Optimal Location and Sizing of Distributed Generation Using Particle Swarm Optimization with Mutation Strategy

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TABLE OF CONTENTS

CHAPTER 4: RESULTS AND DISCUSSIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DG	Distributed generation
LP	Linear Programming
TS	Tabu Search
PSO	Particle Swarm Optimization
CO_2	Carbon dioxide
TNB	Tenaga Nasional Berhad
GA	Genetic Algorithm
ACO	Ant Colony Optimization
PSO-MS	Particle Swarm Optimization with mutation strategy
EP	Evolutionary Programming
ABC	Artificial Bee Colony

Lokasi dan Pensaizan Optimum Penjanaan Teragih Menggunakan Pengoptimuman Kerumunan Zarah Dengan Strategi Mutasi

ABSTRAK

Krisis tenaga yang berlaku pada masa sekarang telah membawa kepada peningkatan permintaan tenaga yang mesra alam sekitar dan berkecekapan tinggi. Antara semua penyelesaian, penjanaan teragih (DG) merupakan salah satu penyelesaian yang mampu menyelesaikan masalah ini. Kesan DGterhadap sistem teragih adalah penting di mana ia boleh digunakan untuk meningkatkan keboleharapan dan kecekapan sistem seperti meningkatkan profil voltan, mengurangkan kehilangan kuasa dan sebagainya. Lokasi dan saiz optimum DG adalah amat penting supaya boleh mendapatkan output maksimum daripada peruntukan DG. Ramai penyelidik mendapati bahawa cara penyelesaian menggunakan kaedah 'metaheuristic' menghasilkan keputusan yang lebih baik berbanding dengan kaedah analisis konvensional. Dalam tesis ini, Pengoptimuman Kerumunan Zarah (PSO) bergabung dengan strategi mutasi (PSO-MS) telah dicadangkan dalam menyelesaikan masalah peruntukan DG dengan tujuan mengurangkan kehilangan kuasa sebenar dan meningkatkan profil voltan sistem. Ini adalah untuk mengelakkan penakungan populasi zarah-zarah yang sentiasa berlaku di algoritma PSO. Satu set eksperimen komprehensif telah dijalankan untuk menyahihkan pelaksanaan kaedah yang dicadangkan di mana mereka boleh dikategorikan kepada sistem kecil (24-bas sistem teragih), sistem sederhana (33-bas sistem teragih) dan system besar (69-bas sistem teragih) untuk keadaan 1 DG dan 2 DG. Keputusan simulasi bagi kaedah PSO-MS dibandingkan dengan PSO dan Algoritma Genetik (GA) supaya dapat mengesahkan pelaksaanaan kaedah yang dicadangkan. Keputusan-keputusan menunjukkan PSO-MS telah berjaya memperoleh lokasi dan saiz optimum DG. Untuk kajian perbandingan dengan PSO dan GA, kaedah PSO-MS juga menghasilkan satu keputusan yang lebih baik daripada kedua-dua kaedah dari segi kehilangan kuasa sebenar, profil voltan dan masa simulasi.

Optimal Location and Sizing of Distributed Generation Using Particle Swarm Optimization with Mutation Strategy

ABSTRACT

The current energy crisis has led to the increasing demand of environmental-friendly and high efficient energy. On top of all the solutions, distributed generation (DG) is one of the solutions that is capable to overcome this problem. The impact of DG towards the distribution system is significant where it can be used to improve the system reliability and efficiency such as improving the voltage profile, reducing the total power losses, etc. The optimal location and size of DG is very important in order to obtain the maximum output from the DG allocation. Many researchers found out that solutions using metaheuristic methods yield a better result compared to the conventional analytical method. In this thesis, the Particle Swarm Optimization (PSO) combined with the mutation strategy (PSO-MS) method is proposed in solving the DG allocation problem with the purpose of minimizing the total real power loss and improving the voltage profile of the system. This is to prevent the stagnancy of the particles' population that usually happens in PSO algorithm. A set of comprehensive simulations have been carried out to validate the performance of the proposed method where they are categorized into small system (24-bus distribution system), medium system (33-bus distribution system), and large system (69-bus distribution system) for single DG and 2 DGs installation. The simulation results of the PSO-MS method are then compared with PSO and Genetic Algorithm (GA) method in order to validate the performance of the proposed method. From the results, it is shown that the proposed method has successfully obtained the optimal DG location and size. As for the comparative study with PSO and GA, the PSO-MS method also yields a better performance in terms of total real power loss, voltage profile and simulation time.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Traditionally in the electric power industry, the main source of energy is powered by the large operating utilities such as hydro power plants, thermal power plants and nuclear power plants. However, this industry is facing some challenges nowadays due to the increasing in various types of demands such as high efficiency, more reliable and clean energy, as well as low energy costs. Therefore, introducing distributed generation (DG) to the distribution system is one of the solutions to solve these problems. Distributed Power Coalition of America, DPCA (Rújula, A. A. B., Amada, J. M. & Bernal-Agustín) defines DG as any small scale power generation technology that provides electric power at a site closer to customers than central station generation. According to them, a DG can be connected directly to the load customer or to a utility's transmission or distribution system.

The optimal number, location and size of the DG to be installed in the distribution system are crucial in solving the DG allocation problem. Placing the DG at wrong location or unsuitable size may deteriorate the efficiency and reliability of the distribution system, where it may increase the power loss, reduces the voltage profile hence bring negative impact to the distribution system. Therefore, finding the optimal location and size of DG is very important to obtain the maximum output from the DG allocation. A lot of conventional analytical methods such as loss sensitivity method, Linear Programming (LP) and Lagrangian approach have been applied to solve the DG allocation problem. However, these methods are very time-consuming and low reliability, especially deal with complex power problems. With the advancement of computation technologies, many researchers have turned their attention to metaheuristic approach.

Metaheuristic method is a computational intelligent method that solves the optimization problems iteratively. It explores and exploits the search space effectively and efficiently in finding an optimal solution. Metaheuristic methods include local search-based methods such as Tabu Search (TS) (Nara, K., Hayashi, Y., Ikeda, K. et al., 2001) and population-based methods such as Particle Swarm Optimization (PSO) (AlHajri, M. F., AlRashidi, M. R., & El-Hawary, M. E., 2007), Ant Colony Optimization (ACO) (Falaghi, H., & Haghifam, M.-R., 2007) and others.

In this project, PSO is combined with mutation strategy to improve the performance of existing PSO method in determining the DG optimal location and size while reducing the total real power loss and improving voltage profile of the system. Mutation strategy is implemented to prevent the PSO particles to be trapped in the local minima, which cause the stagnancy of the population, hence yield a better result in solving the DG allocation problem.

1.2 Motivation

Nowadays, the world electric power industry is facing a tough challenge due to several factors and the energy shortage crisis is one of the major problems that need to be solved. The world energy consumption has been increased drastically since the year

1980, as shown in Figure 1.1. In a survey conducted by the U.S Department of Energy, it is predicted that the energy consumption will reach 722 quadrillion BTU by the year 2030. Detailed information on worldwide total electricity consumption can be referred to Appendix A.

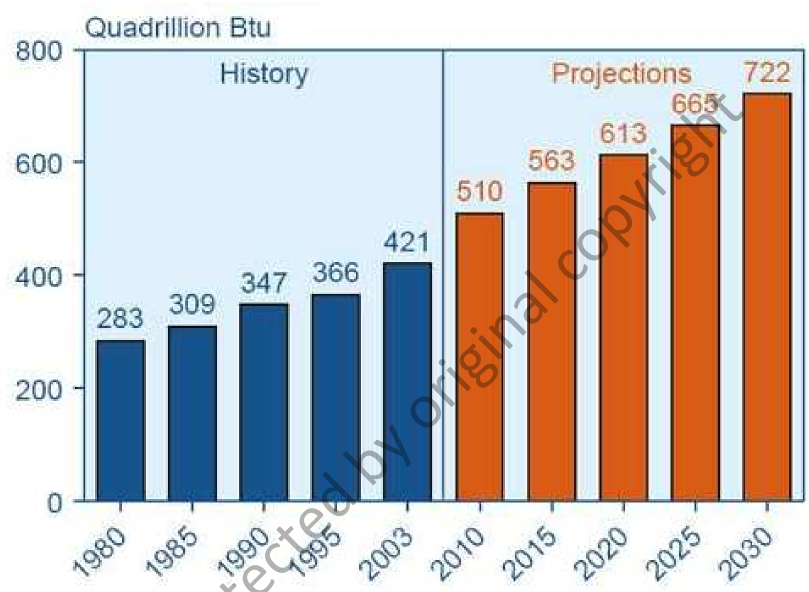

Figure 1.1: World marketed energy consumption from year 1980 till year 2030.

(Source: U.S. Department of Energy)

Although a few new technologies have been developed in order to manage the increasing demands, the rate at which the power is generated might be different with the demand growth rate. Nuclear power plant is one of the solutions that applied by some country to solve the energy shortage problem since it can generate electricity with low fuel cost and less pollutions. However, strict protocols and safety regulations need to be taken into account when dealing with this power plant. The incident of Tsunami and earthquake in Japan at March 2011 that caused the explosions and leaks of radioactive gas at Fukushima Daiichi Nuclear Power Station had brought fresh debate over the nuclear power plants expansion. Some countries even put the brakes on in planning the nuclear power plant. Switzerland has canceled the plans of building new nuclear power plants and upgrades the older one until complete safety review has been done, while Germany government has decided to shut down all the nuclear power plants by the year 2022.

The rising awareness of public towards the green and clean energy has become one of the demands that need to be fulfilled by the local electrical company. According to the 2011 Edition of Global Energy Statistical Yearbook by Enerdata on June 2011, the carbon dioxide (CO_2) emissions to the earth atmosphere are close to 6%, which is at the highest level currently.

Another challenge that the world is facing today is the shortage of the natural resources which are used as the power source such as coal, oil, gas and others. This has led to the increasing price of these resources, and simultaneously affecting the electrical company. In Malaysia, the local electrical company, Tenaga Nasional Berhad (TNB) has experienced a net loss of RM 440.2 million in their third quarter report of year 2011 owing to the increasing price of coal and gas.

Due to the various difficulties and drawbacks of the current electric power industry, the energy trend is now shifting to more reliable and smaller generators. DG is introduced for its advantages for instance small in size and can be associated with different technologies in generating energy, whether is renewable type or non-renewable type, thus reducing the negative impact to the environment, users and electrical company. In industry, DG often used as back-up power source, especially in resilience, emergency services, hospitals, air-ports and others. Because of its multiple positive impacts to the distribution system, DG is widely used in dealing with distribution system problems. More information regarding the benefits of DG can be referred to (U. S. Department of Energy, 2005). Some of the benefits of DG can be summed up as follows (U. S. Department of Energy, 2005) (Aghaebrahimi, M. R., & Amiri, M., 2009):

i. The transmission and distribution costs and losses can be reduced because DG units are located near the customers.
ii. It is easier to find site for small DG installation.
iii. DG units can act as back-up power source during electricity shortage.
iv. DG units can reduce the land-use effect due to the small size of DG.
v. DG units can increase the power efficiency and reliability of the electric system.

1.3 Problem Statement

DG is an emerging approach that is well known in electric power system recently. The installation of DG in the distribution system has brought lots of advantages to the electric power industry such as green and clean energy or higher voltage stability and reliability. The current electric industry may face some challenges with the absence of DG in the distribution system. Long and costly transmission lines are needed to transfer the power from the large power plants which are situated far away from the users. Furthermore, there are lacks of land used and natural minerals for the construction of these large operating utilities.

Conventionally, analytical approaches such as loss sensitivity factor, Lagrangian methods and others are applied to the distribution system in solving the DG allocation problem. However, these methods are difficult to implement with the low reliability and efficiency. The simulation of the algorithms takes a very long time due to the complexity of the system. In addition, different test systems with different complexity and constraints will affect the simulation time of the algorithm. Therefore, metaheuristic method such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) and others are then proposed in solving the DG allocation problem. In general PSO, the particles may converge too fast during the searching process, which cause the stagnancy of the population. Therefore, the general PSO is modified by implementing the mutation strategy of the GA in order to overcome the shortage of the general PSO.

Different distribution system may need different number of DG to be installed in the distribution system. Therefore, the number of DG to be installed in the distribution system should be considered in the DG allocation problem in order to obtain the maximum output from the DG installation.

1.4 Scope

In this research, DG is introduced into the distribution system with the purpose of reducing the total real power loss and increasing the voltage profile of the system. The real power loss and voltage are two main factors in DG allocation problem. With the reduction in total real power loss and improvement in voltage profile, the customers will experience better voltage stability and reliability. However, this can only be achieved with the DG located at the optimal location and size. Therefore, the optimal location and size of the DG have to be determined in order to obtain the maximum benefit from the DG. In this project, a metaheuristic method which is PSO with mutation strategy (PSO-MS) is proposed in dealing with the DG allocation problem. The PSO-MS approach improves the basic PSO by combining the mutation strategy to overcome the shortcoming of the basic PSO, which is the stagnancy of the particles' population.

1.5 Objectives

The main objective of this research work is to develop a modified particle swarm optimization method in determining the optimal location and size of DG to be installed in the distribution system. These objectives can be summarized as follow:

i. To develop Particle Swarm Optimization (PSO) with mutation strategy algorithm in determining the optimal location and size of DG to be installed in distribution system, while minimizing the total real power loss and improving the voltage profile of the system.

ii. To investigate the effects of numbers of DG installed towards the total real power loss and voltage profile in the distribution system.

iii. To evaluate the performance of the proposed method in different case scenarios and compare the results of PSO-MS algorithm with PSO and GA method.

1.6 Project Expectation

The main goal of this project is to determine the optimal DG location and size in the distribution system using PSO-MS method. In spite of obtaining the optimal location and size of DG, the proposed method is expected to reduce the total real power loss and increase the voltage profile of the system. The proposed approach is tested on three different test systems, which are 24-bus, 33-bus and 69-bus distribution system. Furthermore, the PSO-MS technique is then compared with the PSO and GA in order to validate the performance of the proposed method. The PSO-MS algorithm is expected to yield better result than PSO and GA in terms of total real power loss and voltage profile of the system, as well as the simulation time of the algorithms.

1.7 Report Organization

The report begins with an overall introduction of the project which includes a brief explanation on the DG, followed by its contribution towards the distribution system. In addition, the expected output of the proposed metaheuristic method is also discussed.

Chapter 2 presents the literature review of previous research done and methodology used in solving the DG allocation problem. This chapter begins with the background information of DG, including its technologies, applications and impacts towards the distribution system. A detailed review on both analytical and metaheuristic methods used in the DG allocation problem is presented.

The methodology used in solving the DG allocation problem is explained in Chapter 3. It starts with the total power loss calculation, where Newton-Raphson load flow method was used. A full description including the theory and mathematical formulation of the proposed metaheuristic method which is PSO-MS and its algorithm is clearly presented in the following section. Some assumptions that made are also highlighted in this chapter.

Chapter 4 presents the results and discussions of the proposed method. PSO-MS approach is tested on three different test systems under three different case scenarios in