PARABOLIC DISH STIRLING ENGINE WITH SINGLE AXES SOLAR TRACKER SYSTEM

Khairulannuar Bin Abdul Satar

Bachelor of Electrical Engineering

19 JUN 2013

"I hereby declare that I have read through this report entitle "Parabolic Dish Stirling Engine with Single Axes Solar Tracker System" and found that it has comply the partial fulfillment for awarding the degree of *Bachelor of Electrical Engineering (Power Electronic and Drive)*".

Signature : ……...

Supervisor's Name : Datuk Prof Dr Ruddin Ab Ghani

Date : ……..

I declare that this report entitle "Parabolic Dish Stirling Engine with Single Axes Solar Tracker System" 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 degree.

Signature :……

Name : KHAIRULANNUAR BIN ABDUL SATAR

Date : 19 June 2013

Dedicated, in thankful appreciation for support, encouragement and understandings

To:

My supervisor Datuk Prof Dr Ruddin Md Ghani;

My beloved mother Hasmah Bte Abu Hasan;

My beloved father Abdul Satar Bin Hashim

My family members and all friends

ACKNOWLEDGMENT

First and foremost, I would like to praise ALLAH SWT for His blessing. He gave me such physical and mental strength to carry on my final year project (FYP2) till done. I also would like to express my big gratefulness and thanks to my supervisor, Datuk Prof Dr Ruddin Ab Ghani and Puan Rosnani for support, encouragement, guidance, advice and trustworthy patience along the period to complete this project. His encouragement and guidance are really appreciated. Otherwise, this project might not possible even exist.

I have learnt a lot under his guidance, either practically or theoretically. I also would like to thank family members for their encouragement and never ending support. Their support is such my strength in order to complete this project. Other than that, I am also grateful to all my supportive friends who really help me a lot and giving me useful opinions along carrying out of this project.

Finally, I would like to thanks again and I really appreciated a lot for all these supports and encouragement in many terms that I have gained all over the period of this project. Those helps are very priceless, doesn't matter either from small or big things.

ABSTRACT

Malaysia is a country that has plentiful of solar energy and annual average daily solar irradiation for Malaysia have magnitude of 4.21-5.56 kWh/m², sunshine duration more than 2,200 hours per year. Unfortunately, Malaysia has the main energy source which is oil and gas. In addition to limited stock of negative effects of fossil fuel combustion on the environment have forced many countries to inquire into and change to environmentally friendly alternatives that are renewable energy to sustain the increasing energy demand. There is no greenhouse gases release in this technology, therefore a lot of countries are now focusing more on the technology of renewable energy. Among CSP technologies, system that is suitable for small scale plant and modular which is suitable for small scale area is Parabolic Dish system. This project purpose is to investigate the ability of Parabolic Dish system for weather in Malaysia and make comparison of solar efficiency solar energy in converting electricity due to temperature effect between manual stirling dish system with single axis solar tracker system. This project requires parabolic dish mirror, stirling engine, voltmeter, single axis solar tracker system and thermometer. The stirling engine is a heat engine that converts heat energy into mechanical work to drive a generator then converts mechanical energy into electricity, the stirling engine uses a permanently enclosed volume of gas such as air or helium for mechanical work performance. The dish focuses the sun ray on the cylindrical glass bulb of the stirling engine to heat it up, then the air inside the bulb heats up and pushes a piston which turns an electric generator which produces electricity.

ABSTRAK

Malaysia adalah sebuah negara yang mempunyai banyak tenaga solar dan purata sinaran suria harian tahunan untuk Malaysia mempunyai magnitud 4,21-5,56 kWh / m², tempoh cahaya matahari lebih daripada 2,200 jam setahun. Malangnya, Malaysia mempunyai sumber tenaga utama yang minyak dan gas. Di samping stok terhad kesan negatif pembakaran bahan api fosil terhadap alam sekitar telah memaksa banyak negara untuk menyiasat dan menukar kepada alternatif mesra alam yang tenaga boleh diperbaharui untuk mengekalkan permintaan tenaga yang semakin meningkat. Tiada pelepasan gas rumah hijau dalam teknologi ini, oleh itu banyak negara kini memberi tumpuan lebih kepada teknologi tenaga boleh diperbaharui. Antara CSP teknologi, sistem yang sesuai untuk tumbuhan kecil dan modular yang sesuai bagi kawasan kecil adalah sistem Dish Parabolic. Ini tujuan projek ini adalah untuk menyiasat keupayaan sistem Dish Parabolic untuk cuaca di Malaysia dan membuat perbandingan solar kecekapan tenaga solar dalam menukarkan elektrik disebabkan oleh kesan suhu antara manual stirling sistem hidangan dengan paksi sistem tracker solar tunggal. Projek ini memerlukan cermin hidangan parabola, stirling engine, voltmeter, paksi tunggal solar sistem tracker dan termometer. Enjin stirling adalah enjin haba yang menukarkan tenaga haba ke dalam kerja mekanikal untuk memacu penjana kemudian menukarkan tenaga mekanikal kepada tenaga elektrik, enjin stirling menggunakan jumlah yang tetap tertutup gas seperti udara atau helium untuk prestasi kerja mekanikal. Hidangan ini memberi tumpuan sinar matahari di kaca mentol silinder enjin stirling untuk menjadi panas, maka udara di dalam mentol memanaskan dan menolak omboh yang bertukar penjana elektrik yang menghasilkan tenaga elektrik.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1. Project Background

Solar energy is a source of energy production which will inexhaustible and the advantage of solar energy is that both free and abundant. Over the past decade, changes have occurred on the use of energy resources in the world. There is many increasing effort form many sector such as government, industry and academic institutions to study other alternative energy sources and improving energy efficiency. The pressure from different sectors of society to reduce carbon dioxide emission, this problem has motivate the development of enhancing technologies to reduce the dependency on fossil fuels and optimize existing system in order to minimize energy consumption.[12]

Therefore, it is essential to conduct investigation on technical analysis of CSP for Parabolic Dish system in Malaysia environment and this is in line with Malaysia National Renewable Energy Policy where by 2020. To achieve this target, the nation need to increase power capacity, develop needed regulatory framework, business models and strengthen knowledge and skills. CSP could be one of the interesting alternatives for Malaysia to increase the power capability from solar source.

This project focuses on investigating the ability the ability of Parabolic Dish system for weather in Malaysia and make comparison of solar energy efficiency in

converting electricity due to temperature effect between manual Stirling dish systems with single axis solar tracker system. The Stirling engine is a heat engine that converts heat energy into mechanical work to drive a generator then converts mechanical energy into electricity.

1.2. Problem Statement

Malaysia has a magnitude of 4.21-5.56 kWh/m² annual average daily solar irradiation and sunshine duration more than 2,200 hours per year. Unfortunately, oil and gas have been the main energy sources in Malaysia. Oil and gas are limited and relatively high cost compared to solar energy which is free and abundant. Many countries have studied and investigated to change to environmentally friendly alternatives that are renewable energy to sustain the increasing energy demand.

Therefore, with the availability of cheap and abundant energy and to reduce the danger to the environment and ecology is one of the important factors required to increase the quality of life for people who live mainly in the developing world [9]. CSP could be one of the interesting alternatives for Malaysia to increase the power capability from solar source and among the CSP technologies; Parabolic Dish system is suitable for small scale and it modular. The dish technology more recently developed carries the best prospects for off-grid operation as well as providing the highest temperatures and therefore the highest efficiency.

1.3. Project Objective

The aims of this project are to design a single axis solar tracker system and assemble to Parabolic Dish concentrator Stirling engine. After that make a comparison of solar energy efficiency in converting electricity due to temperature effect between manual Stirling dish system with single axis solar tracker system. The objectives of this project are formulated as follows:-

- To measure the temperature and electricity produced by the dish concentrator control by manually and single axis solar tracker system.
- To analyze the impacts of single axis solar tracking system to the temperature by the dish concentrator.
- Design a single axis solar tracker system and evaluated by simulation using Proteus.

1.4. Scope of Project

While doing this project, the scopes of the project must be identified and followed as a guideline. Student must achieve a specified scope but do not go beyond it as to fulfill the requirement of the project. This project is fixed to several scopes and limitations that are narrowed down to the study as below:-

- To design a single axis solar tracker system and evaluated by simulation using Proteus.
- To study and understand function of Dish concentrator solar system in order to accomplish the comparison process.
- To determine which Malaysia weather can produce high efficiency and try to develop it.

1.5. Report Structure

First chapter briefly explain the project background and also problem statements as well as describes the objectives and scope of the project.

Second chapter discusses about the literature review of the project and the source accessible by gathering information through past researcher's work, internet and reference book related to this project.

Third chapter clarified about project methodology used in this project and overall project planning.

Fourth chapter consist of result from design process, analysis by testing procedure or simulation. Definite the Dish Stirling engine equipment and the ways to setup the equipment and application.

Fifth chapter will embody about conclusion of the project, this chapter also includes with some recommendation and suggestion for enhancing future upgrade. Individual who are interested in continuing this project can referred this chapter.

CHAPTER 2

LITERATURE REVIEW

This chapter will review most on theoretical that is applied for this project. Therefore, In order to achieve specified objectives that have been determined, there are several things that need to be identified to the understanding of CSP technologies from previous case study, studies of hardware and software. Furthermore, this chapter had included the background study of CSP technologies and types of CSP that usually use in other countries to generate power which friendly environmental and inexhaustible.

2.1 Introduction

Countries around the world including Malaysia are now more focused on green technology and renewable energy. According to 2011 projections by International Energy Agency, energy that can produce electricity in 50 years is solar power generation and indirectly reduces greenhouse gas emissions that can affect the environment. Solar energy is the most abundant source and renewable [1].

Under Energy Entry Point Programmed [2], Malaysia has targeted to build solar power capacity to 1.25 GW in 2020. Compared with German solar energy has reached capacity of 20 GW by 2012, at this time there is no country that can match the capacity of solar power

production like German while Malaysia has a solar irradiation more than the German. In conjunction with the Malaysia should take advantage of solar irradiation is obtained by building a power system based on solar energy.

A CSP technology is referred as concentrating solar thermal power that represents a powerful, clean, endless, and reliable source of energy. Concentrating solar power plants can produce no Carbon Dioxide (CO^2), thus reducing carbon emissions from electricity generation by approximately 272.2 kg per megawatt-hour [3].

2.2 Type of CSP Technologies

Commonly there are four types of solar concentrators which are parabolic trough, parabolic dishes, central receivers and Fresnel lenses. Linear concentrator systems collect the sun's energy using long rectangular (U-shaped) curve mirrors. The mirror is tilted towards sun then focusing sunlight on receivers that run the length of the mirrors. There are two major types of this concentrator which are linear Fresnel lenses system and parabolic trough systems.

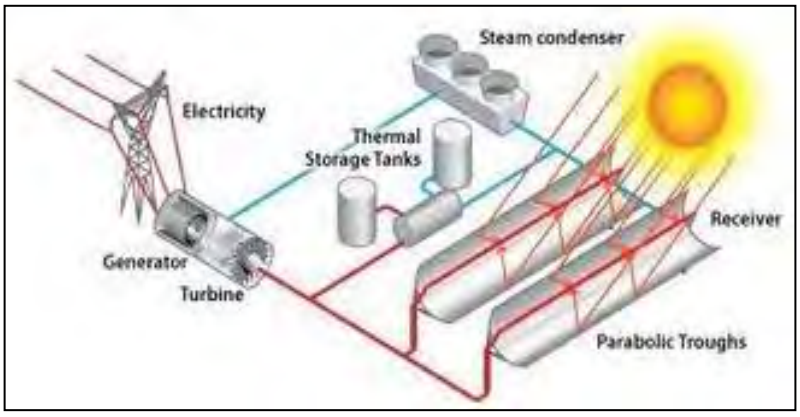

Figure 2.1: Parabolic trough systems. [4]

Parabolic trough concentrates solar radiation onto a line that controls the length of the trough. A receiver carries heat fluid transfer placed along this line and then absorbing solar radiation for heating the fluid inside. The trough is used single axis solar tracker because the surface area of the receiver tube is small compared to trough capture area, temperatures up to 400^{o}C and can be reached without major heat loss.

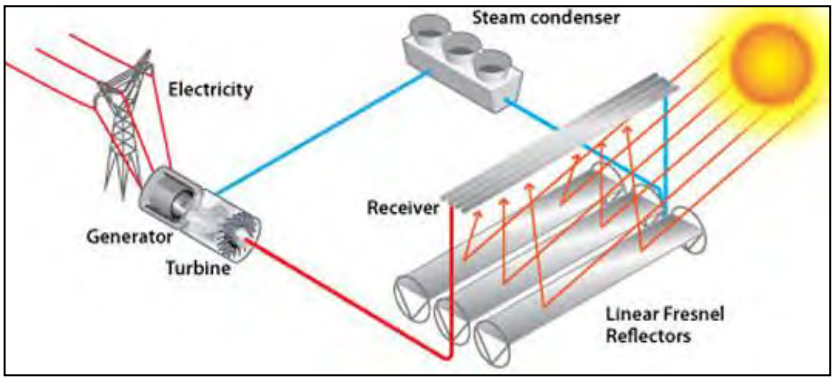

Figure 2.2: Fresnel reflector systems [4]

Fresnel reflector system uses refraction to concentrate the solar energy on the lens surface. Photovoltaic concentrator common uses this lenses which are molded out of

inexpensive plastic. Their use is not to increase the temperature but not enable the use of smaller, higher efficiency photovoltaic cells. Fresnel lenses point focus must track the sun about two axes [5].

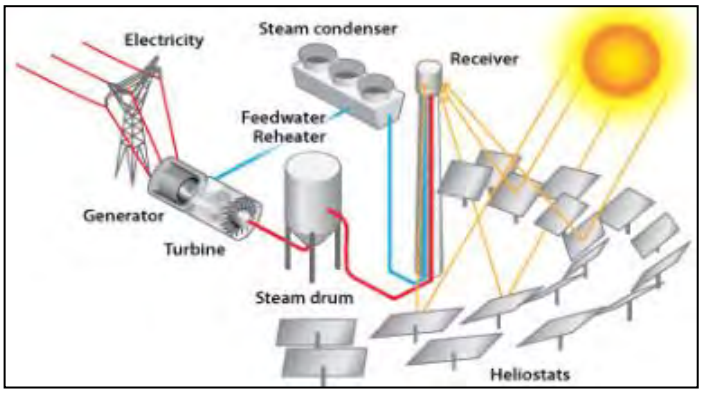

Figure 2.3: Central Receiver Systems [4]

Central receiver system contains of a large space of independently moveable flat mirrors and a receiver located at the top of a tower. All of it is two axes to keep the sun's reflected onto the receiver at the top of tower. The receiver is heated by reflect insolation thereby heating the heat transfer fluid pass through the tubes.

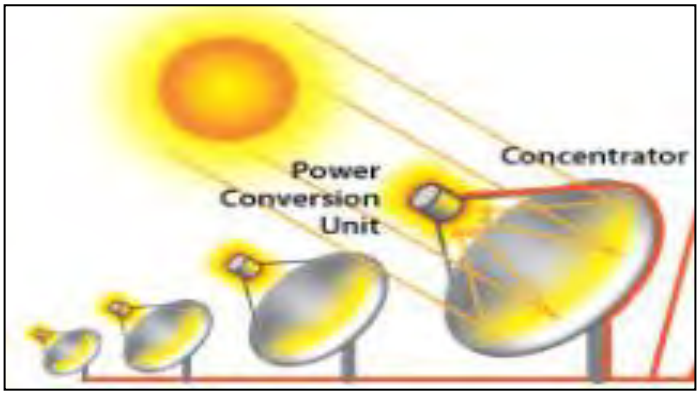

Figure 2.4: Parabolic Trough Systems [4]

Parabolic dish concentrators made up from mirrors reflect. It has a Stirling engine that located at the focal point of the dish reflector. Solar irradiation is concentrated onto a receiver and heat up the gas to generate electricity.

The advantage of CSP technologies is generating clean energy without fuel cost but concentrating solar power plants need more land is the only impact. The more land the more electricity can be able to generate. Although the amount of land a CSP plant is larger than fossil fuel plant but both types use about same amount of land because fossil fuel need additional land for mining, exploration, and road construction to reach the mine [6].

Among all the CSP technologies, parabolic dish has the highest efficiency which 18 - 31.25%, modularity, autonomous operation, inherent hybrid capacity. Followed by solar tower efficiency 14 – 17% and Parabolic trough efficiency is 10 – 15%. Linear Fresnel is the lower efficiency [7]. Apart from the economic justifications, technical and environmental aspects, Dish system for CSP systems can convert solar energy to electricity more efficiently the ever before. Since Dish system can produce both heat and electricity, they can be useful in some industrial applications where they have durability and low operation and maintenance costs.

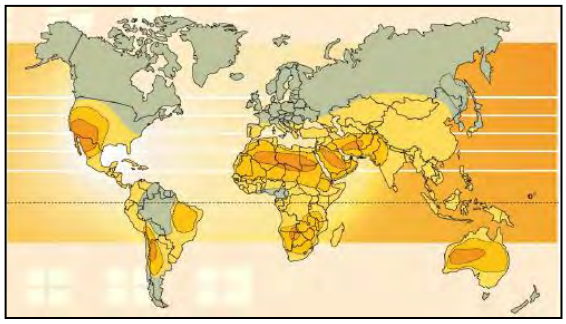

Figure 2.5: Geographical Ranges for CSP Plant

Source: CSP Global Market Initiative

By referring Figure 5, Malaysia is located in the area that has the resources excellent solar irradiation. The Direct Normal Irradiance (DNI) for Malaysia is below than 1900 kWh/m²/y. The annual production of CSP plants decrease to an extent that probably never will

become viable because of cloud [8]. Therefore, the country at the tropical region including Malaysia is difficult to develop their CSP plant.

2.3 Dish Solar Engine

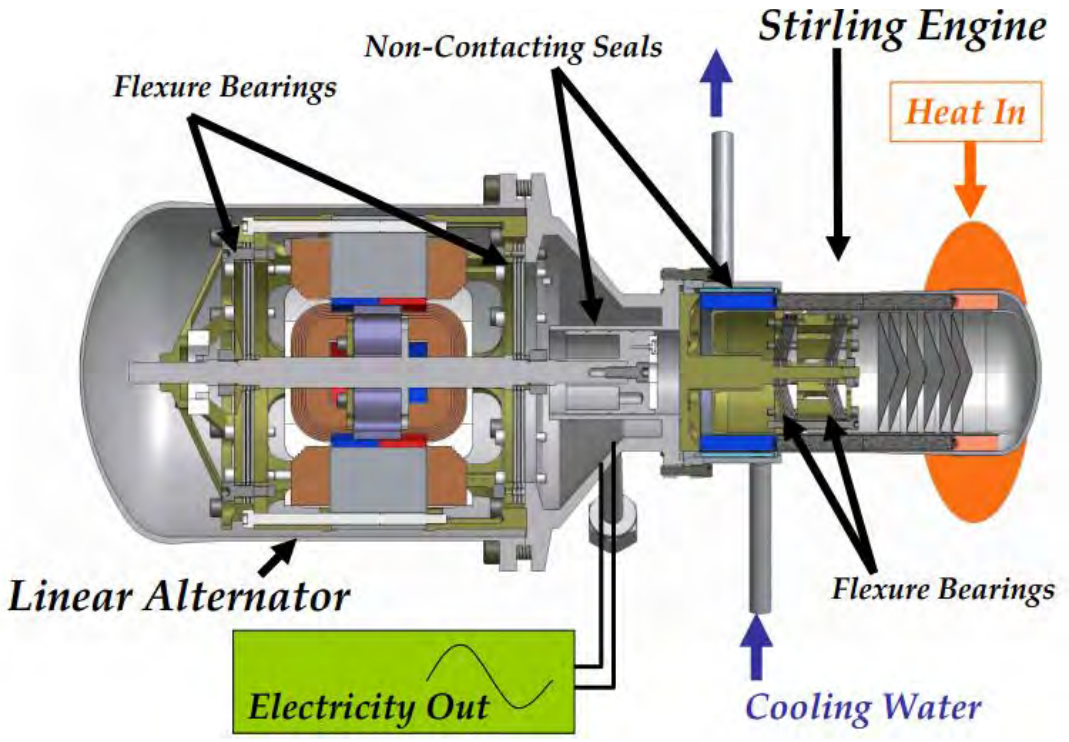

Figure 2.6: Stirling Engine [9]

From figure 2.6 shown that inner structure of Stirling engine. When gas in the cylindrical glass bulb has been heat up, it will push the flexure shaft and will produce the mechanical energy and this movement will turn up the alternator to convert the mechanical energy to electricity.

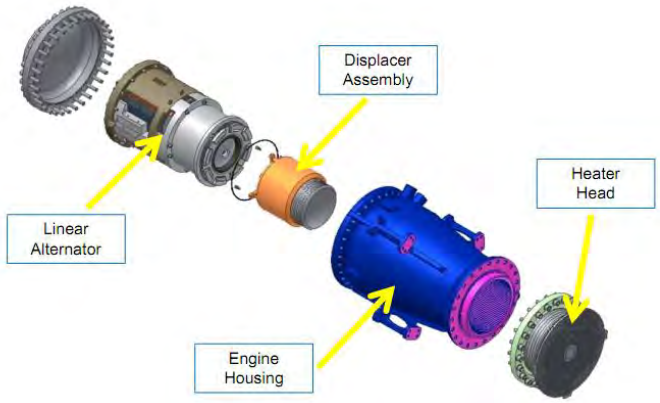

Figure 2.7: Free Piston Stirling Engine [9]

The basic Stirling engine is a device converts heat into mechanical energy by approximate the thermodynamic cycle. The first Stirling Cycle engines produced mechanical energy with rotating shaft which connected to an internal crank attached to two moving pistons. [10]

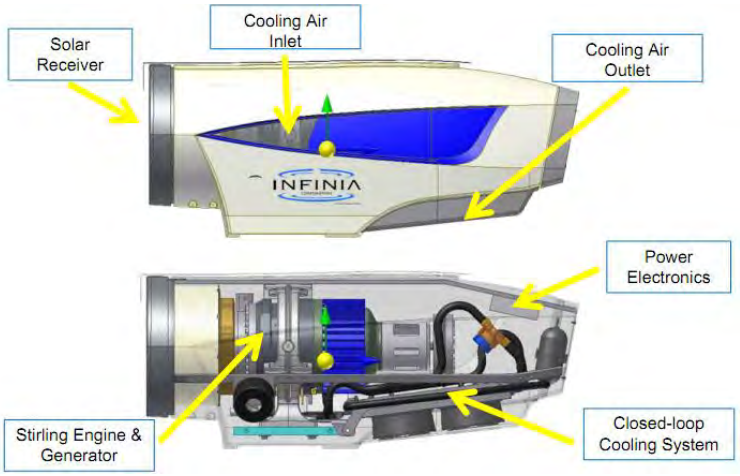

Figure 2.8: Heat Drive by INFINIA [9]