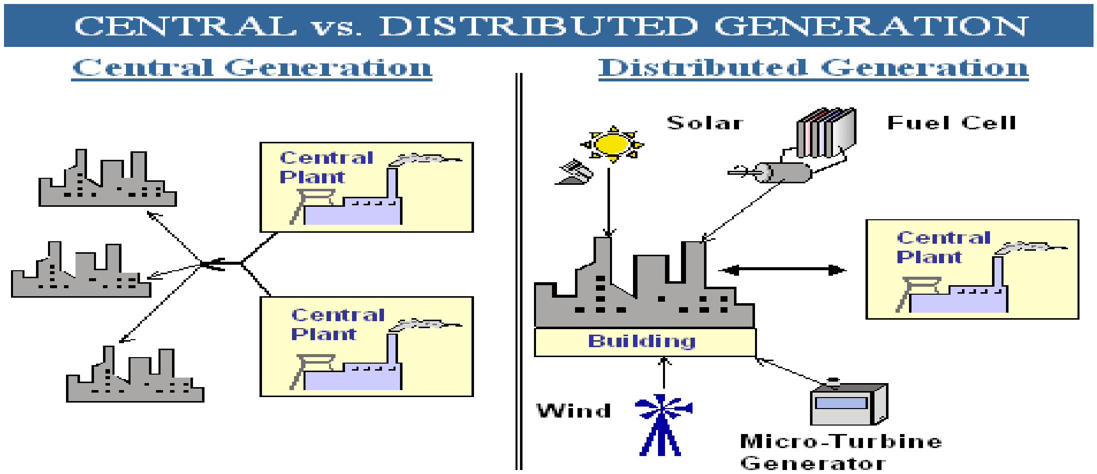

Figure 1.2: Difference Central Distribution with DG. [27]

1.3 Problem Statements

The proposed of this study is to analysis the effect of variation in load levels and in order to achieve reduction energy losses toward DGs placement on distribution generation. An optimization technique should be implement for an engineering system related with electrical system that can allowing the best allocation with less of undesired result. In electrical power system most of losses occur in distribution system. Nonstandard placement of DG units might also result in increased the losses, device value and voltage in a few load buses .System losses, system cost and voltage in some load buses may increase without optimal placement of DG units [4].

One of the real concerns identified with the distributed generation (DG) is the effect on system stability because of the interaction amongst generators and load characteristic. Load in distribution system will affect significantly the DGs planning for the optimal placement and sizing of DG and generally a constant power load model is assumed in most studies [5]. When load increase and vice versa the voltage profile will drop below tolerable operating limit along distribution feeders. Hence, power generating station is work simultaneously but when load increase, design for DGs placement and sizing should consider it load variation to avoid problem toward distribution system when load increases more and more then all generating stations can't bear the load and total blackout happens.

Several method have been introducing a lot to determine the optimal location and size of DG in distribution system. There a lot of heuristic method used for optimal DG placement and sizing that only accurate for the developed model and can be very complicated for solving complex system. Each method has it own strength and weakness.

1.4 Objectives

The objective of this research:

I. To identify the optimal placement and sizing of DG via improved gravitational search algorithm optimization technique.

II. To analyze the effectiveness of the optimal DGs planning with variation of load in distribution system.

III. To compare the performance of the proposed method improved gravitational search algorithm(IGSA) with particle swarm optimization(PSO) and gravitational search algorithm(GSA).

1.5 Scope of research

The scope of this project focuses on identify the optimal and sizing of solar distribution generation for radial system (rooftop PVs solar) considering variation of load in distribution system by using MATLAB simulation only. Proposed method improved gravitational search algorithm (IGSA) with particle swarm optimization (PSO) and gravitational search algorithm (GSA) will be discusses and comparison are made according to optimization method performance after the final result is archived refer to the objective research. The present method will apply on 33-bus and 69-bus test radial distribution network for variation load level.

1.6 Report outline

Chapter 1 introduces some introduction, problem statement, motivation, and scope of study related with this research. It is also covers the project outline that explain for every chapter roughly. Chapter 2 briefly review about the distribution generation with using renewable energy as generation of electricity. Heuristic method such as PSO, GSA, IGSA and GA also are discussed in this chapter on the concept and equation for each optimization technique. Lastly, it also will explain about previous research that related with this report and effects of DGs towards distribution system. Chapter 3 on this chapter, the milestone and Gantt chart are also provided, and the method of the ultimate placement and sizing of DG is mentioned while created the flowchart of this research will be showed out. Besides that, the test system used and the heuristic method as optimization technique will be carried out in flow chart. Finally, the case study will be developed in this chapter. Chapter 4 briefly discussed the result obtained from the simulation using MATLAB. The varying of load level that affect the losses, voltage deviation, total harmonic distortion and DGs sizes will be tabulated in this chapter with illustrated with graph. In addition, discussion and comparison of the result will be done in this chapter. Chapter 5 discusses and summarized the research based on the result for sizing and optimal placement of the DGs in distribution system considering load variation with heuristic method. A short summary of the whole project is made based on research outcome.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the theory and previous research that related with this study. In recent years, this topic has been studied and be investigate in many aspects and using certain optimization technique by previous researcher to evolved the superior allocation of the DG in distribution networks. The most beneficial DG placement techniques used to offer the quality sizing and location of DGS to optimize electrical network operation according to many criteria such as total harmonic distortion reduction, voltage profile improvement, load variation for loss reduction, and other else. All these criteria have been study to provide the best optimal placement and sizing of DGs to achieve maximum benefits of the DG in distribution system. DGs installation will cause many advantages such as, increasing reliability, improve voltage profile, power losses reduction and power quality. Since most of the distribution system loads was uncontrolled, effect of load model on optimum sizing and location should be discussed. In addition, with application of loads, the voltage profile then to drop [6]. Therefore, proposing an optimal pattern for installing DGs, attract a lot of attention these day and DGs can be a better choice for better power generation in the future and it will account for almost 20% of total power generation in the coming days [4].

2.2 Types of DGs.

Solar energy, biomass, hydro generation, and wind energy are the renewable energy that present in Malaysia today. The most suitable energy for distribution generation in Malaysia is solar energy because clean energy source can be generated by Solar Photovoltaic Panel (PV) and it only uses sunlight to generate electricity. Hence, Malaysia is a country that gets lots of light during the 12 months. Consequently, solar system is specially appropriate for producing electricity.

2.2.1 Photovoltaic Distributed Generation.

The maximum important solar technology for dispensed generation of sun electricity to date is photovoltaic, makes use of solar cells assembled into solar panels to transform sunlight into electricity [29]. It's far a quick-developing technology doubling its international installed potential every couple of years. Since most assets of renewable energy and not like coal and nuclear, solar PV is a variable and non-dispatchable. However, has no gasoline prices, working pollutants, in addition to reduce mining protection and operational protection problems. It produces peak power round local noon each day and its potential factor is around 20 percent.

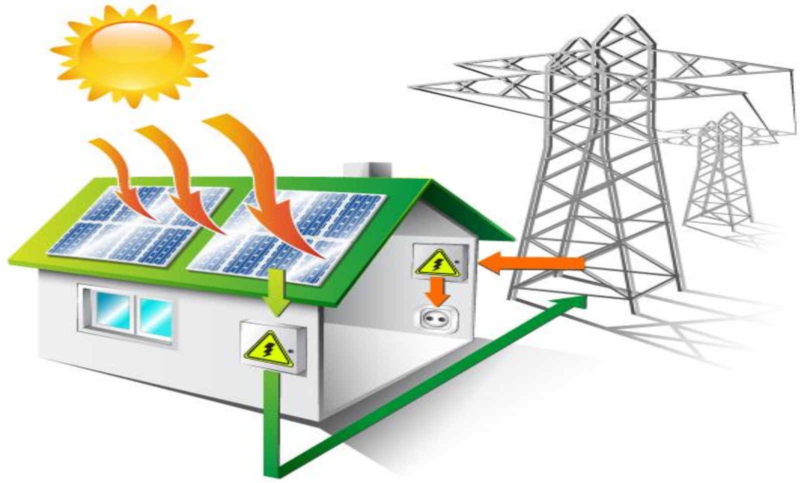

Figure 2.1: Photovoltaic distributed generation system. [31]

2.2.2 Wind distributed generation.

Wind mills can be dispensed energy resources or they may be built at utility scale. The wind is created by way of the uneven warming of the earth's surface by way of the solar. Wind turbines convert kinetic power from wind into the mechanical strength that able runs a generator to supply clean electricity [29] As with sun, wind strength is variable and non-dispatchable. Wind towers and generators have a large insurable legal responsibility caused by sturdy winds, however proper running safety. DG from wind hybrid power structures combines wind energy with other DER structures. These have low protection and low pollution, but allotted wind in contrast to application-scale wind has higher prices than different electricity resources. Wind electricity in Malaysia isn't always suitable for commercial electricity or wind isn't always specially precise in Malaysia as compared to other country around the world. However, islands like Perhentian can positively fulfillment a variety of power mainly when wind turbine is cooperatively equipped with solar.

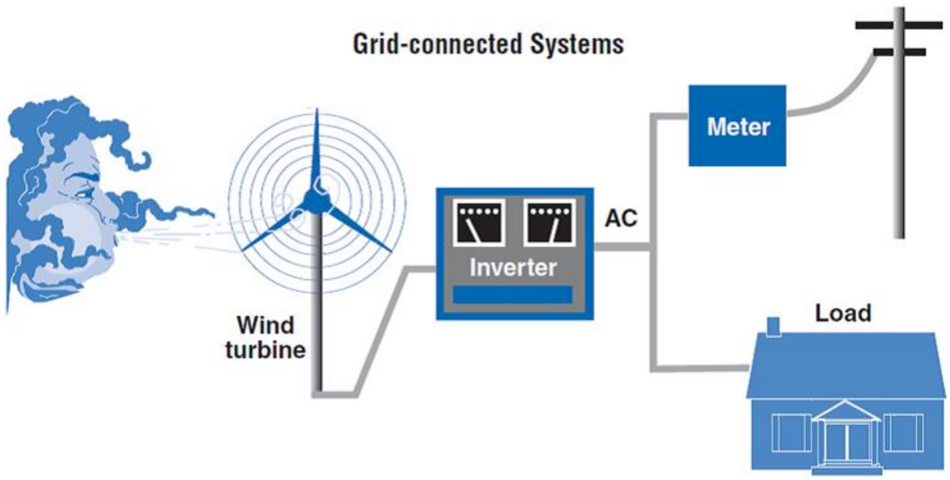

Figure 2.2: Wind distributed generation system [30]

2.3 Review on optimization technique for optimal placement and sizing of DG.

In optimal allocating distributed generation there a lot of intelligent algorithm such as PSO, GSA, IGSA, GA, and other else have been applied for optimal DG allocation. In this sub topic will explained about the intelligent algorithm used in optimal DG allocation.

2.3.1 Particle swarm optimization.

Particle swarm optimization (PSO) was develop in 1995 by means of inspiring social behavior of bird swarms or fish folks [7]. On this approach, role of every particle is up to date based totally on its individual knowledge and its neighbors' experience [7]. The algorithm is based on particles movement towards the optimal point. Best Personal

Position (Pbest) and Best Global Position (Gbest) which are obtained from neighbor's particle's information [8]. Initially, candidate's positions in PSO algorithm are assumed in search space as initial input population [8]. It will describe PSO equations.

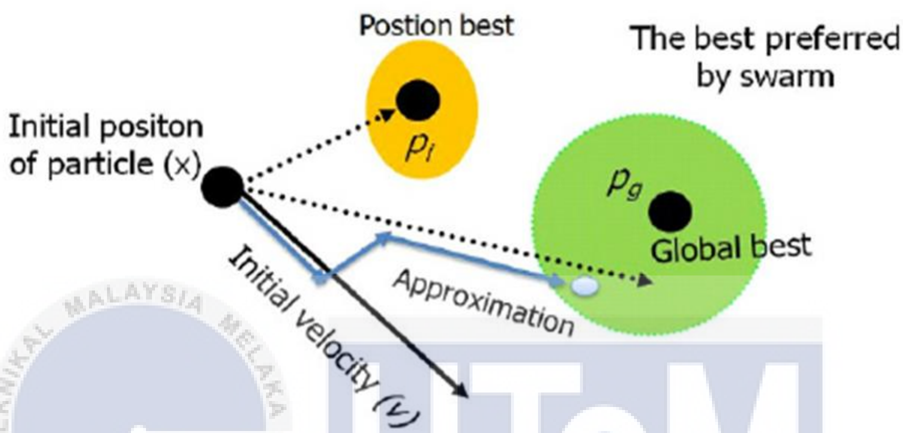

Figure 2.3: PSO illustration concept [8]

$$X_i^d(t+1) = [X_i^d(t) + V_i^d(t)] \quad (2.1)$$

$$V_i^d = V(t)V_i^d(t-1) + c_1 r_{1i}(t)\left[pbest_i^d - x_i^d(t)\right] + c_2 r_{21}(t)\left[gbest^d - x_i^d(t)\right]$$

(2.2)

Where, *gbest* is best position of all particles in whole swarm and *pbesti* is the best position of each individual particle during its path to current position [7]. C_1 and C_2 are used for weighting between the individual term and social term in velocity and called acceleration coefficients. r1 and r2 are two random numbers between 0 and 1 with uniform distribution n [7]. Parameter w is inertia weight and preserves data of velocity in previous iteration [7].

2.3.2 Gravitational search algorithm(GSA).

Rashedi et al. in 2009 had developed Gravitational search algorithm (GSA) based on concept of gravitational kinematics with some based on the Newtonian gravity: “Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them” [9]. There are a few benefits and differences of GSA over other conventional optimization techniques which the agent direction is calculated based on the general force. In addition, GSA is memory less and only the current position of the agent will play a big role in the updating procedure while the force is reversely proportional to the distance [9]. Main important criteria in GSA are exploitation and exploration.

The computational methods of the GSA method are

described as comply [9]:

i. i^{th} agent represent the position given in Eq. (2.3):

$$X_i = \left(x_i^1, . , , , , x_i^d, . , , , x_i^n\right) \quad \boldsymbol{for\ i = 1, 2, 3, 4 \dots . , N} \tag{2.3}$$

$\boldsymbol{x_i^d}$ represent the location of $\boldsymbol{i^{th}}$ agent in the $\boldsymbol{d^{th}}$ dimension.

ii. Update gravitational constant (G) Eq. (2.4):

$$G(t) = G_O \times \frac{T-t}{T} \tag{2.4}$$

G(t) = value of the gravitational constant at time t.

G_0= value of the gravitational constant.

iii. Update mass (M). Fitness are given according to weighting in range [0,1] Eq. (2.5) -(2.6):

$$m_i(t) = \frac{(fitness_i(t) - worst(t))}{(best(t) - worst(t))} \tag{2.5}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \tag{2.6}$$

$fitness_i(t)$= fitness value of the agent i at time t.

$worst(t)$ = maximum fitness.

$best(t)$ =minimum fitness.

iv. Update kbest is given in Eq. (2.7):

$$k_{best} = [K_{best_{final}}] + [\frac{T-t}{T} \times \left(100 - K_{best\_final}\right)] \tag{2.7}$$

v. Total force (F) are given in Eq. (2.8) -(2.9):

$$F_{ij}^{d} = G \times \frac{M_i \times M_j}{R_{ij} + \varepsilon} \times (x_j^d - x_i^d) \tag{2.8}$$

$$R_{ij} = \left| X_i, X_j \right|_2 = \sqrt{\sum_{d=1}^{D} (x_j^d - x_i^d)^2} \tag{2.9}$$

$$\varepsilon = small\ coefficient, 2^{-25}$$

vi. Acceleration (α) in Eq. (2.10):

$$a_i^d = \frac{F_i^d}{M_i} \tag{2.10}$$

vii. Velocity (v) update in Eq. (2.11):

$$v_i^d(t+1) = [rand_i \times v_i^d(t)] + a_i^d(t) \quad (2.11)$$

$rand_i$= random variable in the interval [0,1].

viii. Position (x) update in Eq. (2.12):

$$[x_i^d(t+1) = x_i^d(t) + v_i^d(t+1)\ ] \quad (2.12)$$

2.3.3 Improved Gravitational Search Algorithm

The improved gravitational search algorithm (IGSA) is proposed as an optimization technique that improved from the original method gravitational search algorithm[10]. Therefore, GSA is needing to be improved, to get a better search result applied in the electric distribution network. In GSA concept, agent of performance is considered by their masses since all the agents attract each other by the gravity force causes a global movement of all agents toward the agent of heavier masses [9]. Exploration and exploitation are two contradictory objectives that enhance the achievement of the GSA successes [9]. However, there were some weaknesses of the GSA was the best agent is still exploring the global space even it was at the best position and other weakness was the best agent is till exploring the global space even it was at position [11]. Improved Gravitational Search Algorithm (IGSA) is presented to eliminate the weakness and which aim to improve the quality of the result and achieve fastest convergence speed and the global search ability. In the proposed IGSA, the chaotic dynamic is applied for improvement in the searching behavior and to avoid the premature convergence[12] . Chaos has been innovative optimization technique and strong benefits has been stimulated by the chaos-based searching algorithm due to simplicity of execution and its unique capability to escape from being trapped in local optima[12].

2.3.4 Genetic algorithm.

In 1962, John H. Holland provided genetic algorithm on the premise of Darwinian evolution principle [7]. The GA is creating to designate optimization algorithms that carry out a sort of approximate global search such that depend on the statistics obtained by way of the assessment of numerous factors inside the search space. Each "current point" is known as an individual, and the set of "current point" is called the population. The algorithm keeps this set of "current points", rather than keeping a single "current point" as will be the case of in most optimization algorithms [10].

Figure 2.4: Preparatory Steps of Genetic Algorithms

Human supplied input to the genetic programming system are called preparatory steps. Preparatory Steps of GA are the basic version of genetic programming. The computer program is the output of genetic programming system. [10].

Three operators for Genetic algorithm that provided good result in lots practical issues [13]:

- ❖ Crossover: The individual, paired at random, have a combined spatial location, so each individual partner raises new partner or pair.
- ❖ Mutation: Some individuals are randomly modified, in order to reach out other points of the search space.
- ❖ Selection: The individuals, after mutations and crossover, are assessed. They are selected or not chosen to be included in the new population.

2.4 Review of previous related works.

In current years, control of power system has been going through with the main changes. The greater of expanding a few technologies with other problems consisting of the environmental pollution, creation trouble and other else has lead the growth within the utilization of DG technology. Researches of Electric Power Research Institute has figure out that more than 25 percent capacities of DGs installed [8]. Since the past year, distribution network was not capable to implemented the DG power plant into the main services grid while nowadays the present network is able to connected DG into the utility grid [8]. Researcher were evolved the top-rated allocation of the DG in distribution network. Certain way of analyze based on analytical and also by an optimization approach had been implemented to achieve the best answer DG planning toward distribution network. Optimal placement of DG for loss reduction has been investigated in many references using diverse classical and/or current optimization techniques [14].

There various of method had been utilized by researcher so as to analyze the planning of the DG in distribution network that focus on to discuss various concern like reduction of system losses [13] [15] and the improvement of voltage profile of system [6] [8]and THD reduction [6] [13]and other else [4] [5] [16]. The problem of DGs planning is of great important. In [5] the effect of load models on (DG) design toward distribution system was investigated by the author to determined either load models can significantly affect the DG planning or not. The author was showed that DG planning based on constant power load models was not effective after implementation on actual systems while usually, constant power (real and active) load model was assumed in most studied[5]. Since most of the distribution system loads was uncontrolled, effect of load model on optimum sizing and location should be discuss. In addition, with application of loads, the voltage profile then to drop [6].

From the past study which is done by A.M El Zonkoly[16], particle swarm optimization method was proposed to find the optimal solution of their problem . The result from the study also show that the proposed algorithm is capable of optimal and fast placement of DGS unit and has clarified the efficiency of this algorithm for voltage profile improvement, reduction of power losses and also increasing the voltage stability.

Other than that, from [17] have mentioned that the growing number of DG unit may contribute to harmonic pollution in power system network. Consequently, harmonic evaluation device may be very crucial to distribution system evaluation and design. these installing the DG with most excellent placement and sizing may lead to positive impacts on the reduction of harmonic distortion in the distribution system while reducing the total loss has been generated. In [17] also mentions about sensitivity analysis that was used to find the most sensitivity bus location in order to allocating the DG based on loss reduction because it can reduce the research space and increase the speed of the optimization algorithm.

Furthermore, there are more optimization method used in optimal placement of DG. In [7] the researcher has investigated to decrease operation cost and determine capacity and location of DGs in grid by comparing PSO, GSA and GA optimization. GSA has find better answers with less cost although it used more time to stimulate the resulted. Moreover, the results obtained by GSA in most cases provide superior results and in all cases [9].

For paper in [18], Particle Swarm Optimization (PSO) heuristic method has been propose in order to find the best size and best allocation for the inserted of DG within the distribution networks for active power compensation through way of reduction in real power losses and enhancement in voltage profile. The whole real power loss reduction in the distribution system with active compensation is depending by planning of DG for maximizing the power system performance. However, in practice the pleasant place or sizing will not constantly be possible because lot of constraints i.e. due to size may not be to be had inside the marketplace.

In other paper, the authors [10] has presented new optimization technique for determining surest sizing and placement of DG in a distribution system that was the improved gravitational search algorithm (IGSA).It performance is compared with other heuristic method such as PSO and GSA for optimization placement and sizing. The resulted has showed that the IGSA performs better than PSO and GSA by provided the best fitness value and the fastest average elapsed time. This paper has similarities as this researcher based on optimization techniques used in order to minimize the total losses and voltage deviation in the distribution system.

Besides, on [4] the author proposed about analytical based approach for optimum placement and sizing DG and this method is based at the fact that installations of DG units in distributions network reduced the value of branch currents which in turn lower system energy losses. This system has an advantage that is requires same number of load flow solution either the system is larger with more number of busses present.

2.5 Chapter summary

Based on the review, optimal placement and sizing is very important to minimize losses and improve the performance of distribution system up to highest level. In the most research will have an objective to reduce losses in system because reduction in losses obviously cause the total cost decrease. Based on the research that have been done, they are least study on IGSA for optimal placement of DGs in distribution generation. Methodology of this research will be explained further on the next chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss about the methodology of this research and also the flowchart will be used to assist the procedure and step to analyze the research in order to do the simulation for optimal placement of DG in radial distribution system using proposed method that is improved gravitational search algorithm (IGSA) to achievement our main objective in this research. This section will present the mathematical formulations to solve the multi-objective and related with the operating constraint problem of the research. Moreover, investigation will emphasis on optimal and sizing of the distribution generation and compared the performance of purposed method with other heuristic method that are PSO and GSA. Finally, the simulation MATLAB are presented with details explanation about the simulation. The rest procedures to analyze the result from simulation are given in this section.

3.2 Project Implementation

The process and steps to complete this project must be followed by the order to make sure this project be done within the time. There are flow charts, milestone and Gantt charts that will help clarify processes and steps or procedures for managing this research. All the procedure will be explain based on flow chart given in this research.

Figure 3.1 show the flow of the process that involve upon completion of this research. The first step to start this research is gathered or collect the information and data that needed to carry out this research. Information and studies are very important to fully understand this research and ensure that the project runs smoothly according to the plan. The gathered information also will help to identify the optimal placement of distributions generation in distribution system very well. The second step is study the purposed method that used in this research to give a better understanding about the flow or process of the purposed method. There are various methods used for optimal allocation of DG in distribution generation that why studies the purposed method is very important for better understanding of this research. After gathering enough information, case study can be done based on information obtained so that the performance of the purposed method can be analyzed properly with various type of cases.

Simulation of the purposed method and comparison method are conducted using MATLAB to obtained the optimal placement of distribution generation. The output will be verifying to ensure that the results are fulfilled based on cases conducted. The simulation will simulate with three methods that is improved gravitational search algorithm (IGSA) as purposed method and will be compared of their performance with (PSO) and (GSA). The distribution system will consist two systems that are 33-radial bus system and 69-bus radial system. The feeder load in four different load levels as in percentage of peak load have been considered to be done in this simulation.

After the simulation completed, based on all the results obtained through the simulation the comparison was made between improved gravitational search algorithm (IGSA) with (PSO) and (GSA). The gathered result of the simulation will complete the main objective of this research. Finally, report is written and compiled. All the result, analysis and discussion on the data is presented in the report.

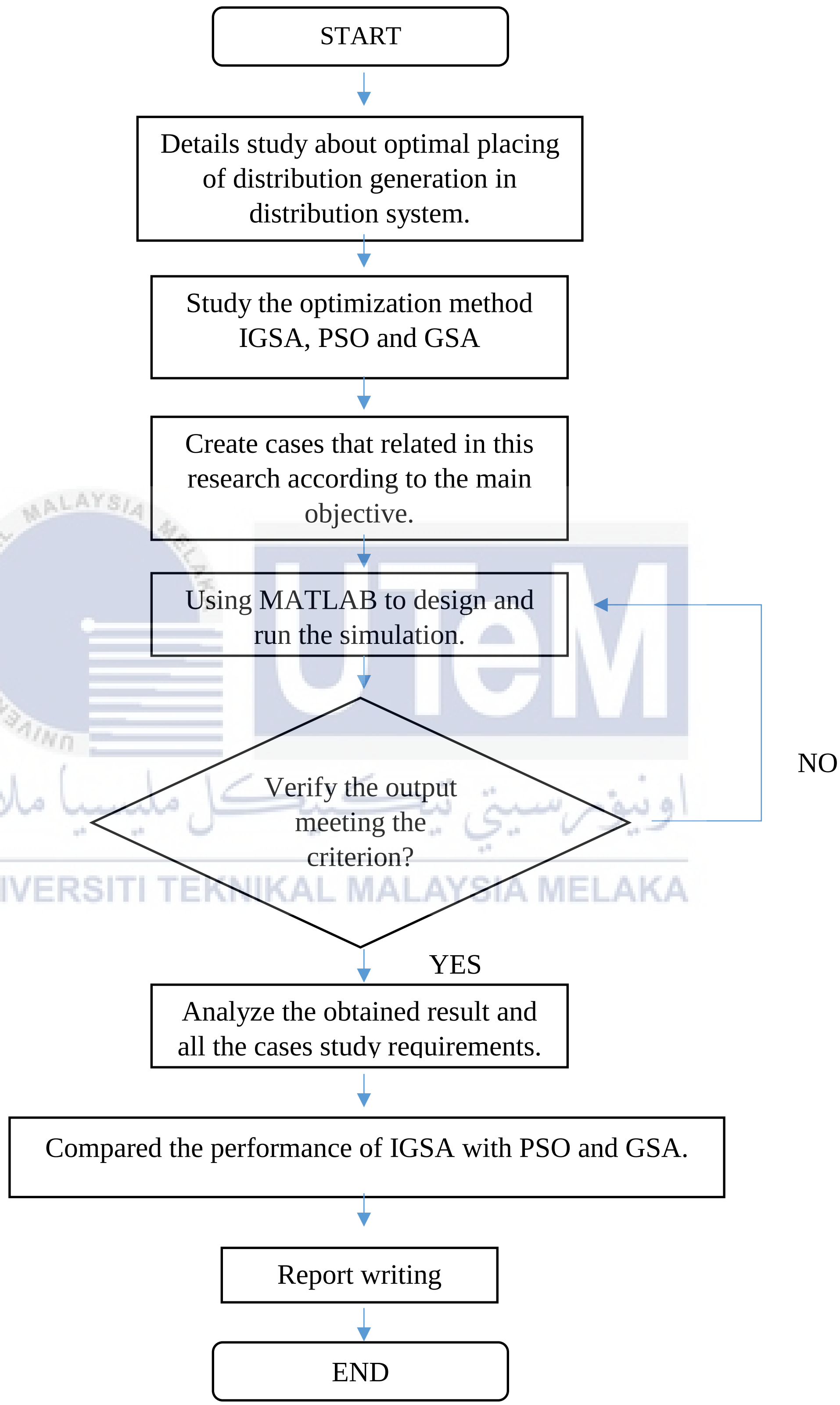

Figure 3.1: Flow Chart of project implementation

3.2.1 Milestone Research

In this part, milestone are creates based on project implementation for overall procedure in order to finish up this research smoothly. There are 6 milestones set for this project to ensure this project run systematically. First milestone is about understanding of this research that related in this study such as definition of the study and main concept of this research while the second milestone is method used in order to carried out the result with using simulation in MATLAB and discussed the result. The third milestone is to validate the data obtained from the simulation. The fourth milestone is to archive the main objective in this study according to simulation result. Finally, report writing is conducted based on all milestone from this research.

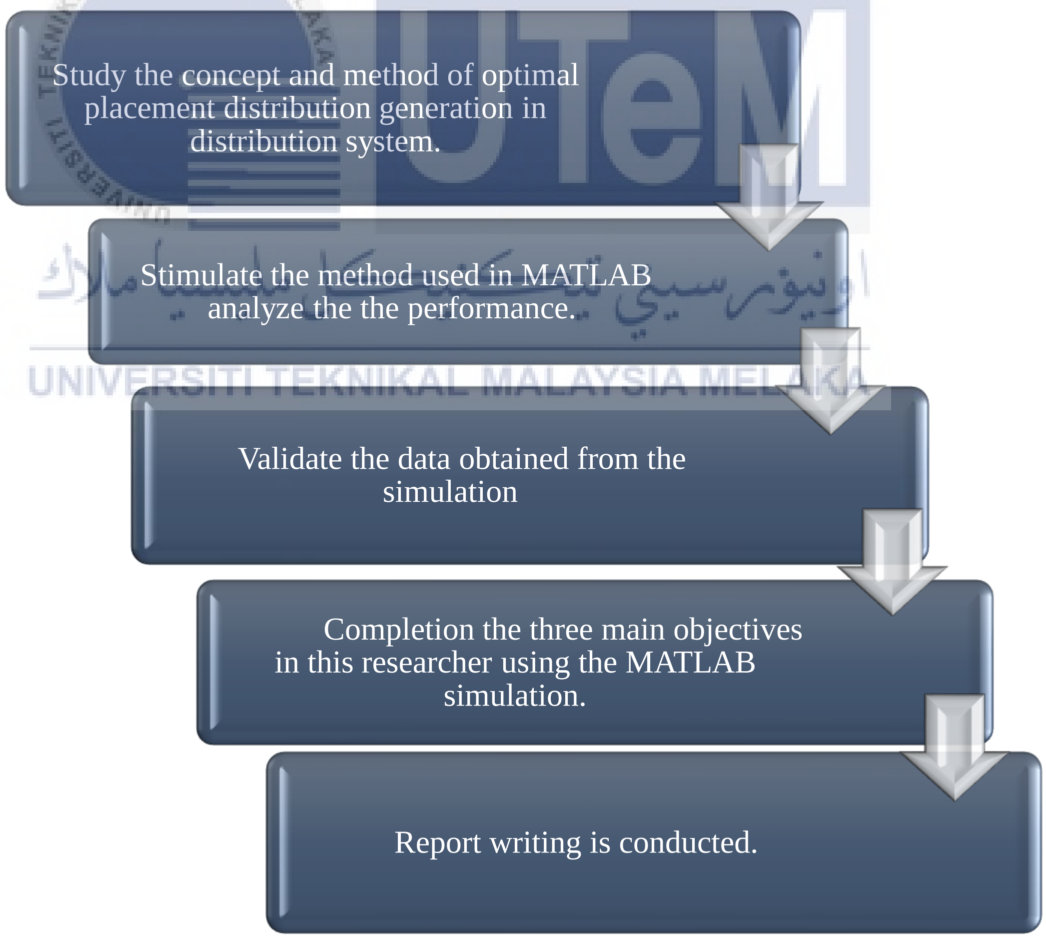

Figure 3.2: The milestone process

3.2.2 Project Gantt Chart

Gantt chart of activities conducted to the along completing this project will inserted in appendices. This project was continues based on fyp 1. The first step to do this project in fyp 1 is doing some researcher on optimal placement of distribution generation. The task has been done within one semester with preliminary result according to certain cases study. This simulation was focused on how the optimal placement of DGs can affect the distribution network considering load. Case study are added based on future works on fyp 1 that consists 33-buses system and 69-buses system with more load variation will be considered. The data form the simulation result will be tabulated with proper way and analyze of the result will be conducted respectively. Validation of the data should be discussed with supervisor to achieve the main objective in this research. Writing paper for publish in IJEEAS is conducted on week 3 until week 7. Finally, correction and addition on report is done within the whole semester to finish the fyp.

3.3 Problem Formulation

Constrained non-linear integer optimization problem is expressed as a multi-objective optimization technique in this paper for proposed for DG placement and sizing in a distribution system. The main objective is to minimize the total power losses, voltage deviation and total harmonic distortion (THD) with variation of load level. The fitness function within the system may be express via:

$$F_{min}=\sum \alpha(P_{LOSS}) + \beta(V_{dev}) + \gamma(THD_V) \tag{3.1}$$

Where F is the fitness function, P loss is the total power loss (%), V*dev* is the voltage deviation (%) and THD*v* is the average THD*v* at all system busbars while α is the coefficient factor for total power loss that set for 0.4, β is the coefficient factor for voltage deviation set for 0.3 and is the coefficient factor for THD*v* set for 0.3. The coefficient factor is set based on study related with multi-objective in this research.

Constrained non-linear integer optimization problem is expressed as a multi-objective optimization technique in this research for proposed for DG placement and sizing in a distribution system. The loss within the system may be calculated via equation [16]:

$$P_L = [\sum_{i=1}^{n} \sum_{j=1}^{n} A_{ij} \left(P_i P_j + Q_i Q_j\right) + B_{ij} \left(Q_i P_j - P_i Q_j\right)] \tag{3.2}$$

where,

$$A_{ij} = \frac{[R_{ij} \cos(\delta_i - \delta_j)]}{V_i V_j} \tag{3.3}$$

$$B_{ij} = \frac{[R_{ij} \sin(\delta_i - \delta_j)]}{V_i V_j} \tag{3.4}$$

where, Pi and Qi are net real and reactive power injection in bus 'i' respectively, V_i and δ_i are the voltage and angle at bus 'i' respectively while *Rij* is the line resistance between bus 'i' and 'j'. Minimize the total real power loss as main objective in this research. Mathematically, the objective function can be written as [19]:

$$P_L = \sum_{k=1}^{N_{SC}} Loss_k \qquad k = 1,2,3,4 \ldots\ldots, n \tag{3.5}$$

where Nsc is the number of lines. The voltage deviation is defined by:

$$V_{dev} = \frac{V_{iref} - V_i}{V_i} \tag{3.6}$$

where V*iref* is reference voltage at bus and V*i* is the actual voltage at bus. The average THD_V is defined by:

$$THD_v = \frac{\sum_{i=1}^{n} THD_{vi}}{n} \tag{3.7}$$

where *n* is the number of buses.

3.3.1 Constraints.

Optimization model that needs to be defined is the constraints. The operating constraints of the problem are divided into equality an inequality constraint.

(a) Equality Constraints

Newton Raphson method and Gauss-Siedel method are usually used[6].

Load Flow Constraints = The real and reactive power flow constraints respectively, as given below [20]:

$$\boldsymbol{P_G + PDG_i = P_{LOSS} + PD_i}$$

$$V_i \sum_{j=1}^{n} V_j \left[G_{ij} \cos\left[\delta_i - \delta_j\right] + B_{ij} \sin\left[\delta_i - \delta_j\right]\right] \tag{3.8}$$

$$Q_G + QDG_i = Q_{LOSS} + QD_i$$

$$V_i \sum_{j=1}^{n} V_j\, [\, \sin[\delta_i - \delta_j] - B_{ij} \cos\, [\delta_i - \delta_j]] \tag{3.9}$$

(b) Inequality Constraints.

The inequality constraints are those associated with the bus voltages and do to be installed.

i. Power Generation Limit[[20] .

$$P_{DG_i}^{min} \leq P_{DG_i} \leq P_{DG_i}^{max} \tag{3.10}$$

$$Q_{DG_i}^{min} \leq Q_{DG_i} \leq Q_{DG_i}^{max} \tag{3.11}$$

ii. Bus voltage limits.

The bus voltage magnitudes are to be saved inside appropriate working limits during the optimization technique. The rms value of the *th* bus voltage involves only the fundamental component[6].

$$V_{min} \leq \left| V_i \right| \leq V_{max} \tag{3.12}$$

$[V_{min}]$ limit bus voltage of lower bound.

$[V_{max}]$ bus voltage limit for upper bound.

$|V_i|$ bus voltage (rms)of the *th*

$$\left| V_i \right| = \sqrt{\left| V_I^{(1)} \right|^2 + \sum_{h=h_0}^{h_{max}} \left| V_i^{(h)} \right|^2} \quad , \quad i = 2,3,4,5 \ldots\ldots n \tag{3.13}$$

n= number of bus.

iii. Total harmonic limits.

The total harmonic level at each bus is to be less than or equal to the maximum allowable harmonic level as expressed as follows:

$$THD_{vi}(\%) \leq THD_{vmax} \tag{3.14}$$

Where THD_{vmax} is the maximum allowable level at each bus (5 %).

3.4 Test system

This section will present the test case that used in this research that is radial network system. The data is obtaining from bus radial system topology and has to been used to illustrate the functionality of the proposed set of rules that allows you to find the top-rated placement of the distribution technology into the predefined take a look at case. There are some preliminary assumptions of the DGs constraints that exact as follows:

I. Voltage limit of the DG: $10\% \leq V \leq 5\%$
II. Power generation limit of the DG: $30\% \leq P \leq 60\%$ of total connected load.
III. Reactive generation limit of the DG: $30\% \leq P \leq 60\%$ of total connected load.
IV. Balanced radial network system is considering and fed by a single source.
V. Constant output generation with unit power factor are considered in DG unit.
VI. Constant power output is modeled for all loads.

3.4.1 33-bus test radial distribution system.

The base design of the framework has a single supply point with 33-buses and tie switches which are kept generally open and is closed to vary circuit resistance for decrease of losses or can be closed just during fault condition to support uninterrupted supply. The line diagram of the system is illustrated within the Figure 3.1. The entire real power for base configuration is 3720kW, 2300 kVar with a real power loss of 203.00kW for the total connected load and generation entire real power for base configuration is 3920kW, 2440 kVar with a real power loss of 203.00kW.

Table 3.1 Details of 33-bus distribution system.

Number of buses	33-bus
Number of branch	37
Number of ties lines	5
Total real power	3720kW
Total Reactive power	2300kVar

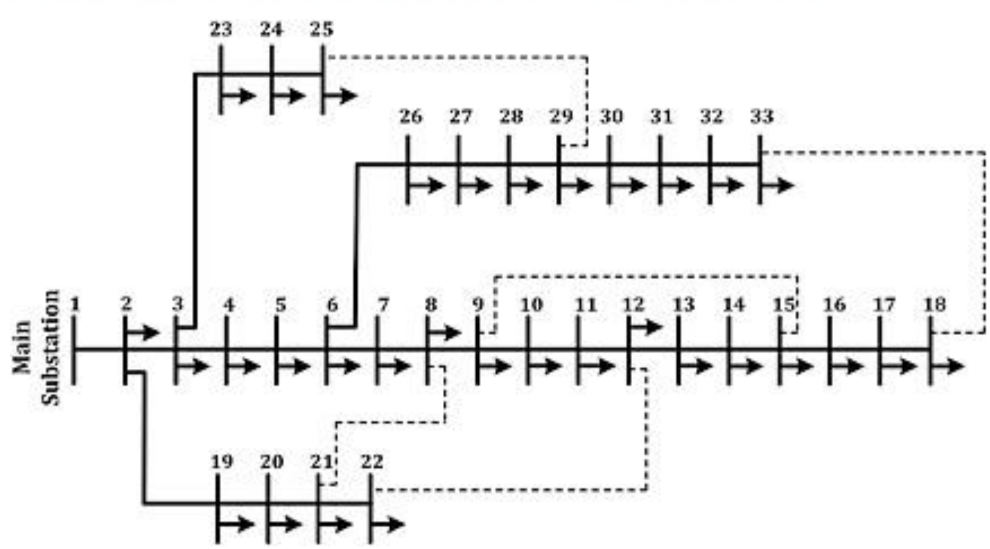

Figure 3.3: 33-bus radial network

3.4.2 69-bus test radial distribution system.

The base design of the framework has a single supply point with 69-buses, and 3 laterals The line diagram of the system is illustrated within the figure 3.2. The entire real power for base configuration is 3800kW, 2690 kVar with a real power loss of 230.00kW for the total connected load and generation entire real power for base configuration is 4030kW, 2800 kVar with a real power loss of 230.00kW.

Table 3.2 Details of 69-bus distribution system.

Number of buses	69-bus
Number of branch	73
Number of ties lines	5
Total real power	3800kW
Total Reactive power	2690kVar

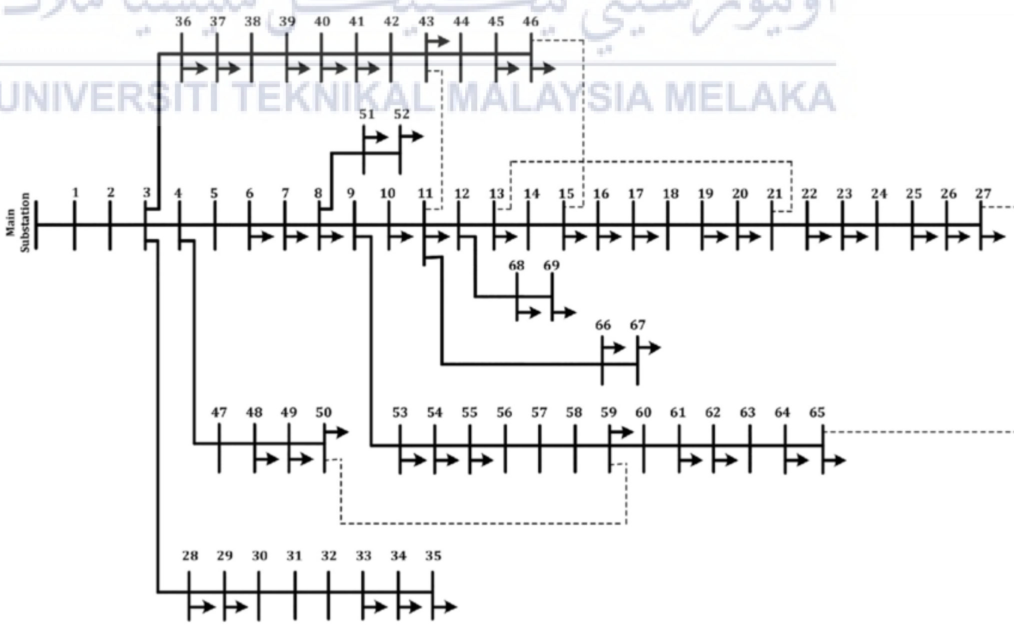

Figure 3.4: 69-bus radial network.

3.5 Heuristic methods

This observe targets to determine greatest placement for DG whilst they are installed in a distribution network. This technique is primarily based on population-based search techniques that practice both random variation and selection. The purposed technique is used to discover the excellent answer of the trouble in this study. In this part will related on how to planning the flow for the purposed method in this research and the implementation the purposed optimization techniques and compared their performance. The purposed method selected in this research is improved gravitational search algorithm (IGSA) and will compared with another optimization technique that are (GSA) and (PSO). The flow chart for this optimization techniques will be illustrating in flow chart.

3.5.1 Improved gravitational search algorithm (IGSA).

The improved gravitational search algorithm (IGSA) is proposed as an optimization technique that improved from the original method gravitational search algorithm. Therefore, GSA is need to be improved, in order to get a better search result applied in the electric distribution network. A (IGSA) is presented to enhance the convergence speed and the global search ability. This method is applied in the 33-bus radial and 69-bus radial distribution system considering load variation. The process of this optimization technique will be representing in flowchart. The flow chart will be representing in figure 3.5. The process of optimal placement and sizing of DG was handle simultaneously as shown in figure 3.6.

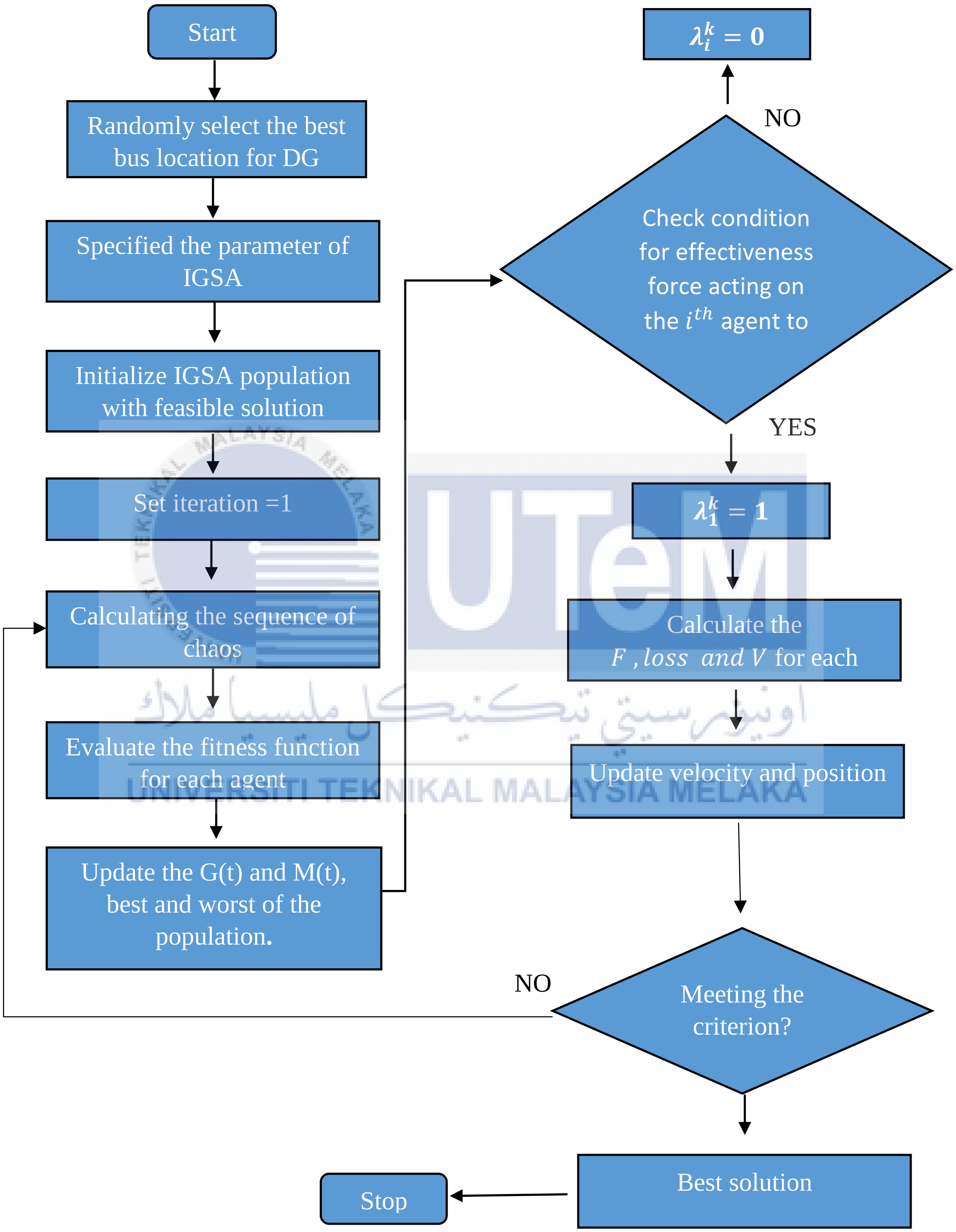

Figure 3.5: IGSA flow chart process.

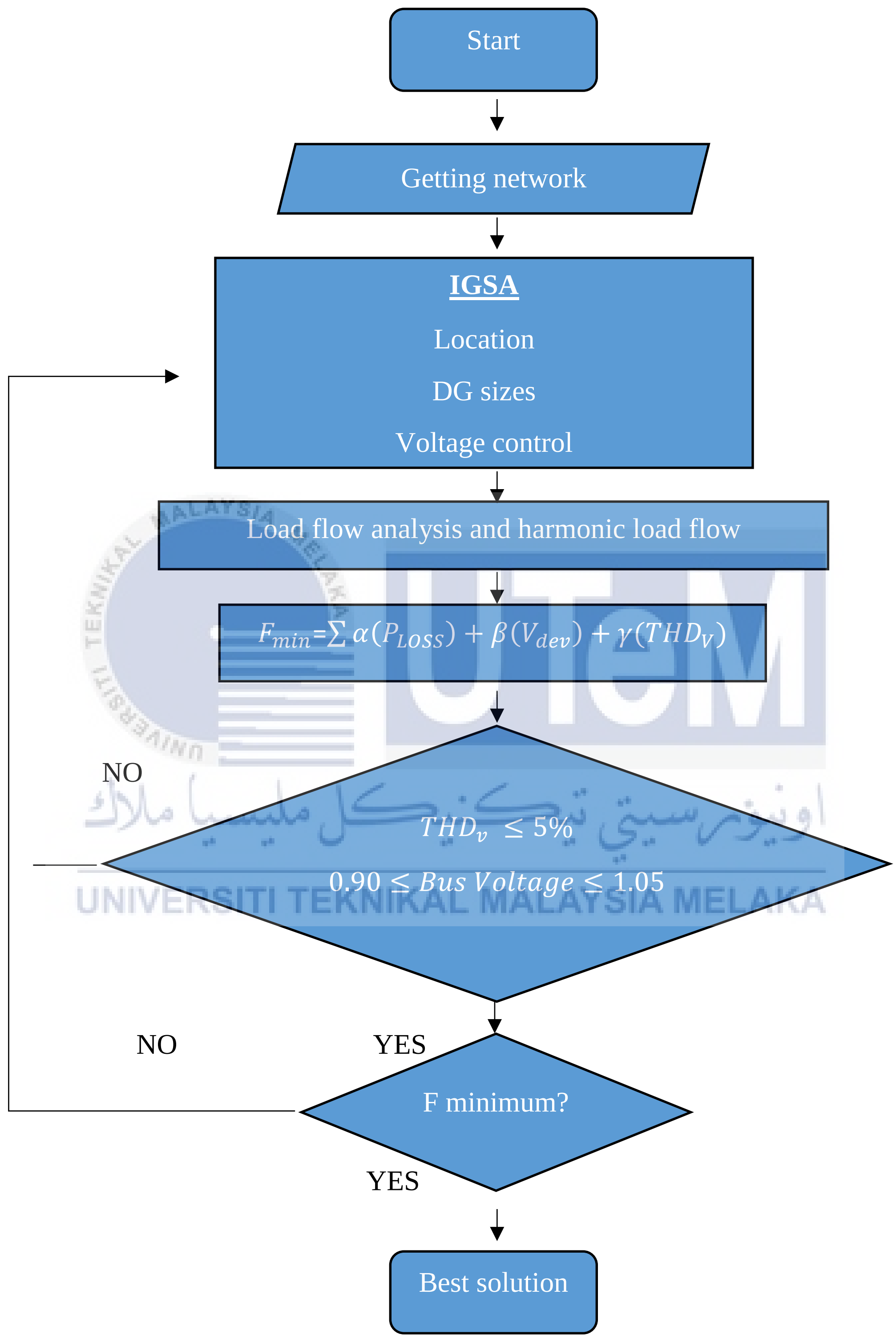

Figure 3.6: Simultaneous process of DG placement, sizing and voltage control using IGSA

3.5.2 Particle swarm optimization (PSO).

This method is applied to determine the optimal sizing and of DGs same as purposed method to obtained the result and compared their performance based on losses, power factor, voltage deviation and fitness value of the distribution system. The process of this optimization technique will be representing in flowchart on figure 3.7.

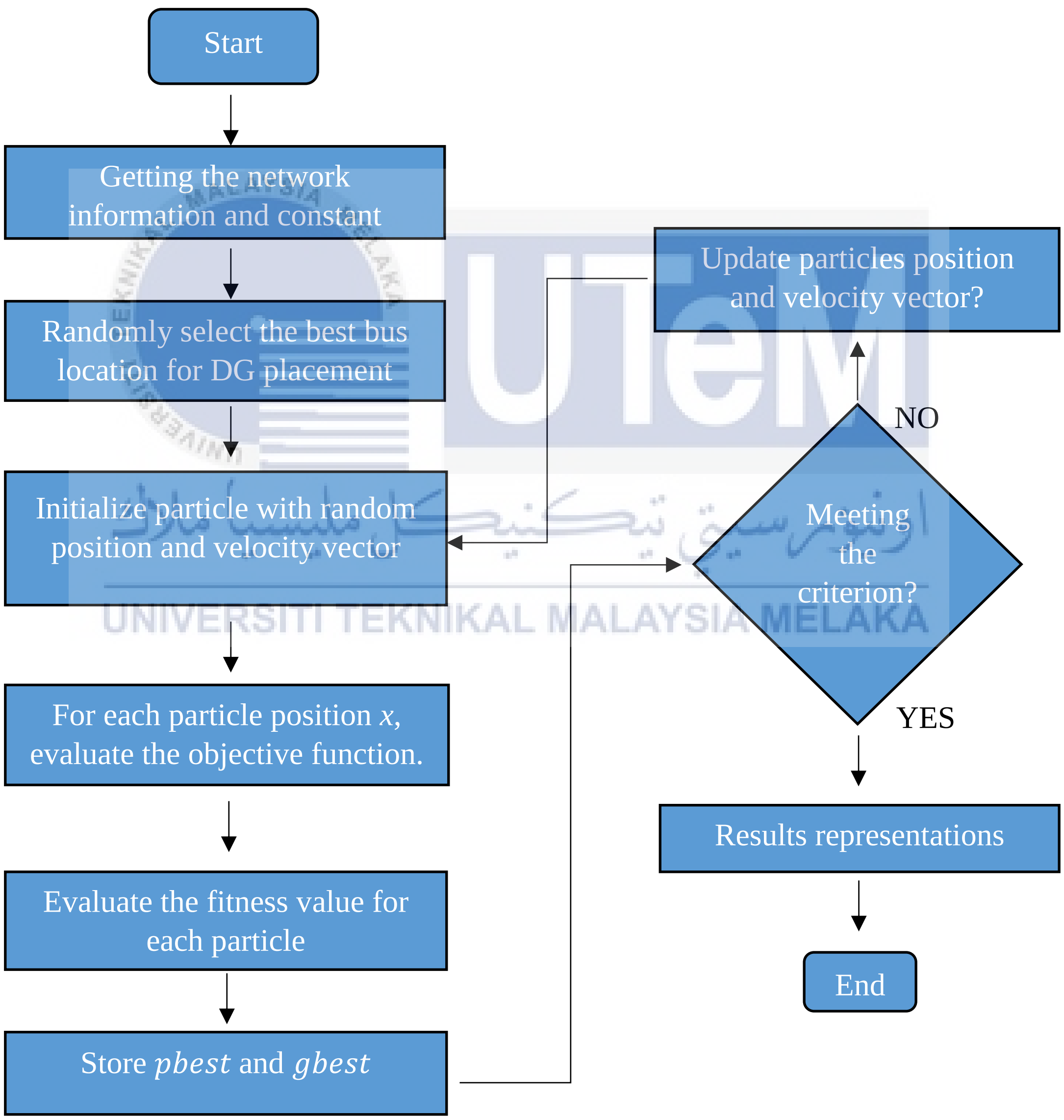

Figure 3.7: PSO flow chart process

3.5.3 Gravitational search algorithm (GSA)

Gravitational search algorithm is an original method of the purposed method in this research. This method is applied to determine the optimal sizing and of DGs same as purposed method to obtained the result and compared their performance based on losses, power factor, voltage deviation and fitness value of the distribution system. The process of this optimization technique will be representing in flowchart in figure 3.8.

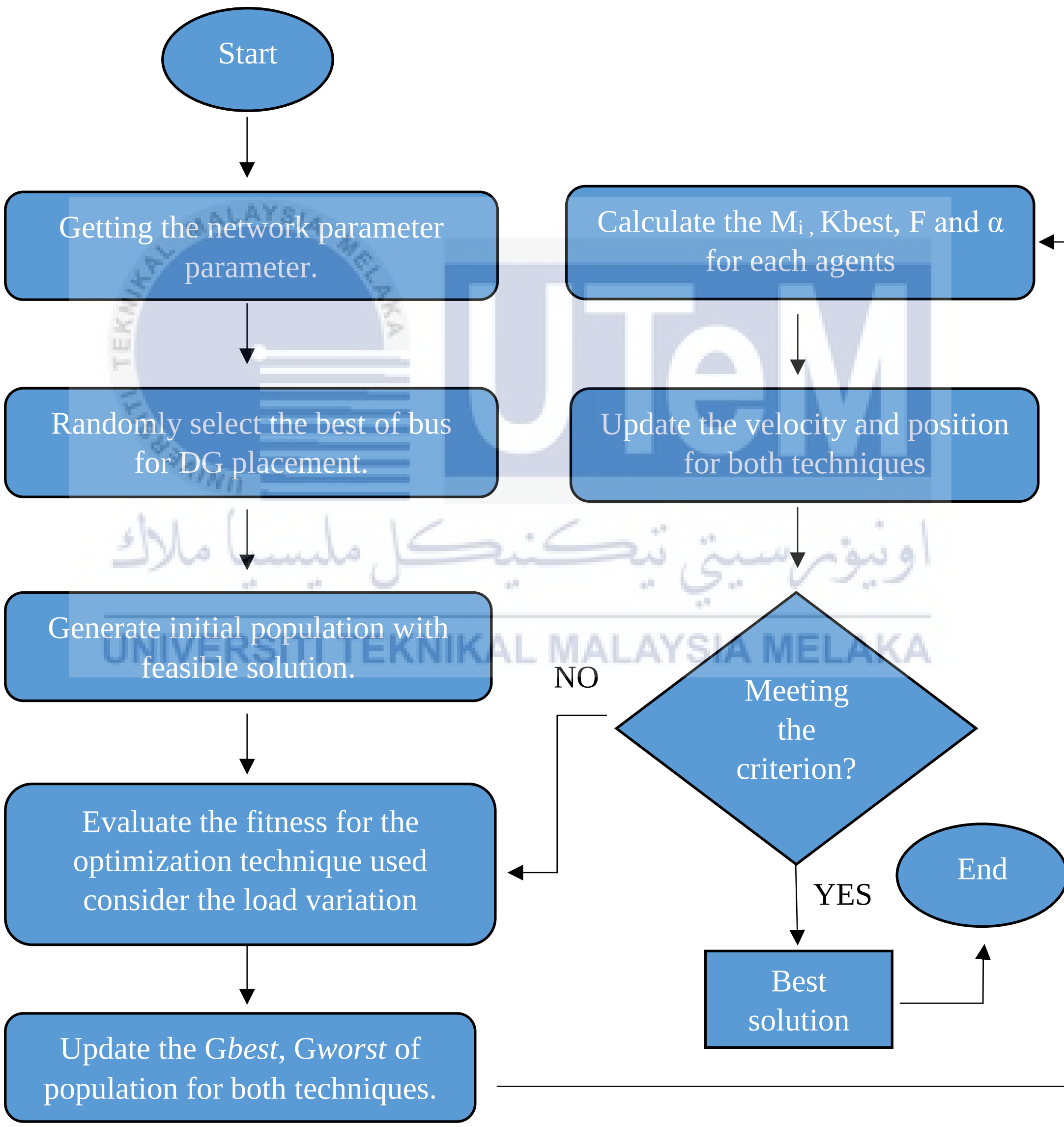

Figure 3.8: GSA flow chart process

3.6 Case study in this research

In this part will explain main criteria need to be done in this research. The control variable that set in this research was power (P), and the location of placement DG in radial distribution system. While based on the result obtained we can calculate entire real power base configuration for each case on the load and generation fitness that we set is losses and voltage deviation that used to simulate the best solution.

3.6.1 33-bus and 69 –bus test radial distribution system.

This algorithm was tested on 33-bus and 69-bus radial system. The system variation of load is a main criterion need to be consider in this research. The only supply source in the system is at substation know as slack bus with a constant voltage. The maximum number of iterations was taken as 300 times for tuning process of each parameter. Six cases are considered in this study with regard to the impact DG installation considering load variation and the multi-objective is formed to minimize the total power losses, average voltage deviation and average total voltage harmonic distortion in the distribution system. All the cases will be implemented on the application of three optimization technique and its overall performance is compared. Table 3.3 show case study for radial distribution system in this research.

Table 3.3: Case study for radial distribution system

<table>
<tr><th>Number of Cases</th><th colspan="3">Optimization Techniques</th><th>Load Level</th><th colspan="3">Present of DGs</th></tr>
<tr><td>Case 1</td><td rowspan="6">PSO</td><td rowspan="6">GSA</td><td rowspan="6">IGSA</td><td>25%</td><td rowspan="6">No DG</td><td rowspan="6">1 DG</td><td rowspan="6">2 DGs</td></tr>
<tr><td>Case 2</td><td>50%</td></tr>
<tr><td>Case 3</td><td>75%</td></tr>
<tr><td>Case 4</td><td>100%</td></tr>
<tr><td>Case 5</td><td>125%</td></tr>
<tr><td>Case 6</td><td>150%</td></tr>
</table>

3.7 Chapter summary

Based on this chapter, the flow of this research is really important in order to finish up this report on time. All the heuristic method with flowchart will easier us to understanding this research well. Two test systems will involve in this research that are 33-bus test system and 69 –test bus system with using IGSA heuristic method to finding better optimal placement and sizing of distribution generation considering load variation. In next chapter will discuss further on the result based on the case study created in this chapter on the MATLAB simulation.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter will discuss about the result obtained based on our case study. This result will be illustrated in table and graph to do the analysis case study. Simulation by using MATLAB has been done to get the result of optimal placement and sizing of the DGs placement which is using IGSA as purposed method as optimization technique. The heuristic method for DG placement and sizing is tested on the 33-bus and 69-bus radial distribution system. The system loads are considered as spot loads, with the total being 3.72MW and 2.3 MVAR for 33-bus, 3.8MW and 2.69 MVAR for 69-bus radial system. The base power of this test system is 100MW. The load and bus data of the radial distribution system are indicated in appendix. The voltage limit is set within 10% and 5% of the voltage as the minimum and maximum voltage limit. The maximum for the IGSA, PSO, and GSA algorithm is set up until three hundred. The proposed algorithm will be implement in MATLAB for simulation. At bus one will have only one supply source within the system, that's a slack bus with constant voltage. Furthermore, the renewable DGs used to generate DC source are rooftop PVs solar. However, due to lack of input data as well as the variation of loading conditions, the general renewable DG (with constant DC source) is considered in this research and will inject only active power.

4.2 Assumption for 33-bus and 69-bus radial distribution system.

The inverter-based DGs will be acting as the harmonic producing device in the distribution system. The typical harmonic spectrum of inverter-based DG is provided in Table 4.1.

Earlier than making use of IGSA, the parameters are tuned to enhance the performance of the proposed algorithm. In this study, six cases are discussing according to multi-objective function for reduce power losses, voltage deviation and average total voltage harmonic distortion. There are several assumptions made almost about the effect of DG installation on power loss, harmonic distortion and voltage deviation, in the 33-bus and 69-bus radial distribution system, as indicated as follow:

(a) The renewable DGs used to generate DC source are rooftop PVs solar. However, due to lack of input data (fluctuates input data of PV) as well as the variation of loading conditions, the general renewable DG (with constant DC source) is considered.
(b) The simulation is implemented based on varying load level.
(c) The installation of rooftop PVs solar units is similar for each phase.
(d) The cost is not considered in this simulation.
(e) Renewable energy DG will be used, and only active power will be injected.
(f) The maximum number of DG connected to the system is 2.
(g) The base case system is not influence and free from harmonic source and harmonic distortion.

Table 4.1 Harmonic spectrum of non-linear loads and inverter-based DG

Harmonic order	Inverter based DG (%)
1	100
5	0.1941
7	0.1309
11	0.0758
13	0.0586
17	0.0379
19	0.0329
23	0.0226
25	0.0241
29	0.0193

4.3 Convergence characteristic of GSA, PSO and IGSA algorithm.

In this study, six cases using 33-bus and 69-bus system will be stimulate using MATLAB. The present of DG in this result using one and two DGs. The best fitness value among the 30 simulation runs using the three-optimization technique to illustrate the best fitness value. Thus, 100 % load level was selected to compare the fitness between these three optimization techniques.

From the simulation of three optimization techniques the result was obtained for the fitness function according to multi-objective. Figure 4.1 and figure 4.2 shows the best convergence characteristic of one and two DGs installed in distribution system. Best fitness value for the IGSA for one DG and two DG has indicated with 0.34668 and 0.38509 as the lowest fitness compared to PSO and IGSA.

Convergence characteristic for 69-bus system with one and two DGs implemented shown in figure 4.3 and figure 4.4. The result show that the IGSA gives the best fitness compared to PSO and GSA compared to PSO and GSA with 0.344522 and 0.356518 as the best fitness indicated through the simulation.

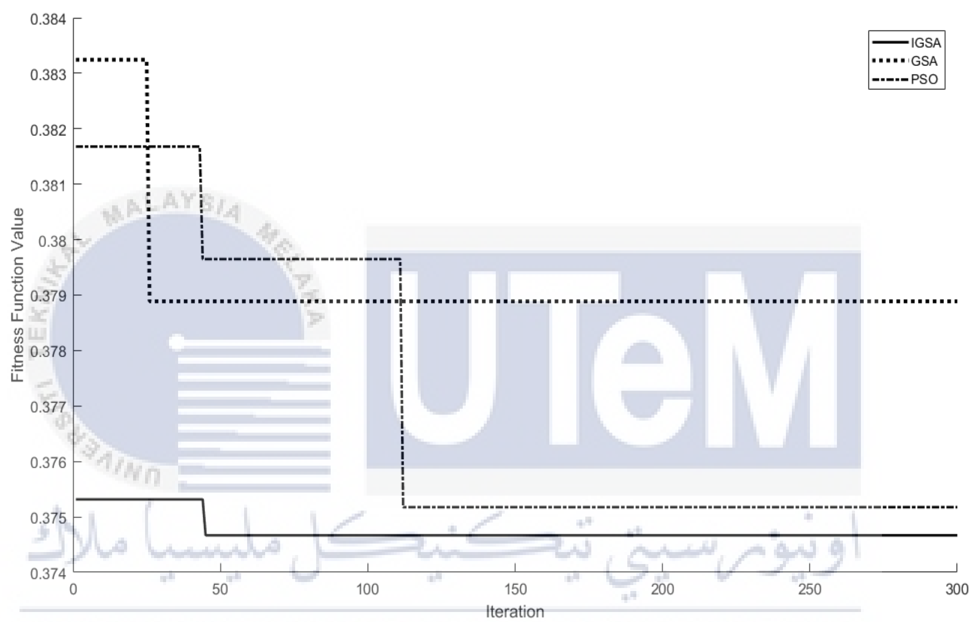

Figure 4.1 Convergence characteristic of GSA, PSO, and IGSA algorithm for 1 DG in the 33-bus system.

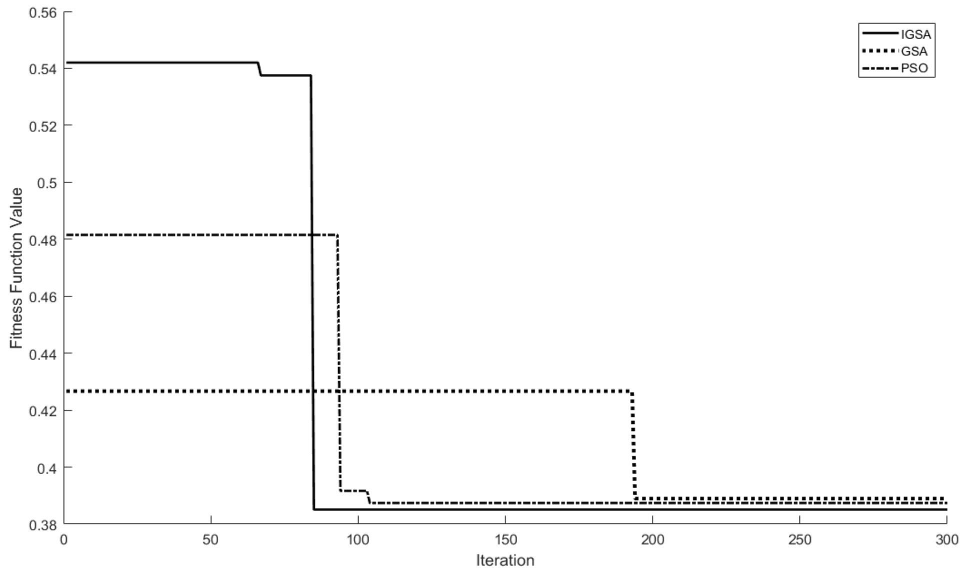

Figure 4.2 Convergence characteristic of GSA, PSO, and IGSA algorithm for 2 DGs in the 33-bus system.

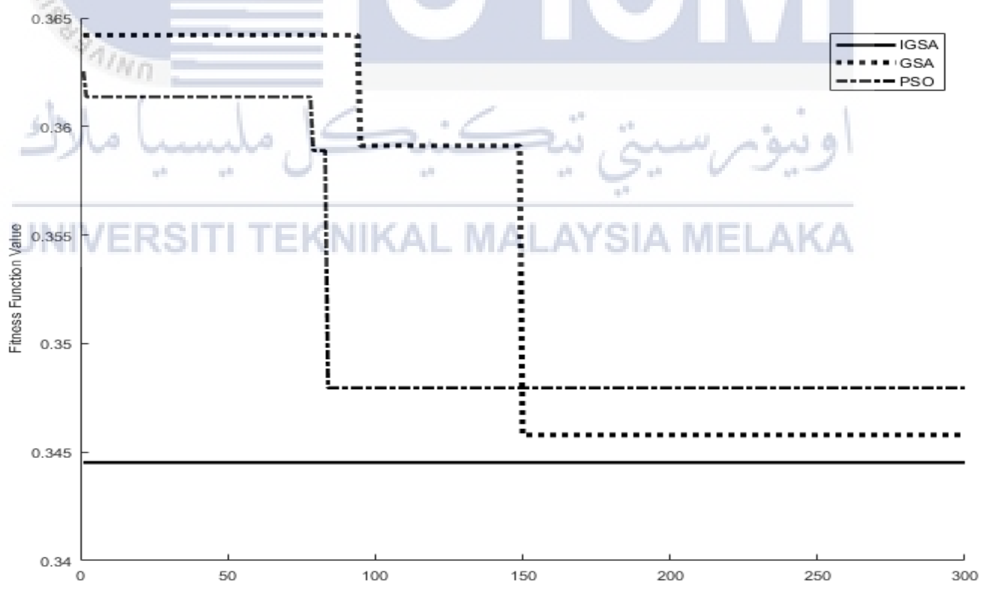

Figure 4.3 Convergence characteristic of GSA, PSO, and IGSA algorithm for 2 DG in the 69-bus system.

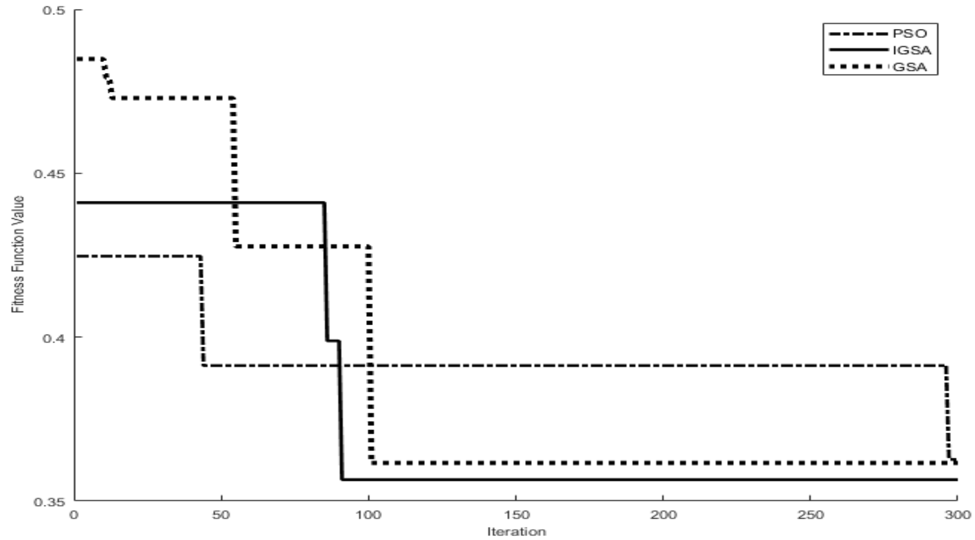

Figure 4.4 Convergence characteristic of GSA, PSO, and IGSA algorithm for 2 DGs in the 69-bus system.

4.4 Base case for power losses, and voltage deviation for variation of load level.

The statistical result for base case of power losses and voltage deviation with variation of load level and two bus system are summarized in Table 4.2. For the all cases, the total power losses are decreased if the load level decrease as shown in Table 4.2. Hence, with 33-bus system for 25 % load level and 150 % load the total power losses system has shown only 0.011MW compared with 0.455MW total power losses. Let turn to 69-bus system, the total power losses increase with respect to load level as shown in Table 4.2. The load level will significantly affect the total power losses in the system and load is directly proportional to the total power losses in distribution system respectively.

From the result shown in table 4.2, it can be noted that average voltage deviation for the base case are varying toward load level. For the 33-bus and 69-bus system, the average voltage deviation tends to increase along tolerable limit of voltage profile when load level is lowest as resulted in table 4.2. The load level is directly proportional with average voltage deviation in distribution system, with 150% load and 25% load for 33-bus the average voltage deviation with 0.923545 and 0.987758. The resulted has shown a large difference for average voltage deviation when variation of load.

To further evaluate the effectiveness of the DG impact toward distribution system, the simulation will be conducted to analyze the effect of DGs according to multi objective in this study. Base case will be used as a reference to evaluate the effect of DGs with application of three optimization techniques for six variation of load level.

Table 4.2 Base case for power losses, voltage deviation and average voltage deviation for variation of load level.

Load Variation	DG availability	Distribution system	Losses(MW)	Average Voltage Deviation
Load 25%	No DG	33-Bus	0.011	0.987758
		69-Bus	0.021	0.992116
Load 50%		33-Bus	0.047	0.975303
		69-Bus	0.053	0.986942
Load 75%		33-Bus	0.11	0.962091
		69-Bus	0.124	0.980014
Load 100%		33-Bus	0.203	0.948484
		69-Bus	0.230	0.972869
Load 125%		33-Bus	0.33	0.934182
		69-Bus	0.377	0.965217
Load 150%		33-Bus	0.455	0.923545
		69-Bus	0.573	0.957246

4.5 DG impact on power loss for variation of load level with application of three optimization techniques.

The table 4.3 and table 4.4 show the result for the power losses for 33-bus and 69-bus radial distribution system with variation of load level. Based on the simulation the data for losses were obtained to compare the total power losses of proposed optimization technique with PSO and GSA either it will affect the performance or not. For all cases the power losses tend to increase with increasing of load level as indicated in Table 4.3 and Table 4.2.

The result for 25% load level with one DG connected, IGSA techniques gives the worst total power losses reduction for both system with 0.017094MW and 0.030754MW while the PSO techniques has shown as best candidate for total power loss follow by GSA techniques. For two DG connected IGSA has resulted the best candidate in losses reduction as shown in Table 4.3 and 4.4. For 50% load level with one DG installed, PSO techniques has shown the worst candidate for total power losses reduction for both system but IGSA techniques with one DG installed, steadily shown the lowest total power loss reduction for 33-bus system and 69-bus system with 0.017331MW and 0.81022MW respectively.

The result for 75% load with one and two DGs installed in 33-bus system and 69-bus system, PSO optimization technique has resulted the optimum power losses as shown in table 4.3 and table 4.4 respectively. IGSA techniques with two DGs installation yield reduction of power losses as the worst optimum as depicted in Table 4.3 while in table 4.4 IGSA techniques with two DGs tend to be second best of total power loss respectively.

For 100% ,125% and 150% load level, the proposed IGSA tend to overcome with lowest power losses reduction compared with PSO and GSA for both system except for 125% load level with one DG implemented since IGSA has resulted the worst candidate for losses reduction as shown in table 4.4. For overall case study, IGSA has shown the average optimum in power losses reduction with respect to load variation in the distribution system respectively.

Percentage of power losses reduction can be analyzed with using this formula:

$$Ploss\ reduction = \frac{Ploss\ base\ case - Ploss\ optimum}{Ploss\ base\ case} \times 100\ \% \qquad (4.1)$$

Table 4.3 and table 4.4 illustrates the percentage of losses reduction improvement when DGs were installed in distribution system. For cases 25% load level the losses reduction not improve but increasing abnormally when DGs installed in both system. The losses are not optimum when optimum DG placement and sizing in distribution system if the load reach 25 % load level due to base case load as shown in table 4.2. For 50% load level the improvement of losses reduction can be seen with implementation of one DG in distribution system for cases 33-bus with IGSA techniques has shown the highest percentage improvement with 63.12 % but for two DGs installed the resulted has shown increasing percentage of load reduction. 69-bus system with one DG and two DGs installed not show any improvement of losses reduction as shown in table 4.4.

The result for 75 % load level, both system has shown improvement of losses reduction when one DG installed and PSO techniques gives a significant impact for improvement of losses reduction for 33-bus system and 69-bus system with 66.89% and

20.51%. Furthermore, when two DGs availability IGSA and GSA techniques not have any improvement of losses reduction except for PSO techniques respectively. For 100% load level, IGSA techniques tend to have significant impact of reduction of power loss for 33-bus and 69- bus system when DGs installed.

From the result shown in table 4.3 and table 4.4, when load level increase, it is noted that installing DGs with optimal placement and sizing has significant impacts in term of reduction of power losses improvement. For load 125% ,100% and 150%, improvement of losses tends to reach higher than 50% improvement when DGs installed in both system respectively. The reduction of losses is clearly seen when DGs installed if the load achieves 50% and above when one DG installed in the system but for two DGs installed the load level must passes above 75% to optimum the losses reduction in the system.

Table 4.3 DG impact on power loss for variation of load level with application of three optimization techniques using 33-bus system.

Load Variation	DG availability	Technique	Losses(MW)	Losses reduction (%)
Load 25%	1 DG	**PSO**	**0.013012**	**-18.29**
		GSA	0.015509	-40.99
		IGSA	0.017094	-55.4
	2 DGs	PSO	0.077647	-605.88
		GSA	0.096913	-781.02
		IGSA	**0.03915**	**-255.91**
Load 50%	1 DG	PSO	0.019751	57.97
		GSA	0.017975	61.75
		IGSA	**0.017331**	**63.12**
	2 DGs	**PSO**	**0.049554**	**-5.43**
		GSA	0.071165	-51.41
		IGSA	0.061179	-30.16
Load 75%	1 DG	**PSO**	**0.036412**	**66.89**
		GSA	0.048765	55.66
		IGSA	0.043954	60.04
	2 DGs	**PSO**	**0.077539**	**29.51**
		GSA	0.119623	-8.748
		IGSA	0.148416	-34.92
Load 100%	1 DG	PSO	0.090213	55.55
		GSA	0.084135	58.55
		IGSA	**0.064468**	**68.24**
	2 DGs	PSO	0.11946	41.15
		GSA	0.129783	36.06
		IGSA	**0.118329**	**41.70**
Load 125%	1 DG	PSO	0.107128	67.53
		GSA	0.105893	67.91
		IGSA	**0.105438**	**68.04**
	2 DGs	PSO	0.135736	58.86
		GSA	0.158036	52.11
		IGSA	**0.100804**	**69.45**
Load 150%	1 DG	PSO	0.150441	66.93
		GSA	0.14558	68.00
		IGSA	**0.142513**	**68.67**
	2 DGs	PSO	0.156046	65.70
		GSA	**0.141781**	**68.83**
		IGSA	0.142916	68.58

Table 4.4 DG impact on power loss for variation of load level with application of three optimization techniques using 69-bus system.

Load Variation	DG availability	Technique	Losses(MW)	Losses reduction (%)
Load 25%	1 DG	**PSO**	**0.018551**	**11.66**
		GSA	0.029951	-42.62
		IGSA	0.030754	-4.64
	2 DGs	PSO	0.029493	-40.44
		GSA	0.060253	-186.92
		IGSA	**0.026038**	**-23.99**
Load 50%	1 DG	PSO	0.09233	-74.21
		GSA	0.071112	-34.17
		IGSA	**0.061022**	**-15.14**
	2 DGs	PSO	0.084924	-60.23
		GSA	**0.062457**	**-17.84**
		IGSA	0.079311	-49.64
Load 75%	1 DG	PSO	**0.098565**	**20.51**
		GSA	0.109554	11.65
		IGSA	0.099578	19.69
	2 DGs	**PSO**	**0.12018**	**3.08**
		GSA	0.13001	-4.85
		IGSA	0.12422	-0.18
Load 100%	1 DG	PSO	0.076623	66.68
		GSA	0.081291	64.66
		IGSA	**0.074243**	**67.69**
	2 DGs	PSO	0.143859	37.45
		GSA	0.137256	40.32
		IGSA	**0.090104**	**60.82**
Load 125%	1 DG	PSO	0.135406	64.08
		GSA	**0.130866**	**65.29**
		IGSA	0.152262	59.61
	2 DGs	PSO	0.067864	81.99
		GSA	0.058397	84.51
		IGSA	**0.050685**	**86.56**
Load 150%	1 DG	PSO	0.177153	69.08
		GSA	0.182928	68.07
		IGSA	**0.168223**	**70.64**
	2 DGs	PSO	0.094758	83.46
		GSA	0.054848	90.43
		IGSA	**0.050869**	**91.12**

4.6 DG impact on average voltage deviation for variation of load level with application of three optimization techniques.

Average voltage deviation is multi-objective in this study for variation of load level with application of three optimization techniques using 33-bus and 69-bus system. Table 4.5 and table 4.6 shows the DG impact when installed in distribution system on average voltage deviation of variation of load level. The present of DG will be installed was one and two DGs respectively.

For case 25 % load level, with installed of one DG for 33-bus system, GSA techniques has shown the optimum average voltage deviation with 0.991644 while using 69-bus system IGSA techniques resulted 0.99994 as the optimum voltage deviation. However, PSO techniques has shown the best average voltage deviation when two DGs installed for 33-bus system while for 69-bus system GSA has the best optimum as shown in table 4.6. Table 4.5 and table 4.6, it is noted that IGSA has dominated as optimum average voltage deviation for 50% load level when one DG installed for both system and when two DGs installed for 69-bus system respectively. Moreover, for 75% load level, IGSA has shown an optimum average voltage deviation for both system either when one DG installed and two DGs installed as shown in table 4.5 and table 4.6.

The resulted for 100%, 125% and 150 % load level, the average voltage deviation tends to drop a little bit as shown in table 4.5 and 4.6. Average voltage deviation increases when load level decrease. For 100% load level IGSA tends to dominate as best candidate for optimum average voltage deviation for 33-bus system while for 69-bus system IGSA has be second best when installed one DG but for two DGs installed, IGSA has shown the best optimum value. GSA has dominated for optimum voltage deviation for 125% load level for 33-bus system and for 69-bus IGSA has shown best value when two DGs installed. IGSA has shown highest average optimum of voltage deviation if load level varies from 25% until 100% load level while GSA tend to dominate average optimum value if load level above the 100% load level as shown in table 4.5 and 4.6 respectively. Percentage of average voltage deviation improvement can be analyzed with using this formula:

$$VDimprovement = \frac{VDbasecase - VDoptimum}{VDbasecase} \times 100\% \tag{4.2}$$

Table 4.5 and table 4.6 shows the average voltage deviation improvement by the calculation using formula 4.2 and the base case in table 4.2. The voltage deviation improves when load level increase and the load level is directly proportional to voltage deviation respectively. Based on the resulted shown in table 4.5, for 25% load level IGSA techniques has no improvement of voltage deviation when one DG installed with -0.299% and GSA tend to improve until 0.393%. For 69-bus system, IGSA has shown almost 1% improvement of voltage deviation at 0.794% when one DGs availability. For two DGs installed, PSO tends to show best improvement in 33-bus system with 0.869% while 69-bus system GSA has resulted 0.646% improvement and as best candidate as shown in table 4.6.

For cases 50% load level the improvement of voltage deviation has clearly seen and the IGSA has shown the average best improvement of voltage deviation for 33-bus system and 69-bus system when except for one DG in 33-bus system since PSO tends to shown and optimum improvement of voltage deviation at 1.707% and follow by IGSA at 1.681% improvement respectively. The proposed method IGSA tends to be as the best candidates for optimal improvement of voltage deviation for 75% load level for both system. In 33-bus system, 3.239% and 3.34% improvement has resulted with one DG i and two DGs installed.

The results of the fourth case study with one DG and two DGs installed, IGSA has shown a highest voltage deviation improvement for both cases except one DGs installed due to GSA has shown 3.749% as highest improvement of voltage deviation. For 125% and 150% load level, GSA has resulted as the best candidates in voltage deviation improvement among three optimization techniques as shown in Table 4.5 and 4.6. IGSA has resulted 3.982% compared with 4.129% of GSA when one DG installed in 33-bus system but for 69-bus system small difference of improvement between GSA and IGSA has resulted for one DG installed while PSO has shown the lowest improvement of voltage deviation. The result of the 150% load level has shown percentage of voltage deviation drastically improve with huge percentage as GSA has shown 4.91% and 3.061% improvement when one DG installed in 33-bus system and two DGs installed in 69-bus system. 6.332% improvement has resulted with PSO techniques as best improvement for two DGs installed in 33-bus system while IGSA tends to be resulted as best candidates in 69-bus system with one DG installed for the sixth case study as shown in figure 4.6.

The variation of load level a directly proportional to voltage deviation improvement as shown in table 4.5 and 4.6. The highest the load level the highest voltage deviation can be improve with installation of DGs in distribution system.

Table 4.5 DG impact on average voltage deviation for variation of load level with application of three optimization techniques using 33-bus system.

Load Variation	DG availability	Technique	Average Voltage Deviation	Voltage Deviation Improvement (%)
Load 25%	1 DG	PSO	0.989541	0.181
		GSA	**0.991644**	**0.393**
		IGSA	0.984804	-0.299
	2 DGs	**PSO**	**0.996333**	**0.869**
		GSA	0.987579	0.018
		IGSA	0.991480	0.377
Load 50%	1 DG	PSO	0.989555	1.461
		GSA	0.997005	2.225
		IGSA	**0.997455**	**2.329**
	2 DGs	**PSO**	**0.991949**	**1.707**
		GSA	0.978855	0.364
		IGSA	0.991694	1.681
Load 75%	1 DG	PSO	0.990155	2.917
		GSA	0.991082	3.013
		IGSA	**0.993249**	**3.239**
	2 DGs	PSO	0.975883	1.434
		GSA	0.964536	0.254
		IGSA	**0.994226**	**3.340**
Load 100%	1 DG	PSO	0.981045	3.433
		GSA	**0.984045**	**3.749**
		IGSA	0.981877	3.521
	2 DGs	PSO	0.988770	4.247
		GSA	0.989192	4.292
		IGSA	**0.991498**	**4.535**
Load 125%	1 DG	PSO	0.970058	3.840
		GSA	**0.972759**	**4.129**
		IGSA	0.971385	3.982
	2 DGs	PSO	0.985050	5.445
		GSA	0.979700	4.872
		IGSA	**0.987402**	**5.697**
Load 150%	1 DG	PSO	0.961255	4.083
		GSA	**0.968894**	**4.910**
		IGSA	0.967659	4.777
	2 DGs	**PSO**	**0.982023**	**6.332**
		GSA	0.978175	5.915
		IGSA	0.977769	5.871

Table 4.6 DG impact on average voltage deviation for variation of load level with application of three optimization techniques using 69-bus system.

Load Variation	DG availability	Technique	Average Voltage Deviation	Voltage Deviation Improvement (%)
Load 25%	1 DG	PSO	0.993455	0.135
		GSA	0.992906	0.079
		IGSA	**0.999994**	**0.794**
	2 DGs	PSO	0.992352	0.024
		GSA	**0.998527**	**0.646**
		IGSA	0.992376	0.026
Load 50%	1 DG	PSO	0.994254	0.741
		GSA	0.994865	0.803
		IGSA	**0.996021**	**0.919**
	2 DGs	PSO	0.994331	0.749
		GSA	0.989541	0.263
		IGSA	**0.997187**	**1.038**
Load 75%	1 DG	PSO	0.986658	0.678
		GSA	0.991558	1.178
		IGSA	**0.995554**	**1.586**
	2 DGs	PSO	0.982455	0.249
		GSA	0.986685	0.681
		IGSA	**0.990003**	**1.019**
Load 100%	1 DG	PSO	0.980651	0.799
		GSA	0.987089	1.461
		IGSA	**0.988073**	**1.638**
	2 DGs	PSO	0.988549	1.612
		GSA	0.989523	1.712
		IGSA	**0.991067**	**1.871**
Load 125%	1 DG	PSO	0.981155	1.651
		GSA	**0.982957**	**1.838**
		IGSA	0.982899	1.832
	2 DGs	PSO	0.990286	2.597
		GSA	**0.990991**	**2.670**
		IGSA	0.989242	2.489
Load 150%	1 DG	PSO	0.964885	0.798
		GSA	0.979626	2.338
		IGSA	**0.979635**	**2.339**
	2 DGs	PSO	0.984419	2.839
		GSA	**0.986550**	**3.061**
		IGSA	0.985540	2.956

4.7 DG impact on average THD*v* for variation of load level with application of three optimization techniques.

The occurrence of the harmonics in the system can be incorporated with the inverter with the harmonic producing loads and device of inverter-based DG that producing of harmonic in the distribution system as shown in table 4.1. Total harmonic is an important aspect in power systems and it should be kept as low as possible where THD*vmax* is the maximum allowable level at each bus is 5% respectively. From the result shown in table 4.7 and table 4.8, the THD*v* is slightly changing with respect to load level. THD*v* is highest when the load level decrease as depicted in table 4.7 and table 4.8.

For 25% load level the THD*v* is slightly increase compared to THD*v* in case fourth, as PSO techniques has shown the highest THD*v* for one DG installed in 33-bus system and 69-bus system with 2.0087% and 1.027733% respectively while IGSA techniques has the lowest THD*v* with one DG installed in 33-bus system and two DGs installed in 69-bus system with 1.9932% and 1.0218% as shown in table 4.7 and 4.8. GSA techniques has resulted with 2.0974% and 1.0119% when two DGs installed in 33-bus system and one DGs installed in 69-bus system. THD*v* is slightly increased with the number of DGs.

The resulted for 50% load level the THD*v* is decreased compared to case 1 where PSO techniques has shown the lowest THD*v* at 0.991653% for 33-bus system follow by IGSA and GSA techniques if one DG installed. However, 0.9949% THD*v as* the lowest percentage resulted by GSA techniques if two DGs installed. Furthermore, IGSA tends to dominate as best candidate for optimal THD*v* for 69-bus system in 50% load level as shown in table 4.8. For 75% load level GSA techniques has shown 0.6509%,0.6628% and 0.5212% as lowest THD*v* in one DG 33-bus, two DGs 33-bus and one DG 69-bus respectively while IGSA with 0.5% for 69-bus system when two DGs installed.

100% load level has shown PSO techniques dominated as optimal placement and sizing for THD*v* reduction for 33-bus system and 69-bus system and the THD*v* is slightly decreased compared to 75% load level. The proposed IGSA tends to result as optimum THDv in 125% load level for both system with present of one DG and two DGs respectively as shown in table 4.7 and table 4.8. 0.393116% is the lowest percentage THD*v* resulted in 33-bus system with using IGSA techniques with two DGs installed. The result of the last case study with one DG and two DGs connected to the system are depicted in tables 4.7 and 4.8. PSO techniques has shown 0.40355% and IGSA with 0.4015% when one and two DGs installed in 33-bus system as best optimum THD*v* with variation of 150% load level. However, in 69-bus, IGSA tends to be best candidate when one DG installed and PSO resulted as best THD*v* with two DGs installed as shown in table 4.8.

Total harmonic distortion (THD) is an important aspect in power systems and it should be kept as low as possible. Lower THD in power systems means higher power factor, lower peak currents, and higher efficiency. Low THD is such an important feature in power systems to set limits on the harmonic currents of various classes of power equipment.

Table 4.7 DG impact on average THD*v* for variation of load level with application of three optimization techniques using 33-bus system.

Load Variation	DG availability	Technique	Average THD*v* (%)
Load 25%	1 DG	PSO	2.008568
		GSA	1.997636
		IGSA	**1.993228**
	2 DGs	PSO	2.146542
		GSA	**2.097424**
		IGSA	2.114125
Load 50%	1 DG	**PSO**	**0.991635**
		GSA	0.997575
		IGSA	0.993167
	2 DGs	PSO	1.013134
		GSA	**0.994911**
		IGSA	0.998376
Load 75%	1 DG	PSO	0.658226
		GSA	**0.650975**
		IGSA	0.654395
	2 DGs	PSO	0.664912
		GSA	**0.662894**
		IGSA	0.674173
Load 100%	1 DG	**PSO**	**0.482678**
		GSA	0.485075
		IGSA	0.498678
	2 DGs	**PSO**	**0.489467**
		GSA	0.49805
		IGSA	0.496432
Load 125%	1 DG	PSO	0.4043
		GSA	0.406037
		IGSA	**0.403294**
	2 DGs	PSO	0.394798
		GSA	0.439641
		IGSA	**0.393116**
Load 150%	1 DG	**PSO**	**0.403448**
		GSA	0.410749
		IGSA	0.409005
	2 DGs	PSO	0.407351
		GSA	0.483203
		IGSA	**0.401549**

Table 4.8 DG impact on average THD*v* for variation of load level with application of three optimization techniques using 69-bus system.

Load Variation	DG availability	Technique	Average THD*v* (%)
Load 25%	1 DG	PSO	1.027733
		GSA	**1.011906**
		IGSA	1.015283
	2 DGs	PSO	1.091303
		GSA	1.078867
		IGSA	**1.021817**
Load 50%	1 DG	PSO	0.711942
		GSA	0.754225
		IGSA	**0.71057**
	2 DGs	PSO	0.696959
		GSA	0.711121
		IGSA	**0.694665**
Load 75%	1 DG	PSO	0.555854
		GSA	**0.521248**
		IGSA	0.528788
	2 DGs	PSO	0.566266
		GSA	0.611588
		IGSA	**0.500215**
Load 100%	1 DG	**PSO**	**0.355385**
		GSA	0.355822
		IGSA	0.358505
	2 DGs	**PSO**	**0.364219**
		GSA	0.367019
		IGSA	0.392891
Load 125%	1 DG	PSO	0.330193
		GSA	0.336369
		IGSA	**0.313716**
	2 DGs	PSO	0.331775
		GSA	0.3014
		IGSA	**0.286754**
Load 150%	1 DG	PSO	0.150441
		GSA	0.14558
		IGSA	**0.142513**
	2 DGs	PSO	0.156046
		GSA	**0.141781**
		IGSA	0.142916

4.8 Voltage profile in the 33-bus and 69-bus radial distribution system.

Besides minimizing the power loss, THDv, appropriate DG planning would improve the overall voltage profile. Voltage profile is observer according to IGSA as proposed method for 100 % load level. Figure 4.5 – 4.6 shows the voltage profile at all the 33 bus and 69 bus system considering pre and post DG integration. In figure 4.5, the simulation result showed the voltage profile for 100 % load level with installed of one DG and two DGs in the distribution system using IGSA techniques for 33-bus system. DG location is selected at buses 29 with 1 DG implementation. The voltage profile is increase directly to 1.0038pu after one DG was optimally installed in the distribution system based on IGSA technique results. Figure 4.5 illustrates the voltage profiles when two DGs are optimally installed at buses 7 and buses 16. The voltage profile tends to increase to 1.006pu when DG was installed at buses 7 compared to no DG installed the voltage profile at buses 7 only reach 0.946pu and at buses 16, when DGs was installed voltage profile slightly start to increase to reference voltage magnitude within the specified limit as shown in figure 4.5 respectively.

It is noted that the voltages magnitudes are increased, especially at the bus where the DGs are installed. In figure 4.6 shows the voltage profile when one DG and two DGs installed for 69-bus system. Voltage profile tends to increase to 0.9888pu at buses 64 when one DG installed at the system as shown in figure 4.6. When two DGs installed at buses 7 and buses 62, the voltage profile has shown a little bit decreased at buses 7 from 0.9969pu to 0.9943pu but it slowly decreased within the specified limit. Hence, in buses 62 the voltage profile tends to reach an optimal voltage profiles as shown in figure 4.6.

The overall voltage profiles show the increase in voltage magnitudes within the specified limit when best allocation of DGs installed at the optimal buses in the system. The comparison of the voltage profile when no DG installed with DG installed is illustrated in figure 4.5 and figure 4.6 when 100% is considered with using IGSA as optimization technique. By increasing the number of DGs at the optimal buses, the overall voltages profiles are significantly improved in which the voltage magnitudes are increased but within the specified limits.

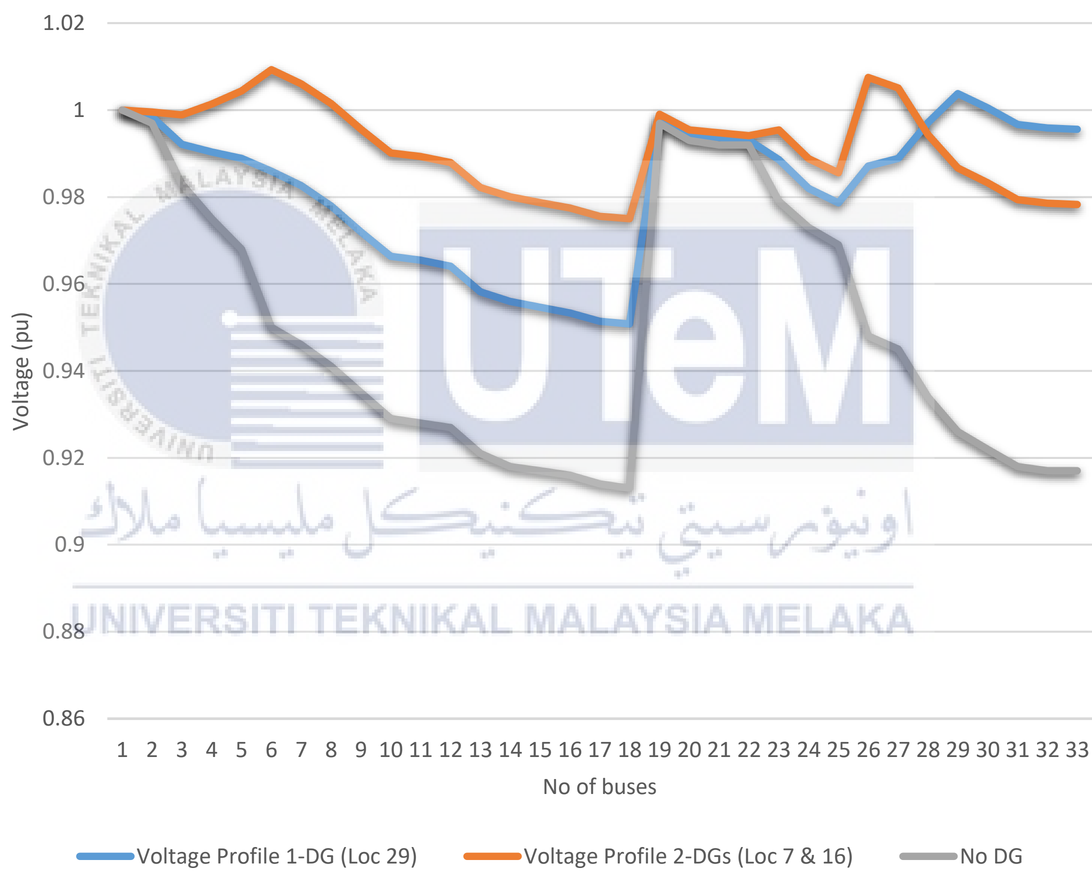

Figure 4.5: Voltage profile in the 33-bus radial distribution test system using IGSA technique.

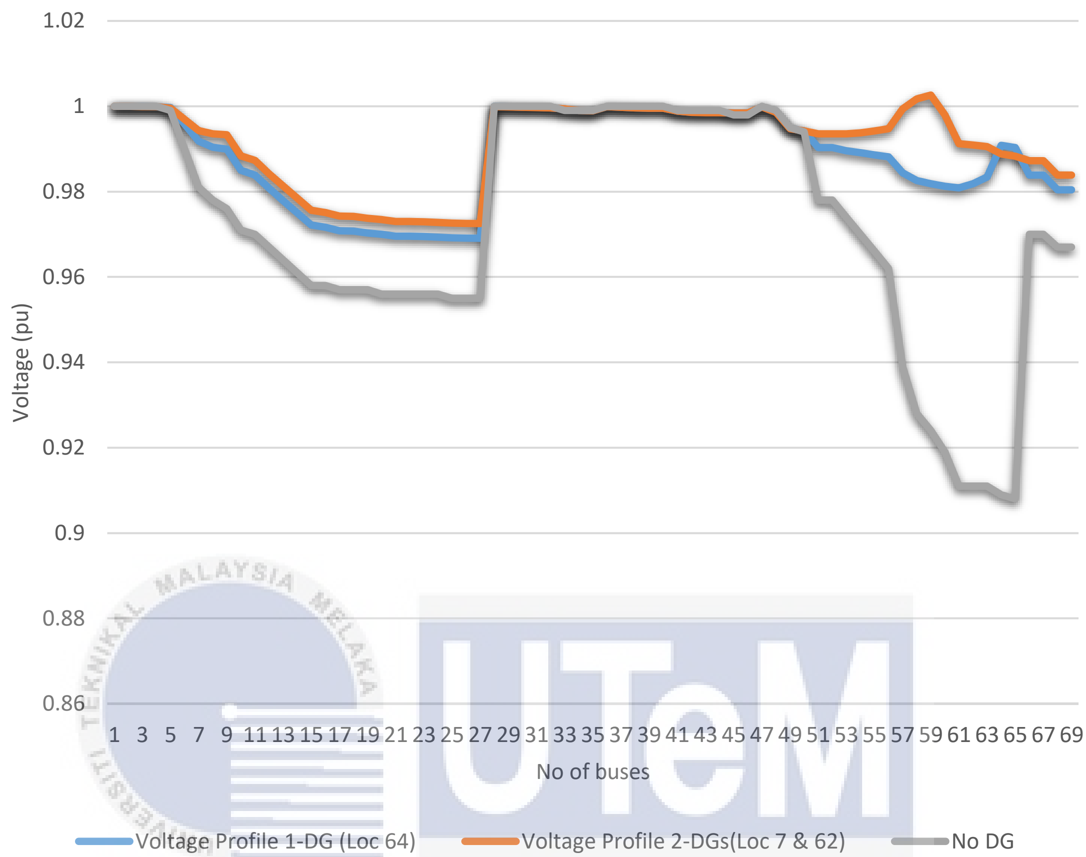

Figure 4.6: Voltage profile in the 69-bus radial distribution test system using IGSA technique.

4.9 Impact of allocation and sizing of DGs for variation of load level.

To further evaluate the effectiveness of the IGSA, Table 4.9 shows the result for sizing and location of the DGs in the distribution system with application of three optimization techniques. DG sizing for each simulation will varying abnormally with variation of load level because the location of the DGs will changing when simulations were conducted using application of three optimization techniques.

DGs sizes cannot be analyze with variation of load level due to location and placement of DGs is different. Sizes of DGs is depends on power will be inject in grid and the location of the buses as optimal placement DG installation. Even though the losses are reduced linearly with load level changing when implementation of DGs, DGs sizes are changing non-linearly with variation of load level because sizes of DGs based on best location of the optimal placement of DGs installed.

Table 4.9 DG sizing and location for variation load level using three optimization techniques.

DG availability	Bus system	Techniques	DG sizing (MW)	Location
1 DG	33-Bus system	PSO	1.970354	16
		GSA	3.234342	16
		IGSA	2.535031	29
2 DGs		PSO	2.822671 & 3.284213	27&29
		GSA	2.695876 & 2.014885	26&28
		IGSA	3.264253 & 2.978947	7 & 16
1 DG	69-Bus system	PSO	1.496606	4
		GSA	1.824211	61
		IGSA	1.104984	64
2 DGs		PSO	2.336721 & 2.184659	38 & 35
		GSA	2.133871 & 1.13226	43 & 49
		IGSA	1.864295 & 2.244324	7 & 62

4.10 Chapter summary

In this chapter the 33-bus and 69-bus radial distribution system was tested in one DG and two DGs availability for variation of load level with three application of load level. The statistical result for best fitness, power losses reduction, voltage deviation improvement, THDv, voltage profile will be summarized. Simulation by using MATLAB has been done to get the result of optimal placement and sizing of the DGs placement which is using IGSA as purposed method and compared with PSO and GSA techniques. The conclusion for overall impact of DGs regarding to objective will be explained in chapter 5.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

This research provided a new approach for determining the optimal placement and sizing of DG using the purposed IGSA techniques. Minimize the total power loss, average voltage deviation and average voltage harmonic distortion are the multi-objective function in this study. The results show that the proposed IGSA is effective in finding optimum size and locations of the DGs in power distribution system according to the result obtained through the simulation in this research. Losses will reduce with the present of DG install in the system if optimum load level is applied in distribution system. The reduction of losses, improvement of voltage deviation and average total voltage harmonic distortion is evidently seen after optimizing the DG placement and sizing. The placement of the DG with the optimal way may tend to achievement the maximum benefit of installation of the DG in the system due to optimization method is capable to resulted the best solution in the distribution system. The IGSA techniques perform better compared to the PSO and GSA in minimizing the losses, improvement of voltage deviation and THD*v* in dominating over the other for variation of load level. Because of that, this research is suitable for future analysis due to growth power demand that tend for installation of DG, so that the data analysis and result that obtained can be used to other else as a reference when related with optimal approach for placement DGs in distribution generation in radial network considering load variation

5.2 Recommendation

There is recommendation for future work for this research. The distribution system can be change with other IEEE distribution system to study the power losses minimization and average voltage improvement in unbalanced system. Furthermore, application with other heuristic method such as genetic algorithm, ant colony and differential evolution can be used as optimal placement and sizing of DG and compared with IGSA techniques with multi objective function added which is power quality control as other multi objective. The impact of DG on short circuit current should be investigated and study the effect of multi-objective function with respect to total cost in the distribution system.

REFERENCES

[1] T. Ackermann and T. Ackermann, "Distributed Generation : A Definition Distributed generation : a definition," vol. 7796, no. August 2016, pp. 195–204, 2001.

[2] N. Iman and B. T. Mat, "Signature Author Date," no. November, 2009.

[3] S. S. Rawat, "Optimum Placement and Sizing of DGs Using Analytical Method for Different Types of Loads," pp. 1–5, 2015.

[4] I. A. Hydro and E. Centre, "{ I," pp. 1–5, 2016.

[5] D. Singh and R. K. Misra, "Effect of Load Models in Distributed Generation Planning," *Power Syst. IEEE Trans.*, vol. 22, no. 4, pp. 2204–2212, 2007.

[6] O. Amanifar, "Optimal Distributed Generation Placement and Sizing for Loss and THD Reduction and Voltage Profile Improvement in Distribution Systems Using Particle Swarm Optimization and sensitivity analysis," *Electr. Power Distrib. Networks (EPDC), 2011 16th Conf.*, pp. 1–7, 2011.

[7] P. Alinezhad, O. Z. Bakhoda, and M. B. Menhaj, "Optimal DG placement and capacity allocation using intelligent algorithms," *4th Iran. Jt. Congr. Fuzzy Intell. Syst. CFIS 2015*, 2016.

[8] M. R. Ab Ghani, C. K. Gan, and I. J. Hasan, "Optimum Distributed Generation Allocation Using PSO in order to Reduce Losses and Voltage Improvement," *3rd IET Int. Conf. Clean Energy Technol. 2014*, p. 29 (6 .)-29 (6 .), 2014.

[9] E. Rashedi, H. Nezamabadi-pour, and S. Saryazdi, "GSA: A Gravitational Search Algorithm," *Inf. Sci. (Ny).*, vol. 179, no. 13, pp. 2232–2248, 2009.

[10] A. F. A. Kadir, A. Mohamed, H. Shareef, A. A. Ibrahim, T. Khatib, and S. Energy, "An improved gravitational search algorithm for optimal placement and sizing of renewable distributed generation units in a distribution system for power

quality enhancement," *J. Renew. Sustain. Energy*, vol. 6, no. 3, pp. 1–17, 2014.

[11] A. A. Ibrahim, A. Mohamed, and H. Shareef, "A novel quantum-inspired binary gravitational search algorithm in obtaining optimal power quality monitor placement," *Journal of Applied Sciences*, vol. 12, no. 9. pp. 822–830, 2012.

[12] M. Eslami, H. Shareef, A. Mohamed, and M. Khajehzadeh, *An efficient particle swarm optimization technique with chaotic sequence for optimal tuning and placement of PSS in power systems*, vol. 43. 2012.

[13] D. Singh, D. Singh, and K. Verma, "GA based optimal sizing & placement of distributed generation for loss minimization," *Int. J. Electr.*, vol. 1, no. 11, pp. 1604–1610, 2007.

[14] M. Hosseini and R. Baghipour, "Optimal Placement of DGs in Distribution System including Different Load Models for Loss Reduction using Genetic Algorithm," vol. 4, no. 3, pp. 55–68, 2013.

[15] A. F. Abdul kadir, A. Mohamed, H. Shareef, and M. Z. Che Wanik, "Optimal placement and sizing of distributed generations in distribution systems for minimizing losses and THDv using evolutionary programming," *Turkish J. Electr. Eng. Comput. Sci.*, vol. 21, no. SUPPL. 2, pp. 2269–2282, 2013.

[16] A. M. El-Zonkoly, "Optimal placement of multi-distributed generation units including different load models using particle swarm optimisation," *IET Gener. Transm. Distrib.*, vol. 5, no. 7, p. 760, 2011.

[17] A. KADIR and A. MOHAMED, "Optimal sizing and placement of distributed generation in distribution system considering losses and THDv using gravitational search algorithm," *Przegl. …*, no. 4, pp. 132–136, 2013.

[18] S. Kansal, B. B. R. Sai, B. Tyagi, and V. Kumar, "Optimal placement of distributed generation in distribution networks," *Int. J. Eng. Sci. Technol.*, vol. 3, no. 3, pp. 47–55, 2011.

[19] H. N. Niri and A. Jalili, "Optimal placement of distribution generation in power system by modified gravitational search algorithm," vol. 4, no. 1, pp. 30–38,

2016.

[20] A. Bansal and S. Singh, "Optimal Allocation and Sizing of Distributed," pp. 15–20, 2016.

[21] Emily ruby ,2016 "Microgrids and Grid Modernization" April 12, 2016

[22] J. Kennedy, R. Eberhart, "Particle Swarm Optimization", IEEE,1995, PP.1942

[23] Krischonme Bhumkittipich, Weerachai Phuangpornpitak. 2013 "Optimal Placement and Sizing of Distributed Generation for Power Loss Reduction using Particle Swarm Optimization." Energy Procedia 34

[24] Purva Shanna, Ankush Tandon, 2015 "Techniques for Optimal Placement of DG in Radial Distribution System: A Review". 2015 International Conference on Communication, Control and Intelligent Systems (CCIS).

[25] Rajkumar Viral, D.K. Khatod, 2012"Optimal planning of distributed generation systems in distribution system: A review", Renewable and Sustainable Energy Reviews, vol. 16, pp. 5146-5165, 2012

[26] Rau N.S., Wan Y.H., 1994 "Optimal location of resources in distributed planning" IEEE. Trans. on Power Systems, 9(1994), No. 1, 2014-2020

[27] Santiago Miret, 2014"Distributed energy generation is coming" 10 September 2014

[28] Somenath Chakraborty, Sarmistha "Genetic Programming –An Approach to Smart Machine" Journal of Institution of Engineers, Vol. 86, pp. 37-40, Dec 2005

[29] (2017, November 18). Distributed generation[online]. Available: https://en.wikipedia.org/wiki/Distributed_generation#Overview.

[30] (2017, November 8) Wind exchange [online]. Available: https://windexchange.energy.gov/small-wind-guidebook#intro[wind].

[31] (2017, November 8) Networktasman [online]. Available: http://www.networktasman.co.nz/solar[solar].

APPENDICES

APPENDIX A

Gannt Chart

Task	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Case study are added based on future works on FYP 1														
Simulation for 33 buses with heuristic method that are PSO, GSA and IGSA. ❖ 25% load (1,2 bus) ❖ 50% load (1,2 bus) ❖ 75% load (1,2 bus) ❖ 100% load (1,2 bus) ❖ 125% load (1,2 bus) ❖ 150% load (1,2 bus)														
Stimulate the method used in MATLAB														
Study the MATLAB coding for the simulation for each case.														
Tabulated the data and analyze the result														
Simulation for 69 buses with heuristic method that are PSO, GSA and IGSA ❖ 25% load (1,2 bus) ❖ 50% load (1,2 bus) ❖ 75% load (1,2 bus) ❖ 100% load (1,2 bus) ❖ 125% load (1,2 bus) ❖ 150% load (1,2 bus)														
Stimulate the method used in MATLAB														
Tabulated the data and analyze the result														

Task	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Validate the data obtained from the simulation with supervisor														
Achieve the main objective in this research according to simulation result.														
Represent all the result in proper way (table, graph, chart) and conclude the result based on main objective.														
Write paper for publish in IJEEAS based on the result obtained.														
Do a correction for FYP report.														
Conclude the data obtain with the theoretical														
Finish up slide for FYP 2														
Preparing for presentation.														
Finish the FYP 2 report.														

APPENDIX B

IEEE 33 BUS TEST SYSTEM DATA

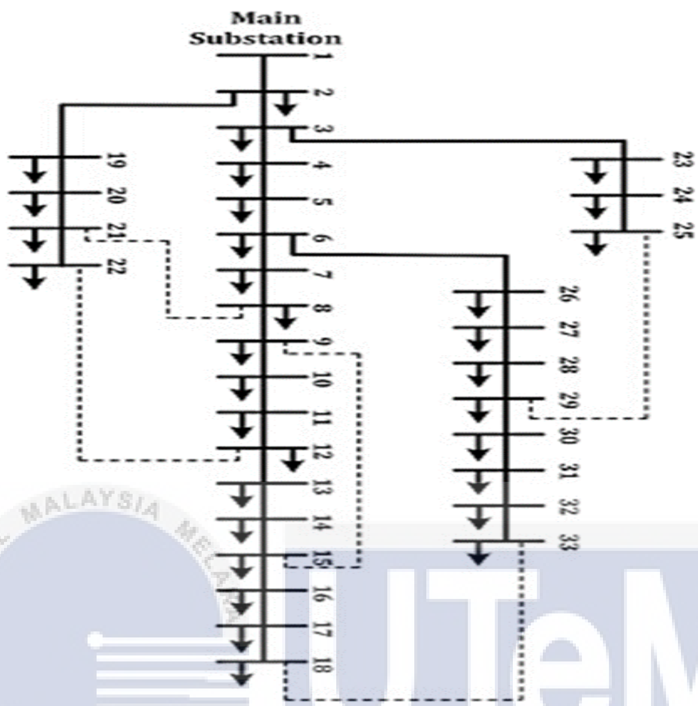

Table 1: Line data in 33-bus IEEE test system

From Bus	To Bus	R (p.u.)	X (p.u.)	From Bus	To Bus	R (p.u.)	X (p.u.)
2	3	0.03076	0.01567	2	19	0.01023	0.00976
3	4	0.02284	0.01163	19	20	0.09385	0.08457
4	5	0.02378	0.01211	20	21	0.02555	0.02985
5	6	0.0511	0.04411	21	22	0.04423	0.05848
6	7	0.01168	0.03861	3	23	0.02815	0.01924
7	8	0.04439	0.01467	23	24	0.05603	0.04424
8	9	0.06426	0.04617	24	25	0.0559	0.04374
9	10	0.06514	0.04617	6	26	0.01267	0.00645
10	11	0.01227	0.00406	26	27	0.01773	0.00903
11	12	0.02336	0.00772	27	28	0.06607	0.05826
12	13	0.09159	0.07206	28	29	0.05018	0.04371
13	14	0.03379	0.04448	29	30	0.03166	0.01613
14	15	0.03687	0.03282	30	31	0.0608	0.06008
15	16	0.04656	0.034	31	32	0.01937	0.02258
16	17	0.08042	0.10738	32	33	0.02128	0.03319
17	18	0.04567	0.03581	1	2	0.00575	0.00293

Table 2: Load data in 33-bus IEEE test system

Bus number	P (kW)	Q (kVAr)
1	0	0
2	100	60
3	90	40
4	120	80
5	60	30
6	0	0
7	200	100
8	200	100
9	60	20
10	60	20
11	45	30
12	60	35
13	60	35
14	120	80
15	60	10
16	60	20
17	60	20
18	90	40
19	90	40
20	90	40
21	90	40
22	90	40
23	90	50
24	420	200
25	420	200
26	60	25
27	0	0
28	60	20
29	120	70
30	200	600
31	150	70
32	210	100
33	60	40

IEEE 69 BUS TEST SYSTEM DATA

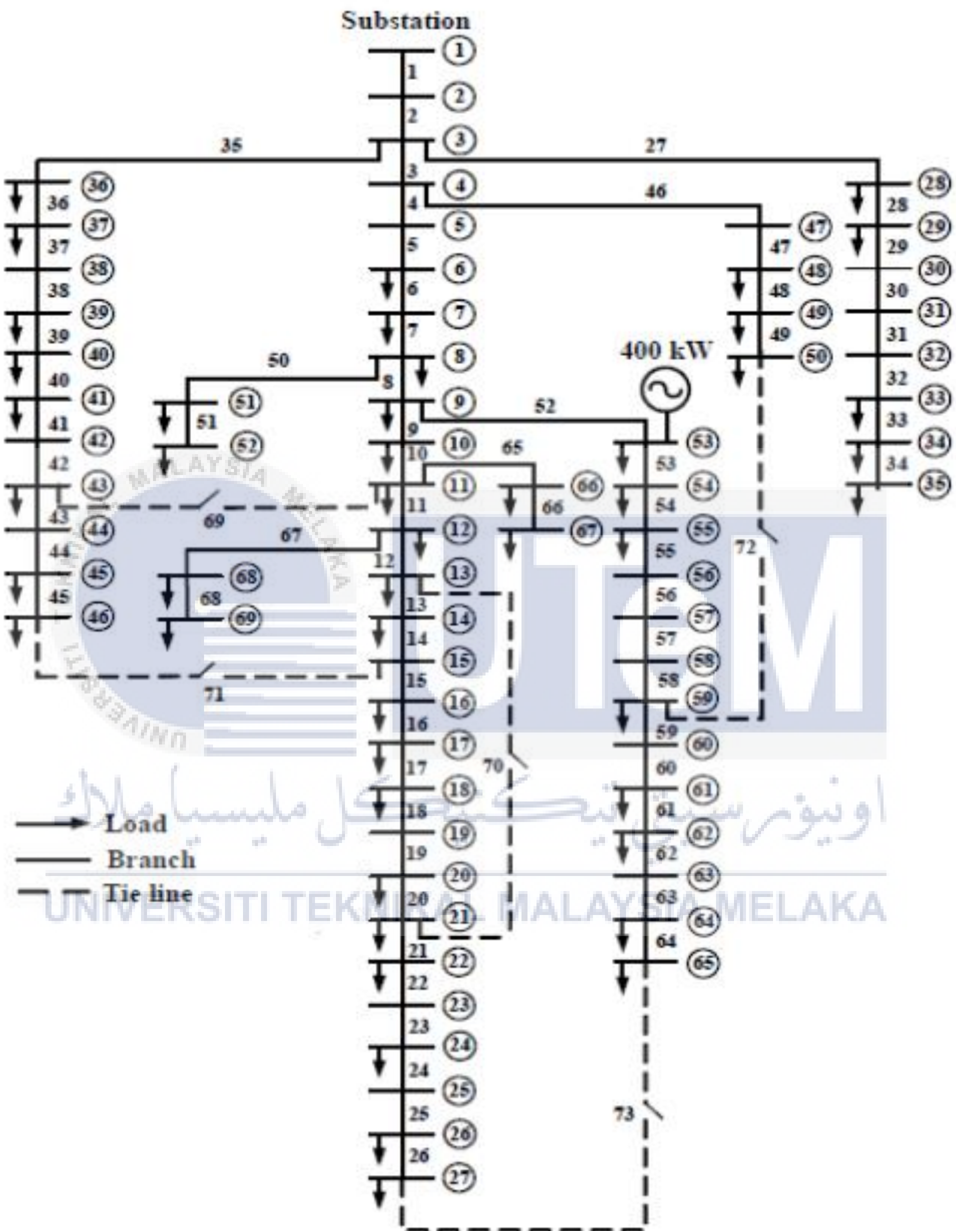

Fig.24. Single line data of 69 bus test system.

Table A: System data for 69-bus radial distribution network ('*' denotes a tie-line)

Branch Number	Sending Bus	Receiving Bus	Resistance Ω	Reactance Ω	Nominal Load at Receiving Bus		Maximum Line Capacity (kVA)
					P (kW)	Q (kVAr)	
1	1	2	0.0005	0.0012	0.0	0.0	10761
2	2	3	0.0005	0.0012	0.0	0.0	10761
3	3	4	0.0015	0.0036	0.0	0.0	10761
4	4	5	0.0251	0.0294	0.0	0.0	5823
5	5	6	0.3660	0.1864	2.60	2.20	1899
6	6	7	0.3811	0.1941	40.40	30.00	1899
7	7	8	0.0922	0.0470	75.00	54.00	1899
8	8	9	0.0493	0.0251	30.00	22.00	1899
9	9	10	0.8190	0.2707	28.00	19.00	1455
10	10	11	0.1872	0.0619	145.00	104.00	1455
11	11	12	0.7114	0.2351	145.00	104.00	1455
12	12	13	1.0300	0.3400	8.00	5.00	1455
13	13	14	1.0440	0.3450	8.00	5.50	1455
14	14	15	1.0580	0.3496	0.0	0.0	1455
15	15	16	0.1966	0.0650	45.50	30.00	1455
16	16	17	0.3744	0.1238	60.00	35.00	1455
17	17	18	0.0047	0.0016	60.00	35.00	2200
18	18	19	0.3276	0.1083	0.0	0.0	1455
19	19	20	0.2106	0.0690	1.00	0.60	1455
20	20	21	0.3416	0.1129	114.00	81.00	1455
21	21	22	0.0140	0.0046	5.00	3.50	1455
22	22	23	0.1591	0.0526	0.0	0.0	1455
23	23	24	0.3463	0.1145	28.00	20.0	1455
24	24	25	0.7488	0.2475	0.0	0.0	1455

25	25	26	0.3089	0.1021	14.0	10.0	1455
26	26	27	0.1732	0.0572	14.0	10.0	1455
27	3	28	0.0044	0.0108	26.0	18.6	10761
28	28	29	0.0640	0.1565	26.0	18.6	10761
29	29	30	0.3978	0.1315	0.0	0.0	1455
30	30	31	0.0702	0.0232	0.0	0.0	1455
31	31	32	0.3510	0.1160	0.0	0.0	1455
32	32	33	0.8390	0.2816	14.0	10.0	2200
33	33	34	1.7080	0.5646	9.50	14.00	1455
34	34	35	1.4740	0.4873	6.00	4.00	1455
35	3	36	0.0044	0.0108	26.0	18.55	10761
36	36	37	0.0640	0.1565	26.0	18.55	10761
37	37	38	0.1053	0.1230	0.0	0.0	5823
38	38	39	0.0304	0.0355	24.0	17.00	5823
39	39	40	0.0018	0.0021	24.0	17.00	5823
40	40	41	0.7283	0.8509	1.20	1.0	5823
41	41	42	0.3100	0.3623	0.0	0.0	5823
42	42	43	0.0410	0.0478	6.0	4.30	5823
43	43	44	0.0092	0.0116	0.0	0.0	5823
44	44	45	0.1089	0.1373	39.22	26.30	5823
45	45	46	0.0009	0.0012	39.22	26.30	6709
46	4	47	0.0034	0.0084	0.00	0.0	10761
47	47	48	0.0851	0.2083	79.00	56.40	10761
48	48	49	0.2898	0.7091	384.70	274.50	10761
49	49	50	0.0822	0.2011	384.70	274.50	10761
50	8	51	0.0928	0.0473	40.50	28.30	1899
51	51	52	0.3319	0.1114	3.60	2.70	2200
52	52	53	0.1740	0.0886	4.35	3.50	1899
53	53	54	0.2030	0.1034	26.40	19.00	1899
54	54	55	0.2842	0.1447	24.00	17.20	1899

55	55	56	0.2813	0.1433	0.0	0.0	1899
56	56	57	1.5900	0.5337	0.0	0.0	2200
57	57	58	0.7837	0.2630	0.0	0.0	2200
58	58	59	0.3042	0.1006	100.0	72.0	1455
59	59	60	0.3861	0.1172	0.0	0.0	1455
60	60	61	0.5075	0.2585	1244.0	888.00	1899
61	61	62	0.0974	0.0496	32.0	23.00	1899
62	62	63	0.1450	0.0738	0.0	0.0	1899
63	63	64	0.7105	0.3619	227.0	162.00	1899
64	64	65	1.0410	0.5302	59.0	42.0	1899
65	11	66	0.2012	0.0611	18.0	13.0	1455
66	66	67	0.0047	0.0014	18.0	13.0	1455
67	12	68	0.7394	0.2444	28.0	20.0	1455
68	68	69	0.0047	0.0016	28.0	20.0	1455
69*	11	43	0.5000	0.5000			566
70*	13	21	0.5	0.5			566
71*	15	46	1.0	1.0			400
72*	50	59	2.0	2.0			283
73*	27	65	1.0	1.0			400