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A COMPARATIVE STUDY OF OPTIMIZATION ALGORITHMS FOR 33KV DISTRIBUTION NETWORK RECONFIGURATION

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

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2014

I declare that this report entitle "*A Comparative Study of Optimization Algorithms for 33kV Distribution Network Reconfiguration*" 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 degree.

Signature : 

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Date : 17/6/2014

To my beloved mother and father.

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ABSTRACT

Distribution Network Reconfiguration (DNR) has been a part of importance strategies in order to reduce the power losses in the electrical network system. Due to the increase of demand for the electricity and high cost maintenance, feeder reconfiguration has become more popular issue to discuss. In a network which connects all electricity form generation, transmission and distribution, the quality of the power is important. The reducing in power losses and voltage profile improvement is a major aspect to achieve an efficient and secure distribution system. In this project, comparative studies among several optimization methods which are Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) had been done. The objectives of this study are to compare the performance in terms of Power Losses Reduction (PLR), percentage of Voltage Profile Improvement (VPI), and Convergence Time (CT) while select the best method as a suggestion for future research. The programming has been simulated in MATLAB environment and IEEE 33-bus system. Artificial Bee Colony (ABC) method has shown the superior results in the analysis of two objectives function that are Power Loss Reduction (PLR) and Voltage Profile Improvement (VPI).

ABSTRAK

Penyusunan Rangkaian Pengedaran (DNR) telah menjadi sebahagian daripada strategi penting bagi mengurangkan kerugian kuasa dalam sistem rangkaian elektrik. Disebabkan oleh peningkatan permintaan bagi bekalan elektrik dan kos penyelenggaraan yang tinggi, feeder konfigurasi semula telah menjadi isu yang lebih popular untuk di bincangkan. Dalam rangkaian yang menghubungkan semua generasi bentuk elektrik , penghantaran dan pengagihan , kualiti kuasa adalah penting. Pengurangan Kerugian Kuasa (PLR)dan Peningkatan Profil Voltan (VPI) merupakan aspek utama untuk mencapai sistem pengagihan yang cekap dan selamat. Dalam projek ini, kajian perbandingan antara beberapa kaedah pengoptimuman *Artificial Bee Colony* (ABC), *Particle Swarm Optimization* (PSO) dan *Genetic Algorithm* (GA) telah dijalankan . Objektif kajian ini adalah untuk membandingkan prestasi dari segi Pengurangan Kerugian Kuasa (PLR), peratusan Peningkatan Voltan Profil (VPI), dan Penumpuan Masa (CT) manakala memilih kaedah terbaik sebagai cadangan bagi kajian akan datang. Pengaturcaraan ini telah di simulasi dalam persekitaran MATLAB dan IEEE 33 sistem bas. Kaedah *Artificial Bee Colony* (ABC) telah menunjukkan keputusan yang lebih hebat dalam analisis fungsi dua objektif iaitu Pengurangan Kerugian Kuasa (PLR) dan Peningkatan Profil Voltan (VPI).

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Nowadays, the world improves in every aspect such as economics, politics, and technology, so does the energy. Energy involve in many aspect, they are fuel, nuclear, gas, and also electricity. In a network which connects all electricity form generation, transmission and distribution, the quality of the power is important to achieve excellent work without wasting any cost. The reducing in power losses and voltage profile improvement is a major aspect to achieve an efficient and secure distribution system. A person or a people who live in this advance growing world all they care is for the light to turn on at time when they need it, for the power to generate when in used, to ease their life because all of them contributed their money on all of this effective lifestyle. To create a technologies world without a lack of demand so that our country will always be compatible with others in the world is not impossible.

1.2 Problem Statement

As demand for electricity in power system increasing compatible with worlds demand, it has been a crucial yet challenging task to power system engineers which require

in reducing the distribution feeder losses and improve system security economically. During heavy load, a high load current drawn from the supply is increasing, which may also lead to increase in voltage drop and power losses [27]. All of this inefficient performances in distribution network that's exist will lead to increasing operation cost due to high power loss and reduced in voltage magnitude. This research will help in settling the problems.

1.3 Objective

The main objectives of this research are:

i. To analyze the power loss reduction for three heuristic methods that are ABC, PSO and GA respectively
ii. To investigate the voltage profile improvement of the IEEE 33 bus test system

1.4 Scope

This research only involve in determining the power losses reduction while considering voltage profile improvement carry out on IEEE 33 bus radial distribution network system in MATLAB environment using heuristic method Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA).

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

These parts are reviewed on five sections which are Distribution Network Reconfiguration, Voltage Profile, Power Losses, and related previous work. In Distribution Network Reconfiguration, research about the distribution network system will be presented to explain more about the distribution network system either for their type, or radiality. In voltage profile and power losses, the studies with specific research performing voltage profile improvement and power loss reduction will be shown. Meanwhile, for related previous work, it is a finding on distribution network reconfiguration for power losses considering voltage profile improvement by variety of optimization method tested on 11kV bus radial, 33kV bus radial, or 69kV bus radial.

2.2 Distribution Network Reconfiguration (DNR)

Electrical supply system have many important parts, one of them is distribution system. Distribution system is a link between power supply and utility's bulk

transmission systems and consumers. Recent reported that 80% losses in a distribution network occur because of the failure in distribution systems [1]. The applied of distribution automation to the distribution feeders benefits in the customer services reliability improvement. Moreover, in primary distribution systems, switches play an important role in various applications for improving in reliability, isolate faults, reconfigure, restoring the networks, and reducing losses after a fault as said in the researches.

As the world growing, the regulations and public awareness are increased, therefore, the energy distribution utilities need to be more efficient for network efficiency as it is treated as more common around the world [2]. One of the tasks to achieve these efficiency is by reconfiguring the distribution feeders. Network reconfiguration in words mean the changes in the open and closed status of two types of switches called sectionalizing and tie in an attempt for power loss reduce in a system by relieving the overloading network components.

In [3] also stated the importance and usable operation of distribution network reconfiguration (DNR) in reducing the feeder losses while improving the system security. Feeder is where the load current can be transfer through it because of the numbers of distribution switches open and closed status and by changing their topology. While during fault occurrence, the switches helps in isolating the faults and restoring the services. DNR had become a complex decision making process for dispatchers to follow because of the numerous existing switches in the distribution systems that making the number of possible switching operation tremendous.

Distribution networks are normally radially configured and generally involved with two types of switches they are normally closed switches and normally open switches. Normally closed switches connects the line sections called sectionalizing switches, while normally open switches connect two feeders or loop type laterals called the tie-line switches. These switches are basically used for protection and configuration management. These switches topology status either open or closed are changes by network reconfiguration [4].

Based on recent studies which indicates that total wasted on power generation is up to 13% in the form of line losses at distribution level [5], therefore, it is a great benefits to find the suitable and best methods for network reconfiguration as it will help in power loss

reduction and also improve the reliability of power supply which make the network more secured.

In operating and plan the distribution system, there will always be a long list of optimization problems that will occur. The problems can be a caused by network reconfiguration, which need to be alerted with certain objective function such as feeder, substation balancing, reduce losses, restoration, minimum switching and others [6]. While distribution networks are structurally meshed, they are radially operated. In fact, most optimization problems are simply aimed at finding the best radial configuration, among a huge number of combinations, for which efficient procedures to check or enforce radiality are needed.

2.3 Voltage Profile

Voltage profile can be calculated along a given transmission line during a system transient [7]. This method can be used to detect low level of voltage signals that appear along the length of a long transmission line during transients caused by switching events or faults also useful in obtaining screen shots of waveforms used in animation of travelling wave transients. Voltage profiles can be recovered at intermediates points along the length of the line using time-series model. During systems faults and switching events, power systems experience a voltage transients which may produce voltages and currents that may exceed allowable limits of operations and/or equipment.

The impacts of maintaining the load bus voltages within permissible limit will ensure the quality and reliability of supply to the consumer [8]. Changes in the power demands and system configuration will give impact towards voltage levels either high or low in the systems and by reactive power generation reallocating the voltage profile can be improved. To improve voltage profile system in a power system, it is necessary to improve the realization of reactive power generations.

By monitoring the voltage profile of distribution feeder can provide for the improvement in reliability and also the quality of the distribution power system as stated in

[9]. However, there is some constraint in economic which limit the widespread deployment of monitoring equipment. For an effective control of distribution system, knowledge on the load and voltage conditions is prior. Because of the constraints in the economic, an intelligent voltage estimation algorithm an optimization method is installed which is a more commercial approach which reduced the number of monitoring equipment and save the cost in installation also maintenance.

The security and reliability problem with the system operation will always occur if there is a stress condition in power systems. The factors such as overexploitation of existing transmission systems, limited number of new power station, are affecting them. One of these concerns also involve the voltage stability that refer to the ability in maintaining a steady voltages at all busses in the system after a disturbance occur from a given initial operating condition, maintaining and restoring the equilibrium between load demand and load supply. If the voltage instable, may results in loss of load in an area, transmission line tripping, and other elements by protective system that leads to cascading outages [10].

2.4 Power Loss

Active and reactive power in a system need to be control for power loss minimization and improving voltage profile, which by optimizing the active power flow with network reconfiguration and reducing reactive power by capacitor control can achieve these goals. Even with different properties and limitations, these two types of control will strengthen each other with their combination to achieve better results in distribution systems [11].

Considerable portion of overall loss which in practice is the power loss on distribution transformer [12]. This is due to Joule effect that there are power losses in a power distribution effect. Power losses are in the form of I^2R and it can be very large since it occurs throughout the conductors of the distribution system; it can account for 13% of the total power generation. Therefore, there have been strong incentives for utilities to try to reduce the losses. To reduce I^2R loss in a distribution system, one approach is to

shorten the overall network resistant path that the current is passing through. This can be achieved by altering the network topology, known as reconfiguration.

2.5 Optimization Methods and Related Previous Work

For distribution network reconfiguration of electric energy distribution, a methodology based on Ant Colony System (ACS) algorithm is proposed in [13]. Constraints such as transmission capabilities and voltage magnitudes limits, it is said to be very flexible method in finding the optimal network with lower transmission losses. It said that ACS is the suitable method in reconfiguration because of its positive feedback, distributed computation, and greedy heuristic.

In [14], for power losses reducing in distribution network, the Network Partitioning Theory novel method is proposed which also offer numerous advantages without limitation towards the maximum size of distribution system in real time. The computational burden of the reconfiguration not only reduces by the partitioning operation serves but also minimize losses on line from the cut set. It is said that proposed algorithm can be used also in industrial and electric utility applications.

In [15], results that got reflects in distribution network reconfiguration sometimes is because of the computation time of the algorithm to finalize in the program. A method of load forecasting which adopted GA algorithm is proposed in solve the distribution network reconfiguration for power losses.

The minimum the feeder losses, the better the distribution network which will act as a target function [16]. Radical distribution network is decided each nodes in degree using Hopfield neural network and either it will be used or not. The state of switch can be decided correspondingly same as the scheme of reconfiguration. For energy function, radial supplying and feeder power losses are considered. Some line also may have no switches so the energy function takes that into consideration.

In [17], power distribution connects all from generation to consumer. The objective is to minimize the power losses of distribution network. The genetic simulated annealing

algorithm is proposed which cover all the speed in simulated and solve for premature convergence in GA.

Ant Colony System Algorithm (ACSA) is proposed in [18]. In solving for the distribution network reconfiguration problem which combined with the features of distribution network, ACSA is said to simply the searching space of the distribution network structure and also improved information update strategy in reduce the local optimum. Compared with Ant Colony System, ACSA has faster speed which provides good method for distribution network optimization problem.

In [19], the contribution is a new fuzzy multicriteria decision making algorithm in emphasize the power losses reduction in a network reconfiguration. The computational system developed from flexibility of method, result in useful yet reliable easy used tool for utilities. Actual data was used and also providing the promising results for actual evaluation of the performances.

A Tabu search approach is proposed in [20]. It designed GIS that is Geographic Information System in terms of support for management, manipulation, analysis, and modeled spartial data. Tabu is a heuristic method that suitable in solving complex optimization problem for power losses. Distribution network also modeled in geometric network (GIS).

In [21], the changing of open/closed switch status modified the network structure of distribution feeder. An enhanced genetic algorithm (EGA) is proposed. The power losses is minimized and also the violation of voltage while current constraints also minimize.

For distribution system, loss reduction is important in saving the energy in [22]. The method using Ant Colony System (ACS) algorithm is proposed and is said to be very flexible in optimizes the transmission losses. Case study of Tamil-nadu Electricity Board (TNBE) consists of 14-bus transmission system, 3 generator and 11 sub-stations is taken as application of the algorithms with significant reduction and computational effort in optimal solution.

In [23], the DNRC distribution network reconfiguration based on comprehensive approach is proposed in minimize the system power losses. DNRC consist of modified heuristic method and rule base. Rules used in selection of optimal reconfiguration network which form from operations experience. Power summation based radiation distribution

network load flow (PSRDNLF) is apply in order to get precise branch current also power losses and is applied in Guiyang South Power Supply Bureau.

By status change of sectionalizing switch open or close the distribution network for power losses is minimize. Tabu search algorithm is proposed and efficiently presented for distribution network optimization. Tabu method combines with switch group which adopt the coding concept for reducing infeasible solution and searched the best solution among candidates [24].

In [25], the customer interruption cost can reduce by figured network, means reducing in power losses and load balancing. This electrically supplied all load points radially by controlling the sectionalizing and tie switches of the system.

In planning the operation of electric power distribution system, topological reconfiguration is used as a tool in [26]. The main concerns in distribution operation planning are the power losses, voltage profile, and also reliability levels which need to be controlled. A new fuzzy multicriteria decision making is proposed to solve the entire problem. The flexibility of the fuzzy method provides wide audience developed tool which are useful yet reliable, while easy to use for utilities.

2.6 Summary

As presented in the previous related work, there are so many optimization methods in solving distribution network reconfiguration in minimizing power losses and voltage profile improvement. In this study, the optimizing methods which are ABC, GA, and PSO will be tested and the best optimization will be selected based on the better results in reducing power losses and voltage profile improvement in the distribution system.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this part, the process of ABC, PSO, and GA are explained in detail. It consists of four tasks. Task 1: Mathematical formulation and constraints. Task 2: Implementation method of ABC. Task 3: Implementation method of PSO. Task 4: Implementation method of GA.

3.2 Task 1: Mathematical Formulation and Constraints

The objective of the feeder reconfiguration is to minimize the total power losses. Therefore, the objective function of this study is:

$$P_{losses} = \sum_{i=1}^{n} |I_{ai}^2| R_i \quad (3.1)$$

Where:

i = Number of lines in the system

I_{ai} = Line real active current

Ri = Line resistance

The second consideration of this study is voltage profile improvement. So that, the voltage bus constraint has been set as follow:

$$V_{min} \leq V_{bus} \leq V_{max} \tag{3.2}$$

The voltage for each bus should operate within the acceptable limit which is in between1.05 and 0.95(± 5) in [27].

The simple constraint of radial configuration is an importance element for feeder reconfiguration. The configuration must be in radial to avoid excess current flow in the system. Therefore, in order to ensure the radial network is maintained, several constraints must be taken into account. Several standard rules have been adopted for selection of switches. Those switches that do not belong to any loop, connected to the sources and contributed to a meshed network have to be closed.

In this work, the particles consist of the tie switches *(S)* has been considered as set particles as shown in Equation (3.3).

$$X_{particle} = \{S_1, S_2, \ldots . S_\beta\} \tag{3.3}$$

Where:

β = Number of tie line switches

Only the particles that satisfy all the constraints above will be considered as the initial population.

3.3 Task 2: Implementation Method of ABC

Karaboga the founder of Artificial Bee Colony (ABC) optimization method that interested in the intelligent of the bee behavior which is foraging proposed an optimization numerical problem named Artificial Bee Colony (ABC) algorithm. In ABC there are: employed bees, and unemployed bees: onlookers and scouts. This divided by two parts between employed bees and unemployed bees. Food sources position as a solution that