UNIVERSITI PUTRA MALAYSIA

OPTIMAL LOCATION AND SIZE ESTIMATION OF DISTRIBUTED GENERATORS BY EMPLOYING GROUPING PARTICLE SWARM OPTIMIZATION AND GROUPING GENETIC ALGORITHM

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By

ZAHRAA ABDULKAREEM MOHAMMED

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2017

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DEDICATION

This thesis is dedicated to my precious father, my beloved mother, my brother and sisters for continually evaluating and inspiring me to work hard in my studies. I thank almighty Allah every day for blessing me with you and I love you all very much.

Abstract of thesis presented to the senate of Universiti Putra Malaysia in Fulfillment of the requirements for the degree of Master of Science

OPTIMAL LOCATION AND SIZE ESTIMATION OF DISTRIBUTED GENERATORS BY EMPLOYING GROUPING PARTICLE SWARM OPTIMIZATION AND GROUPING GENETIC ALGORITHM

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December 2017

Chairman : Wan Fatinhamamah Wan Ahmad, PhD
Faculty : Engineering

Distributed Generators is being implemented in the distribution network to improve the performance of the network by reducing the real and reactive power losses, while improving voltage profile during the operation. These advantages could be confirmed and accomplished if optimal size distribution generation units are installed at the optimal location in the distribution network. Otherwise, the problem of generation may increase when the DG is located in non-optimal location and size which can lead to increase the real and reactive power losses and high voltage deviation. Therefore, there are various algorithms that could be applied in order to integrate distribution generation units into the distribution network. These algorithms can be enhanced to increase their efficient and effective. This work is aimed to decrease the total real and reactive power losses while enhancing the voltage profile of the distribution network with less computation time by proposing two new artificial intelligence algorithms, i.e. grouping particle swarm optimization algorithm and grouping genetic algorithm. These two algorithms are compared to their original artificial intelligence algorithms, i.e. particle swarm optimization algorithm and genetic algorithm. These algorithms are used to obtain the optimal size of distributed generators units to be installed at optimal locations, which are obtained using loss sensitivity factor. Multi-objective function is the summation of three indices that are considered in these algorithms, i.e. real power loss index (*PLI*), reactive power loss index (*QLI*), and cumulative voltage index (*CVD*), and implemented on an IEEE 30-bus test system. This is to test the performance of the four artificial intelligence algorithms by taking into consideration the installation of 5 distributed generators units in the bus test system. It was observed that the grouping particle swarm optimization algorithm has achieved high reduction of total real and reactive power losses, by installing five distributed generators, when compared to the base case. It was observed that the voltage profile was improved with the shortest computation times demonstrated in determining the optimal size (global

optimal) for the multi DG units that were installed in the IEEE 30-bus test system comparing to all the four artificial intelligence algorithms that were employed in this work. Also, it is found that case of installing four distributed generators units is not much difference from case of five distributed generators which is make it optimum to be installed in the IEEE 30-bus test system in terms of reducing the real and reactive power losses. This also relates to the stability of the voltage.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANGGARAN LOKASI DAN SAIZ OPTIMUM BAGI PENJANA TERAGIH DENGAN MENGGUNAKAN ALGORITMA PENGELOMPOKAN PENGOPTIMUM KERUMUNAN ZARAH DAN PENGELOMPOKAN ALGORITMA GENETIK

Oleh

ZAHRAA ABDULKAREEM MOHAMMED

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Penjana Teragih dilaksanakan dalam rangkaian agihan untuk memperbaiki prestasi rangkaian dengan mengurangkan kehilangan kuasa sebenar nyata dan reaktif di samping meningkatkan profil voltan semasa operasi. Kelebihan-kelebihan ini boleh dicapai jika unit penjana teragih dipasang dengan saiz yang optimum pada lokasi yang optimum dalam rangkaian agihan. Jika tidak, masalah pengjanaan akan meningkat apabila DG diletakkan pada tempat dan saiz yang tidak optimum yang mana boleh menyebabkan kuasa nyata dan reaktif serta sisihan tinggi voltan. Maka, terdapat pelbagai algoritma yang boleh diaplikasikan untuk menyatukan unit-unit penjana teragih ke dalam rangkaian agihan. Algoritma-algoritma ini boleh ditambah-baik untuk meningkatkan kecekapan dan keberkesanan mereka. Kerja ini menyasar untuk mengurangkan hasil kehilangan kuasa nyata dan reaktif sambil menambah-baik profil oltan rangkaian agihan dengan kurang masa komputasi dengan mencadangkan dua kecerdasan buatan baru iaitu algoritma Pengelompokan pengoptimum kerumunan zarah dan Pengelompokan algoritma genetik. Kedua-dua algoritma ini dibandingkan dengan algoritma-algoritma kecerdasan buatan asal mereka iaitu algoritma pengoptimum kerumunan zarah and algoritma genetik. Algoritma-algoritma ini digunakan untuk memperoleh saiz optimum unit-unit DG untuk dipasang di lokasi-lokasi optimum yang diperoleh menggunakan faktor kehilangan kepekaan. Fungsi objektif pelbagai iaitu jumlahan tiga indeks yang diambil kira dalam tiga algoritma ini iaitu indeks kehilangan kuasa sebenar IKKS, indeks kehilangan kuasa reaktif IKKR, dan indeks voltan bertoko IVB dilaksanakan pada sistem ujian 30-bas IEEE. Kajian ini bertujuan menguji prestasi keempat-empat algoritma kecerdasan buatan dengan mengambil kira pemasangan 5 unit-unit PT di dalam system ujian bas. Pemerhatian menunjukkan algoritma pengoptimum kawanan zarah telah, mengurangkan kehilangan kuasa nyata dan reaktif dengan pemasangan 5 DG, apabila dibandingkan

dengan Kes Asas, Pemerhatian menunjukkan profil voltan yang lebih baik dengan komputasi masa terpendek dalam menentukan saiz optimum (optimal bagi keseluruhan) untuk penjana teragih yang telah dipasang dengan jumlah yang banyak di sistem ujian 30-bas IEEE berbanding kesemua algoritma kecerdasan buatan yang telah digunakan dalam kerja ini. Selain itu, kajian juga menunjukkan pemasangan 4 unit DG adalah tidak berbeza dengan pemasangan 5 unit DG yang mana adalah optimum untuk dipasang di sistem ujian 30-bas IEEE dari sudut mengurangkan kehilangan kuasa sebenar dan reaktif. Ini juga memberi kesan kepada kestabilan voltan.

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I certify that a Thesis Examination Committee has met on 29 December 2017 to conduct the final examination of Zahraa Abdulkareem Mohammed on her thesis entitled "Optimal Location and Size Estimation of Distributed Generators by Employing Grouping Particle Swarm Optimization and Grouping Genetic Algorithm" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

ABC	Artificial Bee Colony
ASC	Ant Search Colony
ANN	Artificial Neural Network
CVD	Cumulative Voltage Deviation
DE	Differential Evaluation
DG	Distributed Generation
FA	Firefly Algorithm
GA	Genetic Algorithm
GrGA	Grouping Genetic Algorithm
GrPSO	Grouping Particle Swarm Optimization Algorithm
KCL	Kirchoff Current Low
LSF	Losses Sensitivity Factor Method
MATLAB	Matrix Laboratory
MOF	Multi Objective Function
OPF	Optimal Power Flow
PLI	Real Power Losses Index
QLI	The Reactive Power Loss Index
REPSO	Ranked Evolutionary Partial Swarm Optimization

CHAPTER 1

INTRODUCTION

1.1 Background

Producing stable electricity is considered a crucial role of an electrical power system depending on the customer demands. Hence, its reliability is the must important part. The electrical power network consists of three main parts which are power generation station, transmission system, and distribution networks. The major function of a power generation station is to supply enough power to provide electricity due to customers' demands at any time. Generally, it is necessary that the transmission system and distribution network be reliable and stable to ensure safe delivery of the electricity to the customers [1]. For a long time, there is no generation in the distribution network as the distribution networks were designed and used only to provide power to the customers with the optimal voltage level that is set at the distribution stations. In the distribution network, the ratio of *X/R* is lower than their value at transmission system which results in power losses and drop in the voltage level [2]. Recently, the new structure of distribution networks allows adding small size generation to provide energy directly to the customers because of the high change in the power strategy regarding the growth in electricity markets, technological evaluation, and environmental policies [3]. Generating the power from the distribution networks and consumer site known as Distributed Generation (DG). These technologies employ both conventional and unconventional sources of energy. There are main reasons that made this technology catch attention of power companies such as; national requirement for power, provision of different sources of energy, ease in selecting a place with short building times due to the small size of generating units compared to the main power plants, reduction in the transmission lines which indirectly will also reduce the power losses due to the generation unit that is located nearby to the load [4]. This is due to the reason that the performance of DG units depends on load demand. Also, the reliability and efficiency of the distribution network can decrease or increase based on the location and size of DG units installed in the distribution network. If optimal location and optimal size of any DG units are not researched before its installation in the distribution network, it may create problems in terms of safety and technical issues such as interference in the processes of voltage control, voltage oscillations, add to that it can reverse power flow direction, etc. which affect the amount of power that may not cover the demand and cause an increase in power losses and unwanted voltage profile [5]. Basically, the optimal location and optimal size of DG units are a complex optimization problem that needs synchronous optimization of different objectives such as minimising the total real and reactive power losses and managing the voltage deviation of the buses to increase the reliability of the network. The multi-objective optimization provides attractive choices to address the optimization problem to obtain optimal location and optimal size of DG units of any distribution network. Besides, it is important to be sure that the installation of DG units in the distribution network will enhance system technical parameters [6]. Therefore, various optimization techniques have been applied to find solutions for multi-

objective optimization problems. Several artificial intelligence algorithms have been employed to solve DG units problems as they can achieve global solutions. Mainly, such artificial intelligence algorithms include Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Ant Search Colony (ASC), Artificial Bee Colony (ABC), Firefly Algorithm (FA), and Differential Evaluation (DE). One of the main benefits of artificial intelligence algorithms is their ability to apply in different qualitative constraints [7].

1.2 Problem Statement

Recently, electrical power demand is increasing very fast, and the electrical load demands in a power utility service can be varied depending on the number and type of consumers at each location. The main function of power companies is generating power from new recourses such as DG units energy resources to face the high demand of electrical power consumption and sending the power safely to the consumers [8]. In spite of the advantages that are provided by the implementation of DG units in the distribution network, the problems of generation may increase when the DG unit is located at not optimal locations with non-optimal size in the distribution network which can lead to real and reactive power losses, and high voltage deviation [9]. Many studies have presented artificial intelligence algorithms for finding the optimal location and size of DG units to decrease the real and reactive power losses and enhance the voltage profile of buses in the distribution network. PSO and GA considered as the global algorithms in term artificial intelligence algorithms due to the easy implementation and the ability to find the optimal or near optimal solution. However, the original PSO and GA demonstrated high execution time in solving DG units optimal allocation problems [10, 11].

1.3 Research Objectives

This work is aimed at finding the optimal locations and sizes for multi DG units in the distribution network to decrease the total real and reactive power losses, and to improve the voltage profile of the network. The specific objective of this study are;

1) To formulate the multi-objective function for solving the optimal DG unit location and size problem by considering several indices such as real power loss index, reactive power loss index, and cumulative voltage deviation index.

2) To propose the new optimization algorithms called grouping particle swarm optimization (GrPSO) and grouping genetic algorithm (GrGA) in order to reduce the computation time in determining the optimal size units that installed in the distribution network.

3) To investigate the impact of multi DG units installation on the system power losses and voltage profile and validate the proposed artificial intelligence algorithms, i.e. GrPSO, GrGA by comparing the results obtained using original artificial intelligence algorithms, i.e., PSO and GA.

1.4 Research Scope and Limitations

This work focuses on developing new proposed artificial intelligence algorithms, i.e., GrPSO and GrGA to find the optimum location and size of DG units, with the consideration of the computation time. Note that, the cost of DG unit installation is not considered in this research. This study is aimed to minimize the real and reactive power losses and improve the voltage profile. We are looking for the limit of total DG units that could be implemented in IEEE 30-bus test system while enhancing the reliability of the network where the number of installed DG units depends on the previous work. This work considered only DG with PV type. Based on the previous study conducted as reviewed in [69]. The implementation of the proposed IEEE 30-bus test system is established. However, the only major difference lies in the variations in the implemented system parameters, which is not provided in the paper.

1.5 Thesis Organization

Chapter 1 introduces the important information on DG with its impact on the power system. Also, present an overview of the research background and problem statement with clarifying the need for of optimal location and size of DG units to ensure the system reliability at all times. The objectives of this work and its limitations proposed in this chapter.

In Chapter 2, review on DG and its value in power system are presented. Also, optimization techniques that employed for finding the optimal location and size of DG units in the distribution network are discussed.

Chapter 3 detailed the four artificial intelligence algorithms that were employed in this work in detail, which are the two original artificial intelligence algorithms, i.e., PSO and GA and two proposed artificial intelligence algorithms, i.e., GrPSO and GrGA.

While in chapter 4 and 5, the results for IEEE 30-bus test system are obtained and concluded, respectively.

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