"I hereby declare that I have read through this report entitle "Optimal Placement and Sizing of Distributed Generation Considering Costs of Operation Planning" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)."

Signature :

Supervisor"s Name : Dr. Aida Fazliana Bt. Abdul Kadir

Date :

OPTIMAL PLACEMENT AND SIZING OF DISTRIBUTED GENERATION CONSIDERING COSTS OF OPERATION PLANNING

LOO SOON LII

A report submitted in partial fulfilment of the requirements for the Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declare that this report entitles “Optimal Placement and Sizing of Distributed Generation Considering Costs of Operation Planning” 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.

Signature :

Name : Loo Soon Lii

Date :

Dedicated to my beloved Parents, my siblings

Lecturers and all my friends

For their love and sacrifice.

ACKNOWLEDGEMENT

In the name of God, the most gracious, the most merciful, with the highest praise to God that I manage to complete this final year project successfully without difficulty.

My respected supervisor, Dr. Aida Fazliana Binti Abdul Kadir for the great mentoring that was given to me throughout the project. She has provided guidance, motivation, encouragement, patience and advice during this period.

Last but not least, I would like to thank for my fellow seniors and friends who taught and guide me about the final year project. They have taught me a lot knowledge and have also tried their best to teach me as much as possible to enable me to accomplish this degree project. Their cooperation is greatly appreciated.

Finally, appreciation is also extended to the committee who always provide me a lot of useful information about the final year project on how and what to do during the semester.

ABSTRACT

Distributed Generation (DG) can be defined as power generation at the distribution site or on-site generation. DG technology has been growing rapidly in industries as this technology can increase the overall efficiency to the power systems. The optimal placement and sizing of DG is vital as it significantly affects the distribution system. Improper placement and sizing can lead to power losses and interrupt the voltage profile of distribution systems. Studies have been done to solve the DG placement and sizing problem considering various factors and one of the common factor is minimising the power losses. However, it is not adequate by only considering the power losses, whereas, the costs of the generation, investment, maintenance and losses of the distribution system must be taken in consideration. Otherwise, it will create disadvantages after the installation of DG such as the system with DG is generating the same amount of energy but higher costs or losses compared to the conventional generation. In this research, DG chosen to be study is Photovoltaic (PV) type which are Monocrystalline and Thin-film. Costs of operation planning with respect to the power losses is considered which include the costs of investment, maintenance, power loss and generation are determine for optimal placement and sizing of DG. Proposed method algorithm Improved Gravitational Search Algorithm (IGSA) is used in the MATLAB environment to find the optimal placement and sizing of DG and is tested with the IEEE 34-bus system and IEEE 69-bus system. The performance of IGSA is then compared with Gravitational Search Algorithm (GSA) and Particle Swarm Optimisation (PSO) to find out which algorithm gives the best fitness value and convergence rate. Both Monocrystalline PV and Thin-film PV are compared based on the results obtained. The purpose of this report is to identify the operation planning cost based on the optimisation results and improves the optimal placement and sizing of DG in future, in order to provide maximum economical, technical, environmental benefits and increase the overall efficiency to the power system.

ABSTRAK

Penjana teragih (PT) boleh ditakrifkan sebagai penjanaan kuasa pada sistem pengagihan. Teknologi PT telah berkembang pesat dalam industri dan teknologi ini boleh meningkatkan kecekapan keseluruhan pada rangkaian sistem kuasa. Penempatan dan saiz PT yang optimum adalah penting kerana ia memberi kesan ketara kepada sistem pengagihan. Penempatan dan saiz yang tidak betul boleh membawa kepada kehilangan kuasa dan mengganggu profil voltan sistem pengagihan. Kajian telah dilakukan untuk menyelesaikan masalah penempatan dan saiz PT berdasarkan pelbagai faktor dan salah satu faktor yang biasa digunakan ialah meminimumkan kehilangan kuasa pada sistem pengagihan. Tetapi, ia adalah tidak mencukupi dengan hanya mempertimbangkan kehilangan kuasa, malahan, kos penjanaan, pelaburan, penyelenggaraan dan kerugian oleh sistem pengagihan perlu diambil kira dalam pertimbangan. Jika tidak, ia akan mewujudkan kelemahan selepas pemasangan PT seperti sistem dengan PT menjana jumlah tenaga yang sama tetapi kos atau kerugian adalah lebih tinggi berbanding dengan penjanaan konvensional. Dalam kajian ini, PT yang dipilih adalah jenis Fotovolta (FV) iaitu Monocrystalline dan *thin-film*. Kos perancangan operasi berkenaan dengan kehilangan kuasa dalam sistem dipertimbangkan termasuk kos pelaburan, penyelenggaraan, kehilangan kuasa dan penjanaan yang menentukan untuk penempatan dan saiz PT yang optimum. Kaedah cadangan iaitu Algoritma Carian Graviti Diperbaiki (ACGD) digunakan dalam MATLAB untuk mencari penempatan dan saiz PT yang optimum dan diuji dengan sistem 34-bas IEEE dan sistem 69-bas IEEE. Prestasi ACGD kemudiannya dibandingkan dengan Algoritma Carian Graviti (ACG) dan Pengoptimuman Kuruman Zarah (PKZ) untuk memperolehi objektif dan kadar penumpuan terbaik. Kedua-dua FV Monocrystalline dan FV *thin-film* dibandingkan berdasarkan keputusan yang diperolehi. Tujuan laporan ini adalah untuk mengenal pasti kos perancangan operasi berdasarkan keputusan pengoptimuman dan menambahbaikkan penempatan dan saiz PT yang optimum pada masa depan, untuk memberi kesan ekonomi, teknikal, faedah alam sekitar yang maksimum dan meningkatkan kecekapan keseluruhan sistem kuasa.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DG	-	Distributed Generation
PV	-	Photovoltaic
Mono	-	Monocrystalline
Poly	-	Polycrystalline
TF	-	Thin-film
PSO	-	Particle Swarm Optimisation
GSA	-	Gravitational Search Algorithm
IGSA	-	Improved Gravitational Search Algorithm
C_P	-	Costs of Operation Planning
C_I	-	Investment Cost
C_M	-	Maintenance Cost
C_L	-	Power Loss Cost
C_{DG}	-	Generation Cost
IEEE	-	Institute of Electrical and Electronics Engineers
SEDA	-	Sustainable Energy Department Authority
FiT	-	Feed-in Tariff
BOS	-	Balanced of System

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

In this modern era, electricity demand is increasing due to the economic growth. Increasing in energy consumption can be overcome by promoting the technology of distributed generators in distribution systems using renewable resources. Currently in Malaysia, the main energy resources are from oil and natural gas. By introducing the distributed generation technology, it helps to generate energy more efficient and also reduce environment pollution such as air pollution from the burning of fossil fuels [1].

Typical distribution systems are operating without any generation on the systems. By adding generation at the distribution system, it provides benefits to the power system. DG is a technology that could help to enable efficient, renewable energy production both in developed and developing world. Despite their small size, DG technologies are having a stronger impact in electricity markets [2].

Many of different research works on the optimal placement and sizing of DG have been discussed from viewpoint of used optimisation method and objective functions. The most efficient and popular approaches for solving the DG placement and sizing problems is the heuristics methods such as Particle Swarm Optimisation (PSO) and Gravitational Search Algorithm (GSA). The importance of proper placement and sizing of the distributed generators is to improve the reliability and stability of power system [2]. Improper placement and sizing can lead to power losses and interrupt the voltage profile of distribution systems [2].

By using renewable resources as DG units can be very effective in improving technical, economical and especially environmental characteristics of distribution systems [1]. In Asia, the most suitable renewable resource is solar where photovoltaic (PV) DG is used to generating power from the solar energy such as monocrystalline, polycrystalline and thin-film [3]. To have realistic solutions for DG placement and sizing, the costs of operation planning of the renewable energy-based generating units must be considered so that it can minimise DG's investment and operating costs and compensating for system losses along the planning period [2].

1.2 Problem Statement

Improper placement and sizing may lead to some disadvantages such as overvoltage, excessive power losses and stability issues [1]. Therefore, the best types of DG units with the best size should be installed at the best locations in distribution systems. In most of previous works, a very limited number of optimisation algorithms, applied to DG placement and sizing problems where the applied optimisation methods are not known to be the best one. Besides, researches such as in [4], [5], [6], [7], [8], [9] aims were power and energy losses in the power system but it is not adequate by only considering the power losses in determining the placement and sizing of DG. In terms of finding the optimal placement and sizing of DG, the type of DG must be known and the costs of operation planning should not be ignored. The DG installed in the distribution system is generating power, thus the generation cost of the DG must be known in the operation planning. Besides, the efficiency of the DG will be reducing after a lengthy period and maintenance must be done to improve the performance of DG. Power losses will be present as the DG changes the original power flows of the transmission and distribution system. The cost of all these problems must be taken in consideration seriously, if not, it will create disadvantages after installation of DG in the distribution system. Thus, to find the optimal placement and sizing of DG, investment cost, maintenance cost, power loss cost and generation cost should be including in the costs of operation planning.

1.3 Objectives

The objectives of this study are:

- To determine the optimal placement and sizing of photovoltaic distributed generation.
- To compare the performance of proposed method IGSA with PSO and GSA in terms of fitness value and convergence rate.
- To compare the type of PV DG (Monocrystalline or Thin-film) based on the Costs of Operation Planning (C_P).

1.4 Scope

This study focuses on finding the optimal placement and sizing of DG considering the costs of operation planning. In Malaysia, the most suitable renewable energy resources to be used is sunlight so Photovoltaic (PV) generation units are chosen as the type of DG to be study. In this study, two types of PV are chosen to be study and compare which are Monocrystalline and Thin-film based on the costs of operation planning. The proposed method for this study is Improved Gravitational Search Algorithm (IGSA) and is performed in MATLAB environment to solve the problem. The performance of IGSA is then compared with Gravitational Search Algorithm (GSA) and Particle Swarm Optimisation (PSO) to find out which algorithm gives the best fitness value and convergence rate. The costs of operation planning of DG in distribution system are assessed by investment cost, maintenance cost, power loss cost and generation cost. The placement and sizing of the photovoltaic DG is then tested in IEEE 34-bus system and IEEE 69-bus system.

1.5 Report Organisation

This report is divided into five chapter, which are introduction, literature review, methodology, results and discussion and finally conclusion. In Chapter 1 introduction, overview of the project is presented. In this chapter, the research background, problem statement, objectives, and scopes of the project are discussed. In Chapter 2 literature review, research about DG, solar PV and costs of operation planning for optimal placement and sizing of DG are presented. Also, some previous works related to the optimal placement and sizing of DG are reviewed. In Chapter 3 methodology, the methods to optimise the placement and sizing of DG and formulas to calculate the costs of operation planning is presented in detail with the case study. In Chapter 4, the results are presented with analysis. Discussion on the results obtained is also included in this chapter. Finally, in Chapter 5, the overall research is summarised and concluded based on the objectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Distributed power generation has been developing rapidly in power systems seeing that it is an innovation that could help to produce energy more efficient compare to traditional large generators. DG is a small power generating unit installed at the distribution network or consumer site as a better way for centralized generation. Figure 2.1 shows the integration of renewable DG is at the distribution system, where the generation now is nearer to the load compared to conventional generation.

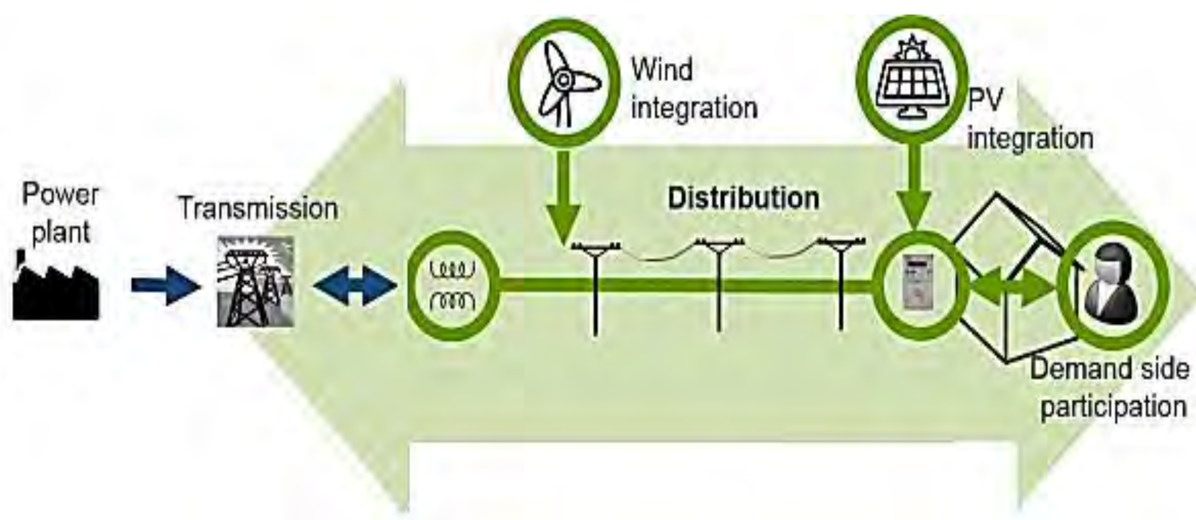

Figure 2.1: Integration of Wind DG and PV DG in Distribution System

DG can produces from less than a kilowatt (kW) to hundreds of megawatts (MW) [2] and it may be grid-connected or work standalone. It is categorized into four sizes based on its capacity. Micro DGs rated between 1 to 5 kW, small DGs rated between 5 kW to 5 MW, medium DGs rated between 5 MW to 50 MW and large DGs rated between 50 MW to 500 MW. Figure 2.2 below shows the criteria for classification of DG [10].

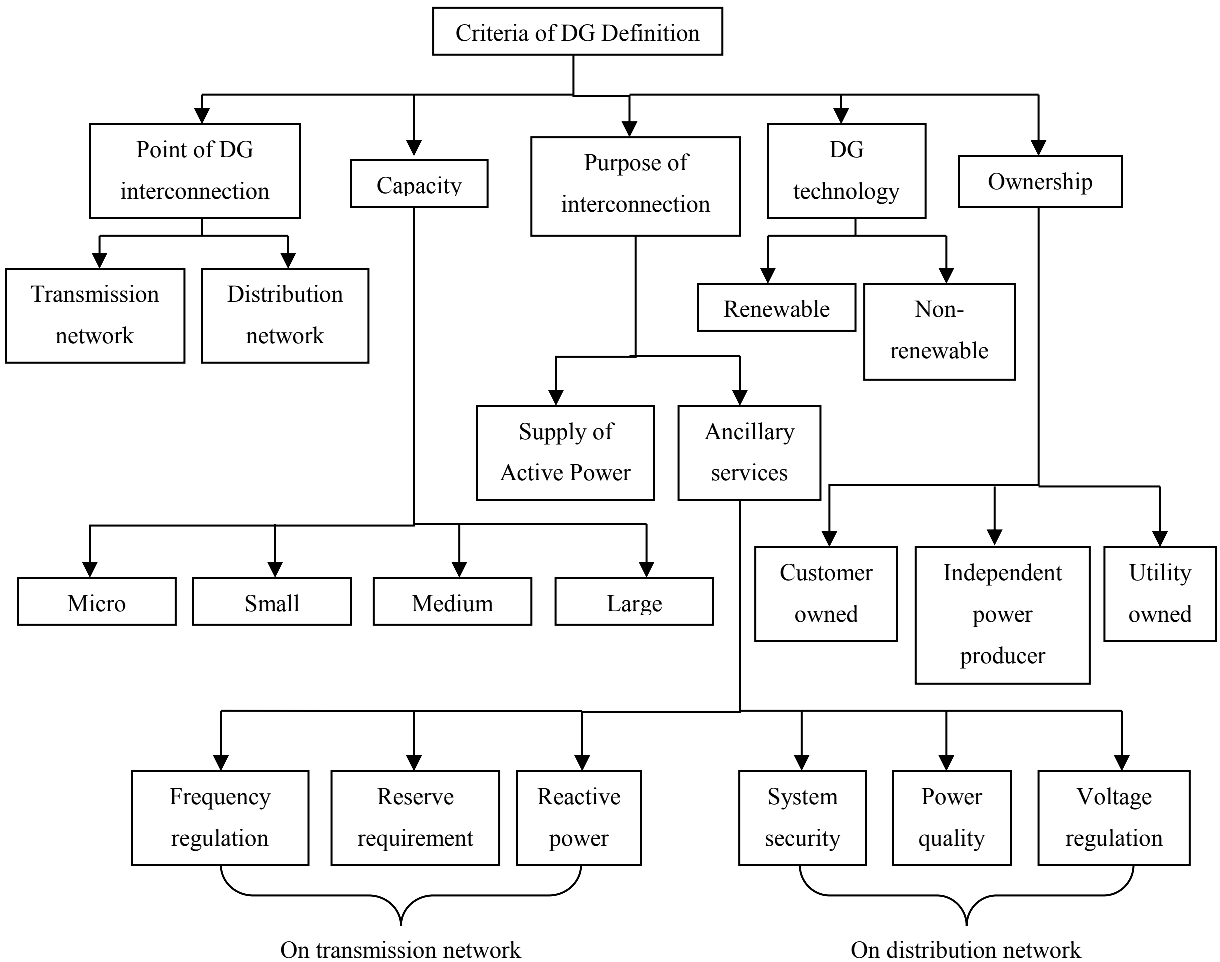

Figure 2.2: Criteria for Classification of DG [10]

2.2 Type of DGs

According to Wichit Krueasuk [11], DGs are classified into 3 types; Type 1 DGs, generate only real power; Type 2 DGs, supplying only reactive power; and Type 3 DGs, supplying real power but absorb reactive power. DGs can based on renewable energy sources such as diesel generators and microturbines; or non-renewable energy sources such as solar photovoltaic, wind power, hydroelectricity and fuel cells [1].

2.2.1 Diesel Generators

For standalone operation, diesel generators are most commonly used as it can be started and turn off easily. Microturbines are rapid and mechanically straight forward devices. Currently, its productivity is constantly expanding and its cost is consistently diminishing [1]. But the commonly fuels it used are natural gas and biogas where the emissions from the fuels are not environmental friendly. Figure 2.3 shows the diesel generator that commonly used for standalone operation.

Figure 2.3: Standalone Diesel Generator

2.2.2 Solar Photovoltaic

Solar photovoltaic (solar PV) converts sunlight into energy supply. Solar PV uses the inverter technology to connect with the grid. In Thailand, a tropical country like Malaysia has enough of sunshine to generate electricity using the solar PV [12]. Incorporation of solar PV with grid network would help with supplementing the persistently expanding of power requires [12]. For example, Figure 2.4 shows the grid connected solar farm in Melaka, Malaysia. More prominent utilization of PV technology can likewise build unwavering quality of the power network. Solar PV is widely used because it is clean, free and sustainable. However, it is a very expensive technology in the early stage but the cost decrease rapidly due to the highly efficient of this solar energy [1]. The primary disadvantage of solar PV is that their yield power is an element of solar irradiation and temperature which fluctuate always, in this manner, their output power is not fixed at various times [1].

Figure 2.4: Grid Connected Solar Farm in Melaka, Malaysia