SIMULATION OF DISH STIRLING SYSTEM
FOR MALAYSIA ENVIRONMENT

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Bachelor of Electrical Engineering (Industrial Power)

June 2014

"I hereby declare that I have read this fully report entitled "**Simulation of Dish Stirling System for Malaysia Environment**" and found that is has achieve the requirement for awarding the Bachelor of Electrical Engineering (Industrial Power)"

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Simulation of Dish Stirling System for Malaysia Environment

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A report submitted to partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering (Power Industry)

Faculty of Electrical Engineering

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June 2014

I declare that this report entitle "**Simulation of Dish Stirling System for Malaysia Environment"** is the result of my own research except as cited in the references. The report has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

Signature : …….

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Date : …….

Specially dedicated, in thankful appreciation for the support, encouragement and understanding for my beloved mother father, siblings, supervisor's and friends.

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ABSTRACT

Renewable energy has become an important source of global electricity generation. Tendency to lean towards renewable energy because it does not work out with use over time compared to conventional fuel electric generator. Another important factor is that renewable energy produces greenhouse gases and environmental pollution that little or none at all. On average, Malaysia receives about 6 hours of direct sunlight each day. The average annual daily solar radiation in Malaysia is in magnitude from 4.21 to 5.56 kWhm-2 and sunlight is more than 2200 hours per year. CSP technologies such as the Stirling dish systems can contribute to the development of a more sustainable energy system by converting solar energy into mechanical energy and then into electricity. Under Entry Point Energy programmed the target for Malaysia to build solar power capacity to 1.25 GW in 2020. The System Advisor Model was chosen to predict the performance of a dish stirling system in this project. The main objective of this project was to simulate and predict the performance of a dish stirling system by using SAM software. The input data to simulate dish stirling system are weather data from U. S. National Climatic Data Centre. The second objective is to analyse the electrical energy produced by a dish stirling system for four locations in Malaysia environment. The selected locations are George Town, Kota Baharu, Kuala Lumpur and Kuching. The highest solar to electrical energy conversion is in George Town. Found that the performance dish stirling system in George Town is better than the other location. All data and analysis in this project is hoped will be a good reference for further research and renewable energy technology development in Malaysia.

ABSTRAK

Tenaga boleh diperbaharui menjadi sumber penting dalam penjanaan elektrik global. Kecenderungan untuk menjurus kepada tenaga boleh diperbaharui adalah kerana ia tidak habis dengan penggunaan sepenuh masa berbanding dengan bahan api konvensional. Satu lagi faktor penting ialah tenaga boleh diperbaharui menghasilkan gas rumah hijau dan pencemaran alam sekitar yang sedikit atau tiada langsung. Secara purata, Malaysia menerima sebanyak 6 jam cahaya matahari setiap hari. Purata tahunan radiasi solar harian bagi Malaysia dalam magnitud 4.21-5.56 kWhm-2 dan cahaya matahari adalah lebih daripada 2200 jam setahun. Teknologi CSP seperti sistem piring Stirling boleh menyumbang kepada pembangunan sistem tenaga yang lebih mampan dengan menukar tenaga solar kepada tenaga mekanikal dan kemudian ke dalam elektrik. Di bawah Entry Point Tenaga, ditetapkan sasaran bagi Malaysia untuk membina kapasiti tenaga solar kepada 1.25 GW pada tahun 2020. Sistem Penasihat Model telah dipilih untuk meramalkan prestasi system piring Stirling dalam projek ini. Objektif utama projek ini adalah untuk merangsang dan meramalkan prestasi sistem piring Stirling dengan menggunakan perisian SAM. Data masukan untuk mensimulasikan sistem piring Stirling adalah data cuaca dari Pusat Data Iklim Kebangsaan, Amerika Syarikat. Objektif kedua adalah untuk menganalisa tenaga elektrik yang dihasilkan oleh sistem piring Stirling untuk empat lokasi di persekitaran Malaysia. Lokasi yang dipilih adalah George Town, Kota Baharu, Kuala Lumpur dan Kuching. Penukaran tenaga solar kepada elektrik yang paling tinggi adalah di George Town. Didapati, prestasi sistem piring Stirling di George Town adalah lebih baik daripada lokasi yang lain. Semua data dan analisis dalam projek ini diharapkan akan menjadi rujukan yang baik untuk penyelidikan lanjut dan untuk pembangunan teknologi tenaga boleh diperbaharui di Malaysia.

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INTRODUCTION

1.1 Overview

This chapter will elaborate about the Project Background, Project Motivation, Problem Statement, Objective, Scope of Project and Report Outline.

1.2 Project Background

Solar energy is one of the most attractive renewable energy sources that can be used as input to the heat engine such as stirling engines to generate electricity. The most common technologies used to harvest energy from the sun are photovoltaic (PV) and concentrated solar power (CSP). Photovoltaic method is based on light, meanwhile thermodynamic process in CSP system is based on heat. CSP systems use mirrors to concentrate solar sunlight and collect the thermal energy on the receiver. The thermal energy then uses to heat a working fluid or gas in receiver and generate super-heated steam to drive a generator through heat engine and then produce electricity. There are four types of CSP systems, namely linear Fresnel Reflectors, Parabolic Trough, Dish Stirling System

and Solar Power Tower. Among these four CSP systems, dish stirling system has higher efficiency at converting thermal to electrical energy.

Dish stirling systems convert heat energy in solar radiation into mechanical energy by stirling engine and then into electricity. The dish stirling system recorded a world record in solar to electrical energy conversion efficiency of 29.4% in 1984 [1]. Since then, this system has gained widespread interest in producing cheap and reliable renewable electricity to the market in the near future. Another fact that increases the interest is the amount of sunlight reaching the earth's surface continuously at 1.05×10^5 TW [2]. The sunlight will produce about 4 times of the global energy needs for 2050 that are expected to be around 25-30 TW if only 1% power can be converted into electricity with an efficiency of 10% [2].

Countries around the world, including Malaysia are now focusing more towards green technology and renewable energy. Under Entry Point Energy programmed, the target for Malaysia to build solar power capacity is to 1.25 GW by 2020 [3]. On average, Malaysia receives about 6 hours of direct sunlight each day. Annual average daily solar radiation for Malaysia in magnitude from 4.21 to 5.56 $kWhm^{-2}$ and the sunlight is more than 2200 hours per year [3]. The dish stirling systems can contribute significantly to developing a more sustainable energy system.

1.3 Project Motivation

The key issue that motivates the drive towards exploring new renewable sources is that the world has a problem with decreasing of non-renewable energy source to generate electricity. Demand renewable energy has become an important issue for a global electricity generation. The high tendency to lean toward renewable energy because it does not depleted with use over time. Environmental issues and rising energy demand have increased interest in the use of renewable energy, especially in solar energy. As previous study of CSP only done outside Malaysia, there is slightly published paper of performance

CSP in Malaysia. So, it is motivated to study on performance CSP for Malaysia environment based on weather data by using System Advisor Model (SAM).

1.4 Problem Statement

The Parabolic dish Stirling engine systems have not been widely studied as other technologies such as photovoltaic solar in the Malaysian environment. Literature on these systems is also difficult to find and rarely organized in one cohesive report. Furthermore, data on the performance of dish stirling systems have typically not been accessible to the public and only a few Stirling dishes have been constructed to date [3]. Hence, the purpose of this project is to simulate and predict the performance Stirling dish system in Malaysia environment. In order to get the amount electrical energy produced in a year, all parameters include concentrator, receiver, stirling engine and parasitics parameter will be used. In this project, it is proposed to use SAM software as a tool to do the analysis of weather data. The weather data is about solar radiation estimated on an hourly basis from earth-sun geometry and hourly weather elements information. The data use for SAM simulation comes in International Weather for Energy Calculation (IWEC) files that originally achieved at the U. S. National Climatic Data Centre. The IWEC are the result of ASHRAE research project 1025 by Numerical logics and Bodycote Materials Testing Canada. The IWEC data files are typical weather data that suitable for use with building energy simulation program for 227 locations outside the USA and Canada. The 227 locations include the location of George Town, Kuala Lumpur, Kota Baharu and Kuching. After the data is successfully simulated using SAM, then the analysis on energy produced by dish stirling system for Malaysia environment can be done.

1.5 Objectives

The objectives for this project are stated as follows:

1. To simulate and predict the performance of a dish stirling system by using SAM software.
2. To analyse the electrical energy produced by a dish stirling system for four locations in Malaysia environment.

1.6 Scope of Project

The main scope of this project is to simulate and predict the performance dish stirling system in Malaysia environment. The prediction of performance is based on energy produced within a year. The location of George Town is selected to simulate the performance because this area receives high solar radiation throughout the year in Malaysia. The weather data year 2012 from U. S. National Climatic Data Centre of George Town will be simulated by using SAM. The dish stirling engine use in SAM are based on the Wilkinson, Goldberg, and Associates, Inc. (WGA) model. This project also analyse the electrical energy produce by stirling system in four different locations in Malaysia. The selected locations are George Town, Kuala Lumpur, Kuching and Kota Baharu.

1.7 Report Outlines

The report consists of five chapters. Chapter 1 discusses the overview of project background, problem statement, objectives and scope of this project. Chapter 2 discusses the literature review on renewable energy, solar technology, and dish stirling system. The literature reviews will regarding on previous researchers work on Stirling dish system from Institute of Electrical and Electronics Engineers (IEEE) journal, articles, book, technical paper and others. Chapter 3 covers the methodology of the project and describe the flow chart of project activities. The result and discussions will be reviewed in chapter 4. This chapter will highlight the initial results achieved from data collection and simulation. Finally, the conclusion and recommendations on future research will be enlightened in chapter 5.

CHAPTER 2

LITERITURE REVIEW

2.1 Overview

This chapter will elaborate about the Concentrating Solar Power (CSP) parabolic which contain Solar Energy, Renewable Energy Technology, CSP Type, Principle of Stirling Engine, and a Preview of Related Previous Work. In this chapter, it starts with the introduction of renewable energy technology, four types of CSP system and its efficiency. Then, continues with the principle of alpha, beta and gamma type Stirling engine. The theory of important parts of the Stirling dish system which are concentrator, receiver, and power concentrating unit were also stated. The previous work is gathering from IEEE journals, thesis, book and also information from internet.

2.2 Solar Energy

Solar Energy is by far the most abundant energy source received by the earth. Solar energy received by the earth is in the form of solar radiation. Solar radiation is closely related to the duration of sunlight that's been receiving by earth. Sunlight is the light and energy that comes from the sun. This energy that reaches the surface of earth is called

insolation. Sunlight is also known as solar radiation. Solar radiation is the heat and radiation from the sun in the form of electromagnetic waves.

Malaysia naturally has an abundant sunlight received in a year. However, it is difficult to have a full day with clear sky. One of the main factors that cut a large sunlight is the presence of cloud. On average, Malaysia received about 6 hours of solar radiation a day. The annual average daily solar irradiation for Malaysia is between magnitude 4.21 – 5.56 $kWhm^{-2}$ and the sunlight duration is more than 2200 hours per years [3].Table 2.1 shows the solar radiation thought out the year in Malaysia location.

Table 2.1: Solar Radiation in Malaysia (average value throughout the year) [21].

Location	**Yearly Average Irradiance Value (kWh/m^2)**
Kuching	1470
Bandar Baru Bangi	1487
Kuala Lumpur	1571
Petaling Jaya	1571
Seremban	1572
Kuantan	1601
Johor Bahru	1625
Senai	1629
Kota Bharu	1705
Kuala Terengganu	1714
Ipoh	1739
Taiping	1768
George Town	1785
Bayan Lepas	1809
Kota Kinabalu	1900

Solar energy can be harvested from the sun basically divided into two categories which is photovoltaic (PV), and concentrated solar power (CSP) or solar thermal.

2.3 Renewable Energy Technology

Renewable energy is energy that comes from natural resources such as sunlight, wind, rain, tides, waves and geothermal heat [12]. The renewable energy can be harvest and converted into electricity.

2.3.1 Solar photovoltaic (PV)

Solar photovoltaic are technologies that convert solar energy into useful energy forms by directly absorbing solar photons. Solar photon is particles of light that acts as individual units of energy. That energy then converts to electricity through the solar PV panel. Solar PV-panels have efficiency around 10-20% [4]. These systems are used in large and small scale applications, for example on the rooftops, satellites, boats, solar farm and other remote system that need direct power. Figure 2.1 shows the example of PV-solar panel applications.

Figure 2.1: Photovoltaic solar panels [5]

2.3.2 Concentrated Solar power (CSP)

Concentrated Solar Power or solar thermal is systems where a large area of sunlight is concentrated on receiver using mirrors or lenses. There are four types of CSP systems, namely linear Fresnel reflectors, parabolic trough, dish Stirling concentrator and solar power tower.

2.3.2.1 Concentrating Linear Fresnel Reflectors

Concentrating Linear Fresnel reflectors as shown in Figure 2.2 use many thin mirror strips instead parabolic mirrors to concentrate sunlight onto two tubes with the working fluid. This system has the advantage of a flat mirror which can be used are much cheaper than parabolic mirrors and many reflectors can be placed in the same amount of space [18]. This technology uses modular flat reflectors to focus the sun's heat onto a receiver that consisting of a system of tubes through which water flows [18]. Concentrated sunlight boils the water in the tubes and generating high-pressure steam for direct use in power generation and industrial steam applications without the need for expensive heat exchangers. This system can generate power up to 150-200MW. The efficiency of this system is about 9-15% [17].

Figure 2.2: Linear Fresnel reflectors [4]