EVALUATION OF PHOTOVOLTAIC POWERED AIR CONDITIONER SYSTEM

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Evaluation of Photovoltaic Powered Air Conditioner System

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DECLARATION OF THESIS

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LIST OF ABBREVIATIONS

AC	Alternating Current
BOS	Balance of System
CERE	Centre of Excellence for Renewable Energy
CFCs	Chlorofluorocarbons
COP	Coefficient of Performance
DC	Direct Current
HCFCs	Hydrochlorofluorocarbons
IIT	Indian Institute of Technology
PV	Photovoltaic
R&D	Research and Development
RM	Ringgit Malaysia
TMY	Typical Meteorological Year
TNB	Tenaga Nasional Berhad
UniMAP	Universiti Malaysia Perlis

LIST OF SYMBOLS

%	Percentage
-	Negative
^{o}C	Temperature (degree Celcius)
A	Current (ampere)
Ah	Ampere hour
Hp	Horsepower
J/m^2	Joule per metre square
mm	millimetre
V	Voltage (volt)
W	Power (watt)
W/m^2	watts per metre square
Wh	Watt hour

Penilaian Sistem Pendingin Hawa Berkuasakan Fotovolta

ABSTRAK

Dalam kajian ini, penilaian terhadap prestasi pendingin hawa yang beroperasi menggunakan penghasilan sistem tenaga solar dijalankan. Penghasilan daripada sistem tenaga suria telah dikaji dan dijalankan. Kajian dan analisis dilakukan terhadap pengeluaran elektrik daripada modul fotovolta dan prestasi serta kestabilan keseluruhan sistem menerusi persediaan eksperimen. Objektif kajian ini adalah untuk mendapatkan dan menilai sinaran suria sebagai tenaga elektrik potensi, merekabentuk dan mengoptimumkan sistem pendingin hawa supaya boleh beroperasi menggunakan arus terus dari tenaga yang dihasilkan daripada sistem fotovolta. Sistem pendingin hawa menggunakan kompresor 500 W yang memerlukan 24 V DC untuk beroperasi di mana sistem itu boleh berfungsi dengan voltan bekalan rendah. Ini dapat mengurangkan penggunaan tenaga elektrik memandangkan ia boleh beroperasi dalam keadaan yang stabil dan tempoh masa lebih panjang menggunakan elektrik percuma yang dijana oleh sistem fotovolta. 16 unit modul fotovolta 21 V 62 W bertindak sebagai sumber utama untuk membekalkan elektrik kepada sistem pendingin hawa melalui mengecasan enam unit bateri 12 V 100 Ah dan menstabilkan sistem. Parameter yang diuji dan dianalisis adalah voltan, arus dan kuasa yang dijana daripada modul fotovolta dan sistem pendingin hawa. Kajian ini meliputi analisa teori bermula dari rekabentuk hingga pemasangan sistem penghawa dingin lengkap dengan modul fotovolta. Dengan purata radiasi solar tahunan sekitar 4.65 kWh/m^2, adalah mustahil untuk memasang sistem pendingin hawa arus terus memandangkan nilai tersebut menunjukkan bahawa Perlis mempunyai potensi dalam menjana tenaga elektrik yang mencukupi bagi keperluan tenaga yang kecil. Selain itu, sistem fotovolta merupakan salah satu kaedah terbaik dalam menjana tenaga elektrik bagi kawasan pedalaman.

Evaluation of Photovoltaic Powered Air Conditioner System

ABSTRACT

In this research, evaluation on the performance of direct current air conditioning is carried out. Generation of solar energy systems have been studied and analyzed. Study and analysis done are on the production of electricity from photovoltaic modules as well performance and stability of the entire system through experimental setup. The objectives of this research is to obtain and assess solar radiation as potential electrical energy, design and optimize the air conditioner system to be operated using direct current from the energy generated by photovoltaic system. The air conditioner system used a compressor of 500 W which required 24 V DC to operate where the system could be running on a small supply voltage. This will reduce the electricity usage since it can operate within a stable and long-term period using free electricity generated by photovoltaic system. 16 units of 21 V 62 W photovoltaic modules act as the main source for supplying electricity to the air conditioning system by charging six units of 12 V 100 Ah batteries and to stabilize the system. The parameters tested and analyzed are voltage, current and power generated from photovoltaic modules and air conditioner system. The study covers theoretical analysis from designing to full installation of air conditioning systems complete with photovoltaic modules. With average annual solar radiation of 4.65 kWh/m^2, it is possible to install the DC air conditioner system as the value shows that Perlis has the potential in generating enough electricity for small energy requirement. In addition, the photovoltaic system is one of the best methods in generating electricity for remote areas.

CHAPTER 1

INTRODUCTION

1.1 Background

During 1800s, the desire to produce the cooling effect initiate the idea of constructing an air conditioning even tough there was no machine available. Dr. John Gorrie (1803 – 1855) who was an American physician became the first person who attempts to build an air conditioning system. As for the foremost of air conditioning system, Dr. Gorrie developed an ice-making machine and then using the equipment to cool the hospital rooms by blowing air over a bucket of ice (Jones Jr., 1997).

The concept of blowing air over ice was once again implemented when President James Garfield was dying in 1881, a box-like structure containing cloths saturated with melted ice water was constructed, where a fan blew hot air overhead. The temperature inside the President Garfield's room decreased by 20 degrees Fahrenheit. However the device utilized half a million pounds of ice in a period of two months (Nagengast, 1999).

An American engineer, Willis Carrier created the first ever modern air conditioning system in 1902 which was known as "Apparatus for Treating Air". The system was employed for the Sackett-Wilhelms Lithographing and Publishing Co. in Brooklyn, New York. With adequate precision, the machine used chilled coils to cool the air and reduce the humidity where the humidity can be adjusted to the required

level. The development of air conditioning system started to grow following the invention by Carrier. A few factories and several hospitals began to install air conditioning system. Yet, the Carrier's air conditioner had some difficulties as the units were huge, pricey and considered hazardous because of the toxic ammonia that was used as coolant. Then, Carrier improved his old design by reducing the size of the unit by putting in compressor and replace ammonia with benign as coolant. The system afterwards became popular in movie-theatre and began to spread the installation in office buildings, department stores and railroad cars (McDowall, 2007).

The air conditioner system requires electrical energy to operate its compressor, blower, fan and control device. The electrical energy requirement is normally met by power supplied by the utility company, for instance in Malaysia, TNB as the main electrical provider. The air conditioner system is generally efficient and is relatively reliable, but in the long run, the total cost of energy consumption is rather high. It would become a financial burden for a normal household.

Nearly all air conditioner system used in worldwide are built based on vapour compression systems driven by grid electricity. Nevertheless, a lot of common methods in generating electricity nowadays usually give some negative effects toward the environment. Therefore, it is desirable to minimize the electricity demand through a technology that is much more environmentally friendly.

Thus, the present technology intends to construct an air conditioner system that utilizes energy gained from the sun which could be a way to reduce the demand of electricity. This means that the system would be operated using the electrical energy

generated by the photovoltaic (PV) system which used the solar sun ray as the energy source. The integration with PV system is a great idea because the solar is available in plenty and the most important factor is free.

1.2 Problem Statement

In this study, the problem statements are stated as below:

- Electrical energy in major location is supplied from the grid. As for remote or isolated district, the grid could not be connected because of financial, maintenance or limitation of ground area. As air conditioner system required large amount of electricity consumption, it is not suitable to install the system to that district. Application of air conditioner system with PV system is a feasible way to provide cooling space in remote area where the system can be operated easily using electricity generated from solar energy. Solar energy is well known for cost effective, renewable and environmentally friendly and it is advantageous to sub-tropical countries such as Malaysia.

- Air conditioner system has become one of the major consumers of electrical energy in many parts of the world today. Besides that, the demand of air conditioner is keep growing due to the effect of climate changes and global warming. With increasing gas and electricity tariffs, renewable energy such as solar energy happen to be an attractive alternative in supplying the electricity.

1.3 Objectives of Study

The study objectives in the design of photovoltaic powered air conditioner system are:

1. To measure and evaluate the solar radiation in Perlis as an energy potential for the supply system of DC air conditioner system
2. To design and optimize a DC air conditioner system in term of the number of photovoltaic, number of battery and size of the solar charger
3. To analyze and compare the performance of DC and AC air conditioner system

1.4 Scope of Project

The scope of this study is primarily about the development solar air conditioner system which includes several important stages in order to produce a complete research.

The initial stage is to study and understand the air conditioner system and PV system. During this stage, the related information must be gathered first such as on the equipments or components to be used and meteorological data for climate. It is because there is major modification need to be done as the air conditioner system must be integrated with PV system.

The next stage is followed by design and installation of the equipment in order to construct a prototype of solar air conditioner system before conducting a test run. In the experiment, the entire test related to the performance of solar air conditioner system

will be carried out. The final stage is to do analysis on the financial and commercial aspects compared to the performance of the system.

1.5 Thesis Organization

This thesis is segregated into five main sections. The sections are introduction, literature review, methodology, results and discussions, and lastly the conclusion where each section is considered as one chapter. Each chapter can be described as below.

Chapter One gives a brief explanation of this project which discuss the background, problem statement, study objectives, scope of project and organization of this thesis.

Chapter Two consists of a literature review on several important aspects of current development and exploration on PV system. This chapter also focus on the operation and important components in constructing air conditioner system. The discussion of existing expansion and investigation in solar energy is included in this chapter.

Chapter Three explains the detail methodologies used in this research. This chapter presents the initial design process, development and construction of prototype of the DC air conditioner system which is then integrated the system with PV system as the energy supply.

Chapter Four describes the analysis of experimental data based on the verification and assessment. The test result such as the performance and electrical characteristic of the system is obtained by doing some experiment.

Chapter Five presents the conclusion of the research. Finally, recommendations for future work also stated in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Photovoltaic (PV) or solar cells are devices which directly convert incident radiation into electrical current. An early public demonstration of solar cells occurred in 1955 in Americus, Georgia, where a small panel of experimental silicon cells provided energy to charge a battery and telephone equipment. Followed by that, PV was initially focussed on providing electrical power to spacecrafts. It has been extensively used to convert sunlight into electricity for earth-orbiting satellites. Since then, tremendous progress has been made in the development of cell technology and applications. Early hand-made cells were 5 % efficient, were 1 or 2 cm^2 in area, and had outputs of a few milliwatts (Duffie & Beckman, 2006).

Since long they have become commercially viable in such small power utilization system as watches and calculators, but photovoltaic-based power generation is yet to outcompete conventional energy sources. Nevertheless, numerous PV solar energy conversion systems have been tried for varying applications ranging from scientific experiments to operational applications by industry and government. Installations from a few watts to over a kilowatt power have been made in Africa, South America, Mexico, the United States, Canada, Europe, Japan, Southeast Asia and the Middle East. These have provided power for lighthouses, navigational and warning lights, radio, microwave and television relay stations, aids to navigation on offshore

platforms, weather monitoring stations, remote educational-television sets, highway emergency call boxes, aircraft-warning lights at airports and remote communications stations for forest management (Abbasi & Abbasi, 2006).

Solar powered air conditioner system is one of the promising ways to address both environment al and energy issues. Since most of a building's heat loads is due to absorbed solar radiation, the time of day with maximum incident solar radiation would correspond roughly to the time of maximum demand.

Moreover, the efficiency of solar collector increases with increasing insolation and increasing ambient temperature resulting in higher energy collection per unit area in the summer. Additionally, solar refrigeration devices are significance to meet the needs for cooling requirements and medical or food preservation in remote areas. Using solar powered air conditioner system will reduce the fossil fuel burning by reducing the required electricity generation hence reducing greenhouse gases in the atmosphere.

Several solar refrigeration and air conditioning systems have been investigated by researchers throughout the world. A solar electric system consists mainly of PV panels and an electrical air conditioning device. There are several kind of solar electric air conditioning systems researched to-date, such as photovoltaic-powered vapour compression, thermoelectric and Stirling refrigerator.

The vapour compression refrigeration cycle requires electricity to the compressor which is provided by the PV modules. PV modules generate electrical power by converting solar radiation into direct current electricity using semiconductors.

Materials presently used for solar cells include mono-crystalline silicon, poly-crystalline silicon, amorphous silicon, cadmium telluride. Silicon remains the most commonly used solar cell material (Gupta, 2011).

2.2 Solar Radiation for Electrical Generation

Photovoltaic (PV) or solar cells are devices which directly convert incident radiation into electrical current. An early public demonstration of solar cells occurred in 1955 in Americus, Georgia, where a small panel of experimental silicon cells provided energy to charge a battery and telephone equipment. Followed by that, PV was initially focussed on providing electrical power

The irradiance reaching the ground varies throughout the day with the movement of the sun and the clouds. The total amount of irradiance received over a period of time is a different measurement. Irradiance is often measured in units of watts per metre square (W/m^2) or milliwatts per centimetre square (mW/cm^2). In very clear weather at midday, the irradiance reaching a surface that faces the sun is about 1000 W/m^2 (Han, 2010). The lower the solar irradiance is, the current output is lower and thus lower the peak power point. Voltage essentially remains constant. The amount of current produced is directly proportional to increases in solar radiation intensity.

According to Daut et. Al (2011), based on meteorological data in Perlis, the average monthly solar radiation was about 5010 Wh/m^2 which the value was larger than the value of normal solar radiation recorded (3000 Wh/m^2). This is because Perlis usually has clear sky and very high solar radiation intensity throughout the year. If all

the terrains in Perlis were assembled with PV modules, with a total annual solar radiation around 1828.5 kWh/w^2, Perlis could generate around 188,972 GWh of electrical energy per year. This shows that Perlis has quite big potential of solar radiation to be exploited in PV power generation.

Ahmed et al. (2003) revealed that solar energy is an established renewable energy sources. This is because solar energy source is free of cost besides a clean energy whereby environmental impacts are almost zero. As one of the tropical countries, Malaysia had seen brisk development in the application of solar energy in some rural areas. Since then, several universities and R&D institutions had shown interest in doing new research to assess the solar energy application potential in Malaysia for proper utilization. Unfortunately, there were a few setbacks which halt the development of solar technology. Some of the main problems surfaced that can stop the progress of solar utilization are the costly equipment and the selection of wrong peak sunshine data that could giving a wrong determination of sizing the equipment for the solar energy projects. Solar radiation figures in daily, weekly and yearly basis of the same location could be different from one data to another if accuracy of the solar energy data is compromised. So, it is very important to prepare a proper design procedures and solar energy components sizing for the solar power production before opting any actual implementation. Perform the correct sizing and utilize the proper data are the crucial success to solar energy applications besides enhancing its performances and trimming down unnecessary costs. In order to obtain and propose suitable design procedures, supporting facts and figures must be presented.