A DISTRIBUTION NETWORK RECONFIGURATION (DNR) OF 132/11KV DISTRIBUTION NETWORK USING IMPROVED GENETIC ALGORITHMS (IGA)

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2015

DECLARATION

I declare that this report entitle "A Distribution Network Reconfiguration (DNR) of 132/11kv Distribution Network Using Improved Genetic Algorithms (IGA)" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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" I hereby declare that I have read through this report entitle "A Distribution Network Reconfiguration (DNR) of 132/11kv Distribution Network Using Improved Genetic Algorithms (IGA)" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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DEDICATION

This report is specially dedicated to my beloved family

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ABSTRACT

The function of distribution system is to deliver power to the customers continuously. However, the increasing amount of load demand has affected the reliability and effectiveness of the distribution system due to the increasing in power losses. Hence, the distribution network reconfiguration (DNR) method is introduced. The initial network is reconfigured by changing the status of tie-switches and sectionalizing switches located at certain points in the network to find the best route that has the lowest power losses. At the same time, a radial network structure is maintained with all loads energized. Multiple parameter constraints are considered for real-power loss reduction, in which all buses voltage profile is kept within a range and is not allowed to exceed their rated capacities. Since the complex branch network, thus genetic algorithm is used to ensure that the DNR process is completed immediately. In addition, the percentage of power losses reduction in the distribution system can be increase by utilizing a small scale power generation known as distribution generation (DG) into the network system. In this project an implementation of DNR using an improved genetic algorithm (IGA) is applied to IEEE 69 bus system to verify the validity and effectiveness of the proposed algorithm. The task consists of two parts; first is the DNR without DG while the other part is the DNR with DG for the identified of IEEE bus system. The results show that the reconfiguration process has given a great impact in term of power losses reduction and voltage profile improvement. Besides that, the participation from distribution generator (DG) make the distribution system perform greater than before DG installation. From the results, the performance of the selection and crossover IGA is better than of the other approaches which is GA, selection IGA and crossover IGA.

Keywords: Distribution Network Reconfiguration (DNR), Genetic Algorithm (GA), Improved Genetic Algorithm (IGA), Distributed Generator (DG)

ABSTRAK

Fungsi sistem pengagihan adalah untuk menyalurkan kuasa kepada pengguna secara berterusan. Walau bagaimanapun, jumlah beban yang semakin meningkat telah memberi kesan buruk kepada kebolehpercayaan dan keberkesanan sistem pengedaran disebabkan oleh peningkatan dalam kehilangan kuasa. Oleh itu, kaedah konfigurasi semula rangkaian pengedaran (DNR) telah diperkenalkan. Rangkaian awal diatur semula dengan menukar status suis tie dan suis sectionalizing yang terletak di tempat-tempat tertentu dalam rangkaian untuk mencari jalan yang terbaik yang mempunyai kehilangan kuasa yang paling rendah. Pada masa yang sama, struktur rangkaian jejari dikekalkan dan pada masa yang sama semua beban disalurkan dengan jumlah tenaga yang secukupnya. Setiap kekangan telah diambil kira, di mana semua profil bas voltan mestilah berada pada paras dan tidak boleh melebihi kapasiti yang telah ditetapkan. Tambahan pula, disebabkan rangkaian cawangan yang besar, algoritma genetik digunakan untuk memastikan proses konfigurasi semula diselesaikan dengan cepat. Di samping itu, bagi meningkatkan kadar peratusan pengurangan bagi kehilangan kuasa dalam sistem pengagihan adalah dengan menggunakan sistem penjanaan kuasa skala kecil yang dikenali sebagai sistem janakuasa pengedaran (DG) dan disalurkan terus ke dalam sistem rangkaian. Dalam projek ini, konfigurasi semula dilaksakan dengan menggunakan algoritma genetik yang telah ditambahbaik (IGA) dan dianalisis menggunakan sistem rangkaian IEEE 69 bas bagi mengesahkan kesahihan dan keberkesanan algoritma yang dicadangkan. Hasil kajian menunjukkan bahawa proses konfigurasi semula telah memberikan kesan yang besar dari segi mengurangkan kehilangan kuasa dan peningkatan profil voltan. Di samping itu, penyertaan dari penjana pengedaran (DG) membuat sistem pengagihan yang melaksanakan lebih besar daripada sebelum pemasangan DG. Hasil kajian menunjukkan bahawa prestasi IGA yang dicadangkan itu adalah lebih baik berbanding pendekatan lain.

Keywords: Distribution Network Reconfiguration (DNR), Genetic Algorithm (GA), Improved Genetic Algorithm (IGA), Distributed Generator (DG)

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, electricity is the most important thing that help human to complete their daily routine. Without electricity, a lot of work will be affected. For example, a factory will be closed down, communication system will be disconnected, national communication system will be affected and there are many bad things can happen to the country. Hence, a good grid power system is very important and many researches are done to improve the national grid system.

Power system is divided into three main part which are generation, transmission and distribution. Generation system or also known as power plant used the concept of thermodynamic where energy cannot be created or destroyed but can be transferred and transformed from one form to another form. For example, fuel power plant used an energy source of burning fuel to rotate the generator turbine and transform the kinetic energy to electric energy. The second stage of power system is transmission part. Transmission system is connected between generation and distribution system. This system is used to transmit electric energy from generation to distribution system. Then the distribution system will distribute the electric energy to the consumers. The distribution system facing all the consumers load demand. In electric energy power system, it is important to make sure the electric energy produced can support all the consumers demand and if fail, it will cause disruption to the system and the whole power system can be breakdown.

There are three fundamentally type of power distribution system used by electric utilities which is radial, loop and mesh network system. Most distribution system are designed to be in radial due to two overwhelming advantages. First, the radial distribution system is much less costly than the other two design. Second, radial distribution system is simpler in planning, design and operation. In radial distribution system, the power flows along a single path from the main substation out to the customer feeders which will results in complete loss if the power is interrupted. Each consumer feeders serves a definite service area. Hence, each feeder will have different value of loads depend on it consumers. When supplying the electric energy, this loads will affect the power loss occur in the network due to the different load current occurred and the network line impedance. The power system can be more efficient if the distribution system has less power losses and good voltage profile at each feeders. Distribution Network Reconfiguration (DNR) is one of the method that can be used in way to reduce the power losses at the distribution network and improve the voltage profile [1,2,3]. Using this method, the distribution network will be reconfigured to find the best route which have the lowest power losses while maintaining the network radial structure. Sectionalizing switches and tie switches is used to connect each feeders at distribution network. The DNR is carried out by changing the status of these switches [3].

Other than DNR, the Distributed Generator (DG) can also provide power losses reduction in the network system and improving the voltage profile. DG is also known as small scale generator which placed near the consumer's area. The successfulness of DG implementation depends on the reliability of transmitting power with appropriate location and exact size of the DG.

In order to find the best route and the most suitable size of DG, the distribution network can be reconfigured based on several ways of developing heuristic algorithms such as Particle Swarm Optimization (PSO), Simulated Annealing (SA), Tabu Search (SA) and Genetic Algorithm (GA) [4]. This project is about improving the methodology of GA also known as Improved Genetic Algorithm (IGA) in order to maximize the reduction of power losses in the distribution network. The improvement is focused on a crossover operation when conducting the GA method so that the solution finding will be more global than the origin hence the best solution can be found.

1.2 Problem Statement

According to [4], the power losses occur during the process of transferring electric energy to consumers due to technical losses. The technical losses means the power dissipated in the conductors used for transmission, transformation, and distribution in power system. Using the DNR method by applying IGA to calculating the best route of network during normal condition in order to reduce the power losses to an optimum level. Besides line losses, the distribution system also need to face with variation of voltage and power flows due to poor switching and power disturbances. Hence, the voltage profile also needs to be improved through this method so that the voltage always satisfy the node voltage magnitude bounds. This is a necessary condition to make sure each load is supplied with its load power requirement and the electric power can be distributed efficiently.

1.3 Objectives

The objectives of this research is:

1. To reconfigure the IEEE 69 bus system into MATLAB vrR2014a software for determining the best configuration using Improved Genetic Algorithms (IGA).
2. To determine the appropriate size of Distributed Generation (DG) to be installed at IEEE 69 bus system using proposed algorithm.

1.4 Scope and work

The distribution network reconfiguration (DNR) is applied at IEEE 69 buses 132/11kV radial distribution network. Although there are few methods of algorithms in finding the solution on DNR such as Particle Swarm Optimization (PSO), Evolutionary Particle Swarm Optimization (EPSO), Simulated Annealing (SA), Tabu Search (SA) and Genetic Algorithm (GA), this project only focusing on using the Improved Genetic Algorithms (IGA) in finding the best solution for DNR. The appropriate DG sizing also will be determined using proposed algorithm. The distribution network is tested by simulation using MATLAB vrR2014a software. The aim is to find the best route of distribution network

which have the lowest power losses and at the same time improving the system voltage profile. Finally, the performance of system when including DG and without DG will be compared in term of power losses and voltage profile.

1.5 Chapter Outline

This project contained with five chapters. For chapter one, it covered the introduction part to this project. Then, chapter two discussed the literature review related to this project. Next, chapter three explain in detail the flows of operation taken during the simulation process. After that, chapter four shows and discussing the result obtained from the simulation of IGA in MATLAB software. Lastly, chapter five contain the conclusion for this project which obtain from discussion of previous chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The distribution power system is a part of electrical power systems. This final system connecting the power supply taken from transmission to the consumers. The main purpose is to meet the consumers demand for energy. In Malaysia, the distribution system covered up voltage from 240V AC until 33kV AC. The distribution network can be in form of overhead lines for rural areas or underground cables for urban area. Generally, the distribution network system is built in mesh interconnected network system to provide reliability but will operating in radial system to increase its protection scheme and reduce the possibility of short circuit fault [1]. The consistency increase of power demand has led to the growth of power system. This affecting the distribution network reliability due to low voltage level but high operating current which contribute to the increasing of power losses. Thus, Distribution Network Reconfiguration (DNR) is introduced to overcome this problem.

Distribution Network Reconfiguration is a process of changing the distribution network structure by altering the status of open and closed switch. However, the larger numbers of buses system make this method very time consuming. Hence, it is more efficient to use an artificial intelligence algorithm such as Particle Swarm Optimization (PSO), Tabu Search (TS) and or Genetic Algorithm (GA) to solve for DNR. This project focuses on using the improved version of GA for best solution on 69 buses network system.

2.2 Distribution Network System

As mentioned before, the least reliable part in power system is distribution system due to its high power losses contribution. Therefore, a well planning of distribution network is necessary to meet the demand on various forecast loading figures and supply reliability. Generally, the distribution network configuration is divided into three major types of distribution networking categories which are radial, loop and mesh systems.

2.2.1 Radial configuration

Radial distribution network system or single-end radial fed system as shown in figure 2.1 is a distribution network system that supplying its distributor feeders with one end primary substation only [2]. In this system, the power from primary substation is extended to each feeders in single route and the feeders are separated in radial configuration. The load estimation and sizing of the component for this system become simpler due to the simple system design. Therefore, the installation for fault protection system become easy to be set up and the potential for fault current to occur is reduced. The radial network configuration has been chosen among configuration because it is simplest and cheapest to be construct, easy to analyzed and easy to reconstruct.

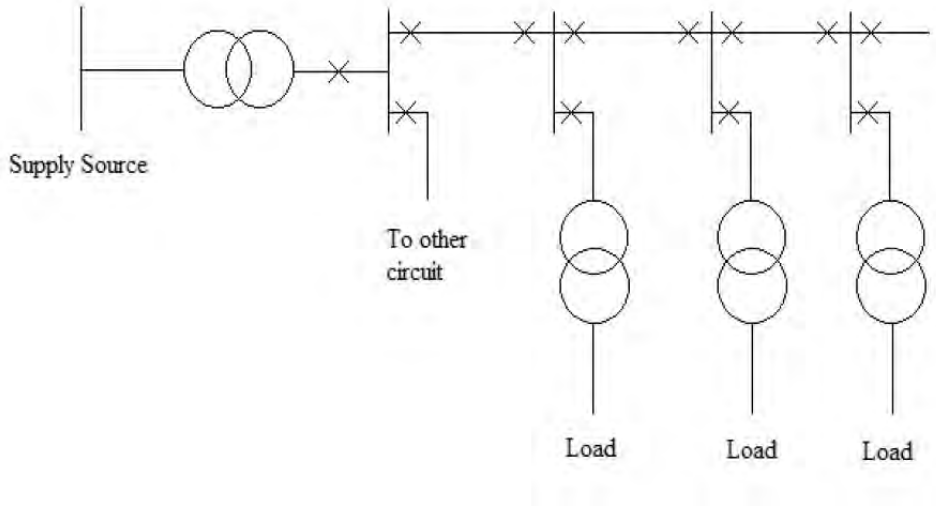

Figure 2.1: The radial distribution configuration.

However, there are also several weaknesses when using radial system. The distributor that near to the feeding point will be heavily loaded [3]. When a power failure

occurs, the entire line power will be interrupted. The failure must be fixed before restore the power meaning that the supply restoration will depend on the fault repair time. When the load on system changed, the consumers at the end of distributor would be subjected to serious voltage fluctuations [4] due to non-alternative route for supplying power.

2.2.2 Loop configuration

Figure 2.2 illustrates loop configuration or also known as double-end fed network where the power can be supplied through all service areas before returned back to the original point. The loop circuit start from main substation bus then going through the area to be served and returns back to main substation. The loop network can either be connected to the same source or more than one source [5]. To provide a better supply reliability, the service substations can be fed from two sources as shown in figure 2.2.

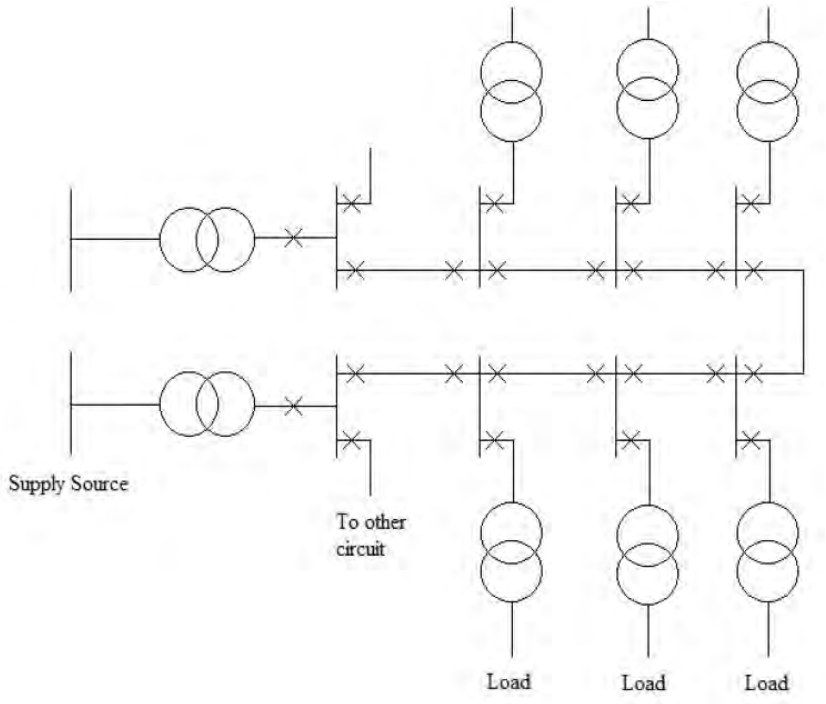

Figure 2.2: The loop distribution configuration.

According to [6], loop distribution network system can be operating either in open loop or closed loop system. The configuration is acted as radial system when operating in open loop. Hence, the direction of supplying power from main substation to service

substations can easily be change simply by changing the switches status. In case of supply from one direction is failed, the power will fed to service substations from the other end. The supply can be restored after the faulty portion of component is isolated by simply closing the normally open switches or opening the normally closed switches. Therefore, the supply restoration will be faster and the additional routes provided by loop system make it more reliable compared to radial system. This condition makes the system has less voltage fluctuations at consumers terminals [7]. However, this system is more expensive because more switches, circuit breaker and conductors are required to construct this system.

2.2.3 Mesh configuration

Figure 2.3 shows an example of mesh configuration network system or also known as ringed network system. It is the combination of several loop systems. This network configuration are interlocking loop systems which are the most complicated among the network configuration but the most reliable system [8]. The service feeders can be supplied from more than one main substation. According to [9], the existence of multiple path between all levels in mesh network system can make the network immediately and automatically re-routed it supply path when there are power failure occurs. The complicated of the system makes the mesh configuration be the most expensive system to be construct. For this reason it is normally used only in congested and high load density areas.

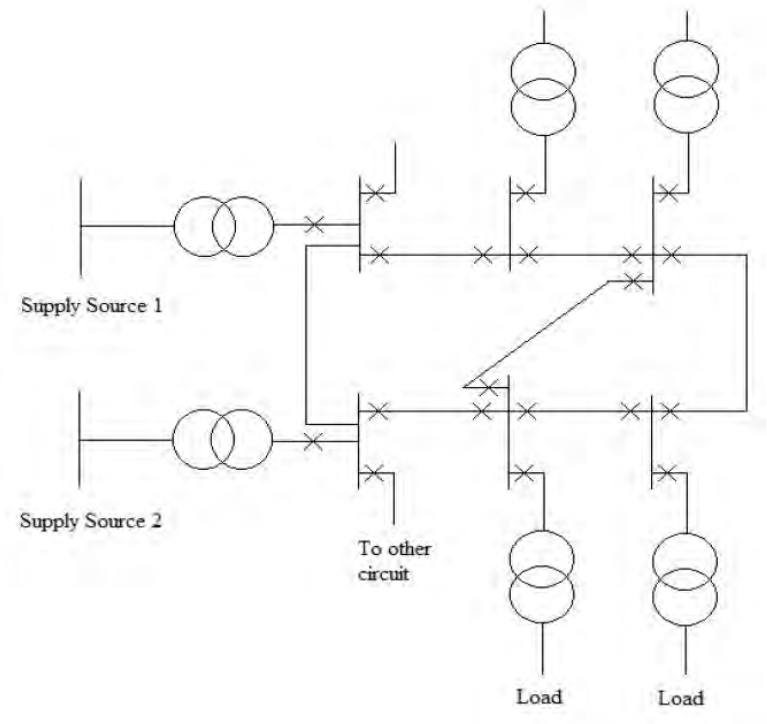

Figure 2.3: The mesh distribution configuration.

2.3 Theory and basic Principles

2.3.1 Distribution Network Reconfiguration (DNR)

Distribution system reconfiguration for loss reduction was first proposed by Merlin [2]. The network reconfiguration is carried out by changing the status (on/off) of the sectionalizing switches and tie-switches. Distribution network reconfiguration is performed to find the minimal loss operating configuration for the distribution system represented by a radial structure at a specific load condition. Other than that, the DNR may be required for load balancing, service restoration and improve the quality and reliability of power supply [3]. However, in real distribution network system, it is difficult to obtain a fast solution for DNR especially when the reconfiguration involved a large scale network system. It needs combinatorial optimization method since various operational constraints are to be considered.

When reconfiguring the network, the reconfiguration method must take into consideration few conditions like network connectivity, radial configuration where each

node has to be supplied from a single feeder, limits on voltage drop, limits on power flow in branches, limits on feeder capacity and load satisfaction where each load node has to be supplied with its load active and reactive power requirements [10]. Parameter constraint must be fulfilled for an optimization solution to avoid faulty condition.

Particle Swarm Optimization (PSO), Simulated Annealing (SA), Tabu Search (TS) and Genetic Algorithm (GA) is a few example of artificial intelligence of algorithms. However, this research is only focusing on using GA and IGA based approaches.

Artificial intelligence algorithms is commonly referred to as a machine learning that enable the computers system to learn. Artificial intelligence algorithms are combination of several branches of computer science and mathematics field such as pattern recognition, genetic programming, heuristics, predictive modelling, text mining and search, inference, and ontology and data analytics [11]. A few example methods of artificial intelligence algorithms is Particle Swarm Optimization, Simulated Annealing, Tabu Search and Genetic Algorithm.

First example is Particle Swarm Optimization (PSO). It is a population based stochastic optimization technique. This technique is inspired by social behavior of bird flocking or fish schooling [12]. Animal which has the closest position with a food source (potential solution) will notify it to its flocks. A swarm of particles and each particle represent a potential solution consisted in PSO. PSO have many similarities to Genetic Algorithms (GA) method. PSO continues finding for optimal solution by updating generations which initiated with a population of random solutions [13].

Second example is Simulated Annealing (SA). Simulated annealing is adapted of an analogy to statistical mechanics of annealing in solids using temperature [14]. The work of "controlled cooling" operations for nonphysical optimization problems in changing a poor unordered solution into an optima proper solution. Simulated annealing will reshape mathematical insights from the domain of physics into insights for actual optimization problems.

Third example is Tabu Search (TS). Tabu Search used an adaptive memory which produce more flexible finding behavior. The solution space can be searched economically

and effectively. Solutions that were latterly tested are inserted in a constantly updated tabu list to avoid selecting same solution. Tabu Search is suitable to be directly applied to any kind of optimization problem [15].

The last example is Genetic Algorithm (GA). Genetic algorithms are taken from the basic process of biological evolution and natural selection. GA method moving one population of chromosomes to a new population by natural selection process along with the genetics operators which is mutation and crossover [16]. In this project, GA method have been successfully applied to find actual or approximate optima solutions of the search problems.

2.3.2 Genetic Algorithm (GA)

Genetic Algorithm (GA) is a searching technique adapted from basic process of biological evolution and natural selection which are mutation, selection and crossover. The process is basically a combination of survival candidates among string structure and randomly perform an information exchange between them to form a search algorithm [18]. GA offering a very effective tool and simple approach of solving global optimization searching network when closed form optimization technique cannot be used. This artificial intelligence algorithms usually used with computing and mathematical field to search for possible problem solution and optimization. This research performing the GA concept to searching optimal solution for DNR and DG sizing.

The algorithm starts with a set of solutions called a population. The solution is represented by chromosomes. New forms of population are created using the solutions (chromosomes) from one population. GA first defines the chromosomes according to fitness function before going through selection process according to roulette wheel method. The next stage of GA would be crossover and mutation process before obtaining the best solution. The new population is created to be better than the old one. This condition is repeated until it find the best improvement of solutions.

2.3.3 Improved Genetic Algorithm (IGA)

Improved genetic algorithm (IGA) is the enhancement of the conventional genetic algorithm (GA). Compared to conventional GA, the IGA can provides better set of solution with faster computational time. IGA also can avoid premature convergence when generating a new chromosome [19]. Thus, IGA is very suitable to be used as a solving tool to get a better solution for distribution network reconfiguration. The performance of GA is mainly influenced by its operators. Thus, a good improvement of GA can be found by altering selected stage either at fitness function, selection, crossover or mutation [20].

A group of chromosome is ranked based on fitness size. In [21] said that, chromosomes with high fitness value have high chances to be selected as the parents. The selected ones will proceed as possible solution. The genes from parent (chromosomes) is selected to create a new offspring in crossover. The crossover operation can be in one point, multi point or random point. In original state, the first child is produce by taking the left sides of the point copy from first parent while the right side copy from second parent. However, this swapping process can be change in order to get a better global searching area. When a particular crossover is create for a specific problem, it can improve the performance of the genetic algorithm (IGA). The mutation process takes over after the crossover is performed. Mutation is done after crossover to prevent falling of all solutions in population into a local optimum of solved problems. The new offspring create by crossover is randomly changes. For example, mutation switch a few bits string of new offspring either from bit 1 to 0 or bit 0 to 1.

In order for not getting invalid solutions when using GA, every stages of genetic operator process need to take a proper measures since the radially of the network must to be maintained. Thus, using IGA with small length of chromosome will help keeping the radial network during the optimization process [21].

2.3.4 Distribution Generation

A power generation system is an industrial facility for the generation of electricity. It is a process of generating electric power that used other sources of primary energy. Hence,

power generating station is located near the power source such as fuel sources for fuel power plant or dam for hydropower plant. Furthermore, power plant usually located further from populated area due to the environmental concern. A long distant of power transmission from generation system to distribution system has contributed to power losses. Thus, a small scale power generation system or distributed generation (DG) is used to overcome this problem.

Distributed generation (DG) is an alternative electricity supply instead of the traditional centralized power supply. The power generate by DG are sufficiently smaller than centralized power supply to allow connecting at any point in power system. The purpose is to cater back the power losses and at the same time fulfill the consumer demand. The installation of DG in optimal locations and size will result in several benefits such as improvement of voltage profile, reduction of line losses, peak demand shaving, relieving the overloading of distribution lines and increasing overall energy efficiency [17]. The installation of DG at inappropriate location will result in increasing of power losses, whereas the installation of non-optimal DG size will cause in insufficient load supply. Hence, the successfulness of DG implementation depends on the reliability of transmitting power with appropriate location and exact size [16].

2.4 Review of previous related works

Previously, a lot of studies related to power optimization for distribution system using distribution network reconfiguration method and distributed generation (DG) placement has been done. Most of it has applied a method such as Particle Swarm Optimization (PSO), Tabu Search, Genetic Algorithm (GA) and Improved Genetic Algorithm (IGA) to construct the new configuration network with less losses and improved voltage profile.

According to research in [13], placing a generator (distributed generation) in distribution system on consumer side of network will lead to reduction of power losses and voltage drop at transmission and distribution system. The Particle Swarm Optimization (PSO) algorithm is used to solve the optimization problem for placing and sizing the distribution generation (DG) in the network. PSO will find the most optimize fitness function which including the level of network stability, the voltage profile and the power losses for