SIZING OF ENERGY STORAGE BASED ON LOSS OF LOAD PROBABILITY OF STANDALONE PHOTOVOLTAIC SYSTEMS

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Special dedicated

to my supervisor and family who encouraged

me throughout my journey of

education

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ABSTRACT

If the standalone PV system is optimally design, it can be cost effective and reliable. This process is called optimal sizing, which focused on finding the lowest cost for the PV system at the acceptable reliability. The project is focused on finding the optimum configuration for PV system at FKE Building, UTM, Johor. The configuration consists of two components; number of PV arrays and number of battery. By manipulating these two components, the reliability of the PV system can be controlled. For this project, the reliability is measured using Lost of Load Probability (LOLP) concept for one year duration. The LOLP of the system is calculated for every configuration starting from one PV array and one battery until 100 PV arrays and 100 batteries. The project used 0.1 LOLP as the reliability level, which means only 10% of the total energy demand could not be satisfied by the PV system. Out of the configurations that meet the 0.1 LOLP, the most cost effective configuration needs to be determined. For this project, two methods are used for the optimal sizing; Graphical Construction Method (GCM) and Life Cycle Cost (LCC) analysis. GCM is focus on finding the optimal size of the system depending on the initial cost of the PV arrays and batteries, while LCC analysis considered all the cost throughout the entire project.

ABSTRAK

Jika sistem PV jenis Berdiri Sendiri direka bentuk dengan baik, ianya akan menjadi murah dan boleh dipercayai. Proses ini dipanggil saiz optimum, iaitu proses mencari sistem PV yang termurah pada kebolehpercayaan yang boleh diterima. Projek ini fokus dalam mencari configurasi yang optimum untuk Sistem PV di Banggunan FKE, UTM, Johor. Configurasi ini terbahagi kepada dua komponen; bilangan tatasusun PV dan bilangan bateri. Dengan memanipulasi dua komponen ini, kebolehpercayaan sistem PV boleh dikawal. Untuk projek ini, kebolehpercayaan diukur dengan menggunakan konsep Kebarangkalian Kehilangan Beban (LOLP) selama satu tahun. LOLP bagi sistem ini dikira bagi setiap konfigurasi bermula dari satu tatasusun PV dan satu bateri hingga 100 tatasusun PV dan 100 bateri. Projek ini menggunakan 0.1 LOLP sebagai tahap kebolehpercayaan yang bermaksud hanya 10% daripada kesemua permintaan tidak dapat dipenuhi oleh sistem PV. Daripada kesemua konfigurasi yang memenuhi 0.1 LOLP, konfigurasi yang paling murah perlu ditentukan. Untuk projek ini, dua kaedah digunakan untuk menentukan saiz optimum; Kaedah Pembinaan Grafik (GCM) dan analisis Kos Kitaran Hayat (LCC). GCM lebih menfokus dalam mencari saiz optimum sistem yang bergantung kepada kos permulaan bagi tatasusun PV dan bateri, manakala analisis LCC mengambilkira kesemua kos disepanjang projek ini berjalan.

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LIST OF ABBREVIATIONS

LOLP	-	Loss of load probability
LPSP	-	Loss of power supply probability
GCM	-	Graphical Construction Method
LCC	-	Life cycle cost
SOC	-	State of charge
ACS	-	Annualized Cost of System
FLNS	-	Fractional load not served
PV	-	Photovoltaic
PSH	-	Peak solar hour
DC	-	Direct current
DOD	-	Depth of discharge
LLP	-	Loss of load probability
AEC	-	Annual equivalent cost
OC	-	Operating cost
CR	-	Capital cost
SFF	-	Sinking fund factor

LIST OF SYMBOLS

E	-	Energy
N	-	Number of parameter
P	-	Power
L	-	Load
I	-	Current
V	-	Voltage
T	-	Period
t	-	Time
K	-	Boltzman constant
q	-	Electron charge
η	-	Efficiency
^{o}C	-	Celsius
Pr	-	Probability
α	-	Cost of a PV array
β	-	Cost of a battery
P	-	Present factor
F	-	Future cost
C	-	Cost
%	-	Percentages

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays, the fossil-fuel resources on a worldwide basis have been decrease tremendously [3, 4, 10]. If the usage of fossil fuel is constant throughout the year, the oil and gas reserve will exhaust in 22 years and 30 years separately in India while the coal is expected to exhaust in 80 years time [15] It is necessary to find an alternative energy sources. There are many alternatives energy sources such as photovoltaic and wind energy has huge potential to meet the continually increasing demand for energy. These type of energy are unlimited, pollution-free, and their easy to access. The system that is located at remote area which is far away from conventional power system such as radio telecommunications and satellite earth stations, the system that use renewable sources is preferred [4, 10].

Since the output power of these renewable sources are unpredictable [6, 12], diesel generators are use for short period of time to meet the peak load demand when there is a shortage of available energy to overcome the load demand. The usage of diesel generator can be replaced with batteries [4]. The combination of renewable energy sources with backup batteries can satisfy the source fluctuations [4, 10].

Researchers and utility engineers are interested in Photovoltaic (PV) technology. Despite the high cost of PV panel, the price is slowly declining and gradually improving its efficiency [3]. PV technology is expected to be the competitive contenders for electric power generation in the future. Nowadays, the application of stand-alone PV systems is both technically and economically practical for remote area. For this off-grid design, loss of power supply probability (LPSP) is considered as the design parameter.

Loss of power supply probability (LPSP) is the ratio between the energy shortage and the energy demands on the load for a long period of time [8]. LPSL is also known as loss of load probability (LLP), loss of power probability (LOPP) and load coverage rate (LCR) [7].

To optimize the utilization of the renewable energy sources efficiently and economically, an optimum configuration design sizing method is needed [6]. The sizing of stand-alone PV system is important in system design that still remains an active area of research [9]. Sizing optimization method can help reducing the investment cost for installing PV system without sacrificing the reliability of PV system [1, 3-6]. Without the system sizing procedure, the system design may over-size, which result in costly design [10]. Various optimization techniques have been develop by researcher that will be discussed in chapter 2.

The most fundamental form of sizing procedure is relationship between the size of PV array and the battery that can overcome the load demand with certain reliability that can be tolerated by the electrical consumer [9]. The result can be summarized in form of sizing curve [7, 9]. Modelling of PV system is needed construction of sizing curve based on LPSP [9, 20].

1.2 Problem Statement

Since the standalone PV system is solely rely on onsite source which is the PV module and the batteries, finding the best configuration of the standalone system is essential to make sure the system is reliable and economical.

1.3 Objectives of Project

The objectives of the project are:

- To design a reliable PV system using Load of Load Probability (LOLP)
- To determine the optimal sizing of the PV system design using Graphic Construction Method (GCM) and Life Cycle Cost (LCC) analysis.
- To simulate the standalone solar system design using MATLAB.
- To improve the system reliability without tremendously increase the Life Cycle Cost of the System

1.4 Scope of Project

The design of PV system is depend on the location of plan site. Therefore, the location needs to be study and analyse before the design of the PV system can be started. The first data that need to be obtained is the solar irradiance data. The data will be obtained from meteorological department. The second data needed for the study is the load profile. The case study for the project report is the Faculty of Electrical Engineering (FKE), University Teknologi Malaysia (UTM), Johor, Malaysia.

The system to be tested is the PV system which consists of solar module and batteries. The design will focus on finding the optimum PV size and battery size for the location chosen. The system is a standalone system and the system will not connect to grid.

1.5 Project Report Outline

Chapter 1 generally describe on the PV system. This chapter also provides information on the objectives of the study, problem statement and the scope of the study.

Chapter 2 focused on the previous work done to optimizing the reliability of PV system and methods available to achieve the optimization. This chapter also include the modelling of component that will be used in the Matlab software.

Chapter 3 discuss on the modelling of the PV System using Matlab software.

Chapter 4 analysed the result obtained from Matlab software. The analysis of loss of power source probability and life cycle cost (LCC) will be discussed in this chapter.

Chapter 5 explain the conclusion of the PV system and the suggestion for future works.

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