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

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

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

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STUDENT DECLARATION

I declare that this report entitle "Distribution Network reconfiguration (DNR) and Voltage stability analysis for radial distribution network using Improved Genetic Algorithm (IGA)" is the result of my own project except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date :

To my beloved mother and father

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ABSTRACT

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

ABSTRAK

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

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CHAPTER 1

INTRODUCTION

1.1 Motivation

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

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

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

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

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

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

1.2 Problem Statement

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

1.3 Objective

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

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

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

1.4 Scope

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

1.5 Significance of Project

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

1.6 Report Outline

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

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

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

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

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

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

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principles

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

2.1.1 Electrical power system

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

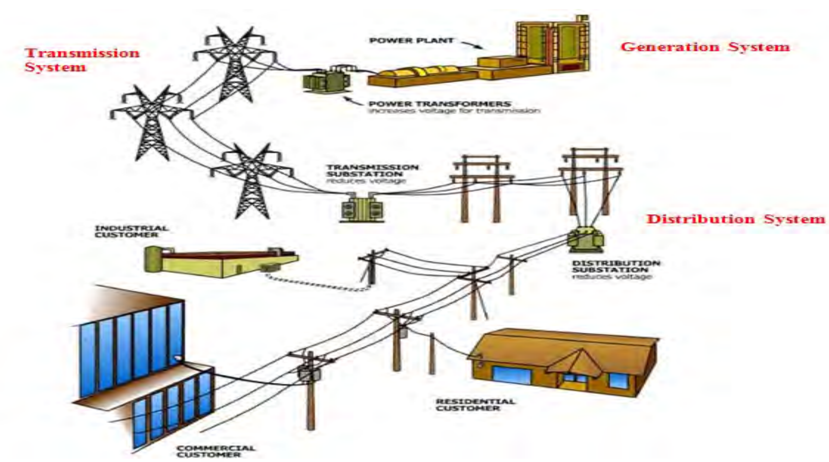

Figure 2.1: Electrical power system [2]

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

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

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

2.1.2 Network security and operation

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

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

2.1.3 Distribution of Network Reconfiguration (DNR)

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

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

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

2.1.4 Voltage Stability Index

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

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

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

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

2.1.5 Genetic Algorithm (GA)

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

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

2.1.6 Improved Genetic Algorithm (IGA)

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

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

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

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

2.2 Review of previous related works

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

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

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

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

2.3 Summary of review

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