MODELING, SIMULATION AND FEASIBILITY STUDY OF THE PARABOLIC DISH SYSTEM UNDER MALAYSIA ENVIRONMENT

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A thesis submitted
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DECLARATION

I declare that this thesis entitled “Modelling, Simulation and Feasibility Study of The Parabolic Dish System under Malaysia Environment” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Rosnani Binti Affandi

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature :

Supervisor Name : **Datuk Professor Dr. Mohd Ruddin Bin Ab Ghani**

Date :

DEDICATION

To my beloved husband, mother, and children

ABSTRACT

The primilarily aim of this research is to carry out the fundamental investigation of the performance and feasibility of solar CSP, focusing on Parabolic Dish (PD) type in Malaysia environment. Three main components of the PD system that is under consideration, consists of the concentrator, the receiver, and the Stirling engine. By using a simulation approach and Matlab Simulink as the simulation tool; a background of the PD system is provided, along with a detailed description of the components model. Meanwhile, the performance for the three main components in PD system, is examined under three solar irradiance conditions that are low, medium and high. Besides that, the geometric design for the concentrator and receiver as well as the site location for this study is given through emphasis. Therefore, concentrator in PD system use reflective material with high efficiency to increase the PD concentrator efficiency, choose high value for the intercept factor to reduce loss for the solar intercept by the receiver and select a site with excellent solar irradiation in order to achieve high efficiency and as a result can produce high output power. Thus, by considering the highest Direct Solar Irradiance (DNI) and based on regions, five sites or locations has been chosen for this study. The site or locations with highest DNI in Malaysia are George Town at the Northern part of Peninsular Malaysia. Meanwhile, other locations are Subang in central of Peninsular Malaysia, Kuantan on the east coast of peninsular Malaysia, Senai in the Southern part of peninsular Malaysia and Kuching located in East Malaysia. To accomplish the research objectives, the performance of the PD system under Malaysia environment and the output from each of the main components were analyzed. In addition, the feasibility study in terms of technical and economic are thoroughly investigated. This includes defining the characteristics and constraints, as well as the overall system performance in monetary term. The PD system are considered feasible if the PD system reaches 54,750 kW of yearly output power, capacity factor reach the value around 25 – 28% and the Levelized Cost of Electricity (LCOE) lies between RM1.72/kWh and RM 0.7522/kWh. However, the result of this research has shown that the system is technically feasible but not economically feasible. The yearly output power, the annual energy and the capacity factor shows that the PD system in Malaysia are not capable of meeting the demand reliably. Thus, the new developed model for the 25kW PD system and the finding of this research can provide useful information for Malaysia regulators on the potential of CSP development in Malaysia or in other equator region countries.

ABSTRAK

Matlamat utama kajian ini adalah untuk menjalankan kajian asas terhadap kebolehlaksanaan teknologi CSP dengan memberi tumpuan kepada Parabolic Dish (PD) dalam persekitaran Malaysia. Tiga komponen utama bagi sistem PD yang diberi perhatian adalah penumpu, penerima, dan enjin Stirling. Dengan menggunakan pendekatan simulasi dan Matlab Simulink sebagai alat simulasi, latar belakang sistem PD disediakan bersama-sama dengan penerangan terperinci mengenai model komponen. Prestasi bagi tiga komponen utama dalam sistem PD iaitu penumpu, penerima dan enjin Stirling, dianalisa mengikut tiga isyarat sinaran solar iaitu rendah, sederhana dan tinggi. Selain itu, reka bentuk geometri bagi penumpu dan penerima serta lokasi tapak untuk kajian ini diberikan penekanan . Oleh itu, penumpu dalam sistem PD menggunakan bahan reflektif dengan kecekapan yang tinggi. Ia bertujuan untuk meningkatkan kecekapan concentrator PD. Pemilihan nilai yang tinggi bagi faktor pintasan digunakan untuk mengurangkan kerugian terhadap pintasan tenaga solar oleh penerima. Manakala, kecenderungan memilih kawasan dengan sinaran solar yang sangat baik untuk mencapai kecekapan yang tinggi mampu menghasilkan kuasa keluaran yang tinggi. Oleh itu, dengan DNI tertinggi dan berdasarkan wilayah, lima tapak atau lokasi telah dipilih untuk kajian ini. Lokasi dengan DNI tertinggi di Malaysia ialah George Town yang terletak di utara Semenanjung Malaysia. Sementara itu, lokasi lain ialah di Subang, di tengah Semenanjung Malaysia, Kuantan di timur Semenanjung Malaysia, Senai di selatan Semenanjung Malaysia dan Kuching yang terletak di Malaysia Timur. Untuk mencapai objektif projek, pelaksanaan sistem PD di bawah persekitaran Malaysia, data pengeluaran dari setiap komponen utama telah dianalisis. Disamping itu, daya maju teknikal dan ekonomi sistem PD disiasat dengan teliti. Ini merangkumi penentuan ciri-ciri dan kekangan, dan prestasi keseluruhan sistem dalam bentuk kewangan. Sistem PD dianggap boleh dilaksanakan jika sistem PD mencapai 54,750 kW kuasa keluaran tahunan, faktor kapasiti mencapai nilai sekitar 25 - 28% dan Levelised Cost of Electricity (LCOE) di antara RM1.72/kWj dan RM 0.7522/kWh. Namun, hasil daripada kajian ini telah menunjukkan bahawa sistem ini secara teknikal boleh dilaksanakan tetapi dari segi ekonomi ianya tidak dapat dilaksanakan. Kuasa keluaran tahunan, faktor kapasiti dan LCOE menunjukkan bahawa sistem PD di Malaysia tidak mampu memenuhi permintaan. Dengan itu, model baru bagi PD 25 kW yang dibangunkan serta hasil dari kajian ini, dapat memberikan maklumat yang berguna kepada Malaysia mengenai potensi pembangunan CSP di Malaysia atau di negara-negara yang terletak di rantau khatulistiwa.

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CF	Capacity factor
CO_2	Carbon dioxide
CSP	Concentrating Solar Power
DHI	Diffuse Horizontal Irradiance
DIR	Direct Illuminated Receivers
DNI	Direct Normal Irradiation
GHI	Global Horizontal Irradiance
HTF	Heat Transfer Fluid
IIR	Indirect Illuminated Receivers
IEA	International Energy Agency
LCOE	Levelized Cost of Electricity
NREL	National Renewable Energy Laboratory
NPV	Net Present Value
O&M	Operating and Management
PD	Parabolic Dish
PV	Photovoltaic
PCU	Power Conversion Unit
RE	Renewable Energy
R&D	Research and Development
SAM	Solar Advisor Model