DEVELOPMENT OF SOLAR WATER PUMP FOR SMALL SCALE PADDY FIELD IRRIGATION

by

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LIST OF ABBREVIATIONS

A -	Ampere
AC -	Alternating Current
BOS -	Balance of System
CPS -	Contact less power supply
d -	Day
DC-	Direct Current
DOA -	Department of Agriculture Malaysia
DOY -	Day of year
H -	Solar radiation
H_0 -	Extraterrestrial solar radiation
ha -	Hectare
IADA -	Integrated Agriculture Development Authority
KADA -	Kemubu Agriculture Development Authority
KETARA -	North of Terengganu
MADA -	Muda Agriculture Development Authority
m -	meter
m^2 -	meter square
m^3 -	meter cubic
min -	minute
MJ -	megajoules
mm -	millimeter
MMD -	Malaysian Meteorological Department
MOA -	Ministry of Agriculture and Agro-Based Industry Malaysia
MPPT -	Maximum power point tracker
Ni-Cd -	Nickel-cadmium
NOCT -	Normal Operating Cell Temperature

PCU -	Power Conditioning unit
PV -	Photovoltaic
Q -	Flow
s -	second
STC -	Standard test condition
V -	Voltage
W -	Watt

PEMBANGUNAN PENGEPAM AIR SURIA UNTUK PENGAIRAN SAWAH PADI YANG BERSKALA KECIL

ABSTRAK

Dalam tesis ini, pengepam air dari penjanaan suria telah di kaji selidik dan di analisis dari segi keluaran elektrik modul fotovolta, prestasi, cerapan lapangan, dan penyelakuan komputer untuk sinaran suria. Objektif penyelidikan ini adalah untuk memperoleh radiasi suria dengan menggunakan kaedah Hargreaves, menentukan keluaran elektrik fotovolta melalui beberapa pemasangan dan spesifikasi yang diperlukan untuk di aplikasi pada pengairan sawah padi. Pemasangan di lapangan meliputi sebuah modul fotovolta 50 W, pemasangan terus pam air 12 V berarus terus, pengesan suria dan pemasangan lain yang merangkumi 12 V 100 Ah bateri, penyongsang kuasa, pam air yang berarus ulang alik dan penyecas bateri. Parameter yang dicerap dan diawasi adalah voltan, arus, kuasa pada modul fotovolta dan pam air. Manakala kadar alir untuk pam air dan suhu sekitar juga dimasukkan dalam pengumpulan data. Oriantasi bumi dan geometri suria membantu untuk menentukan kesesuaian sudut penyendengan dalam pemasangan modul fotovolta untuk posisi tetap manakala alat pengesan adalah sebagai alternatif pembangunan. Kajian ini meliputi teori dan teknikal dalam rekacipta dan pemasangan sistem pengepam air suria. Daripada keseluruhan tesis ini, penyendengan sudut 30° dalam pemasangan modul fotovolta berposisi tetap adalah paling sesuai untuk di aplikasikan pada latitud yang berada di garisan khatulistiwa. Selain itu, sistem penyesan adalah lebih baik untuk meningkatkan hasil keluaran sistem berbanding posisi tetap dari segi kos dan juga prestasi pada teknikal.Sistem ini juga dilengkapi dengan pengawal paras air pada penakungan air dan sawah padi disebabkan sifat tanaman padi yang sangat sensitif dengan paras air. Kaji selidik yang dilakukan ini dapat membantu para petani untuk meningkatkan hasil tanaman padi yang tidak terletak dalam kawasan gelapang padi.

DEVELOPMENT OF SOLAR WATER PUMP FOR SMALL SCALE PADDY FIELD IRRIGATION

ABSTRACT

In this thesis, the solar powered water pump have been thoroughly investigated and analyzed in terms of the Photovoltaic (PV) module electrical output, performance, field observation, and modeling of solar radiation. The objective of this research is to obtain the solar radiation using Hargreaves method, determine the PV electrical output through some installation and specification required to apply for paddy fields irrigation. The field installation involved a 50 W PV module, direct connected to a 12 VDC water pump, solar tracking system and other installation include a 12 V 100 Ah battery, power inverter, AC water pump and battery charge controller. The parameters observed and monitored are voltage, current, power of PV module and water pump. While water flow for water pump and ambient temperature also include in data collecting. Earth orientation and solar geometry help to obtain suitable tilt angle to mount the PV module for fixed position otherwise tracking device as an alternative of development. This research had covered the theory and technical in solar water pump system design and installation. From the overall of this thesis, 30° tilt angle is most suitable to apply in equator latitude for fixed position to mount the solar panel. Otherwise using tracking system is better to increase the system output compared to fixed position in term of cost and technical performance. The solar water pump system able to support the small scale of paddy field from quarter acre up to seven acre. This system is completed with water level control for water reservoir and paddy field because paddy plantation behavior which is sensitive to water level. This research able to helps the farmer to improve the paddy production for outside the granary of paddy field.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Agricultural sector in Malaysia consists of several types of crops such as paddy, cocoa, oil-palm, rubber and pineapple. These agricultural activities are affected by topology, soil type, climate and irrigation. Factors of high temperature from 23˚C to 27˚C and heavy rain which from 1500 to 2000 mm annually are suitable for paddy plantation particularly in Northern Malaysia also known as rice bowls of Malaysia. In Peninsular Malaysia, paddy plantation areas are at Kedah-Perlis plain, Kelantan plain, Hilir Perak plain, Seberang Perai plain, Tanjung Karang plain at Selangor, Paya Besar-Pahang Tua area, Rompin-Endau area at Pahang, Besut plain at Terengganu and Pamah soil at Selangor-Melaka. Natives in Borneo plant Huma paddy at hills which required lesser water to grow. Paddy field in Sabah located at Papar, Tuaran and Peninsular Kolias while in Sarawak located at Rajang and Baram plain.

Three agencies related with paddy and rice industry in Malaysia which function to control and monitor the paddy field irrigation. There are Muda Agriculture and Development Authority (MADA), Kemubu Agricultural and Development Authority (KADA) and Integrated Agricultural and Development Authority (IADA). These agencies covered from Seberang Perak, Kerian-Sungai Manik, north Terengganu, Kemasin-Semerak, Barat Laut Selangor and Penang. MADA is wider granary area in Peninsular Malaysia which cover about 96 558 hectare of paddy field from 125, 155 hectare for Kedah and Perlis.

This research studies are to improve the rice crops production located at outside the granary area which not fully irrigated. Arau, Kayang, Kangar, Tambun Tulang and Simpang Empat are one of MADA province at Perlis. Otherwise for outside MADA areas are Mata Air, Bintong, Paya, Beseri, Padang Siding and Titi Tinggi or

Padang Besar. These areas are known as outside granary area because not locate at main dam water passing and only depends on rainfall. A paddy field needs almost 85% of water flooded in each area. Irrigation was very important to help the farmer to increase their crops (Department of Agriculture Malaysia, DOA, 2009).

The importance of this research, involving a complete photovoltaic (PV) water pumping system, falls within the potential application for supply the water from nearest water source to the paddy field that located outside the granary area. Many additional losses are incurred due to the inefficiencies in transferring energy from the PV module to a load, such as a pump or battery bank, thus resulting in a secondary decline of performance. Though there have been studies measuring outdoor performance of PV modules, there is a great need for further field studies of complete PV system. Another important aspect would be the ability to model the potential solar radiation, PV power output, and subsequent water output for purpose of irrigation usage. The result attained from this field research can used to determine the viability of PV powered paddy field irrigation systems for range of the field area.

1.2 Problem Statement

28 597 hectare of paddy field state as outside granary area or not located at main water dam passing in Kedah and Perlis. These areas identified to be irrigated by rainfall and hill water. If these areas of paddy field are fully irrigated, the paddy and rice production in Malaysia will increase. Malaysia is one of the countries that receive abundant of sun light in average mostly in northern side of Peninsular Malaysia. Kedah, Perlis and Penang have high potential in applying solar energy especially in agricultural sectors. Solar technologies in water pumping system able to apply in paddy field and increase the rice and paddy production by improving the irrigation for these areas.

1.3 Aims and Objectives

The aim of the research is to determine the feasibility of using photovoltaic (PV) modules to power a water pump for small scale irrigation system of paddy field in Perlis, Malaysia.

The specific objectives of this research can be summarized as follows:

1. Obtain the available solar radiation, using current and historical climate data from Malaysia Meteorological Department (MMD) for Chuping Station, Perlis using Hargreaves method.
2. Measure the PV electrical output by using a combination of PV module and installation specifications, meteorological input, and solar geometry for analysis of solar water pumping.

1.4 Scope of Project

This thesis focused on the development of solar powered water pumping system for small scale irrigation of paddy field located at outside granary area in Perlis. The duration of this project was in a year from June 2008 to June 2009. This project began with collection of meteorological data for current and historical climate data from MMD. The data is applied to obtain the available of solar radiation using Hargreaves method. Draft the experiment for different tilt angle, tracking device based from the meteorological input and solar geometry. The project follows by design and installation of the equipment and instrumentation. Data were collected daily for the precise input of solar water pumping system.

1.5 Project Overview

This project begins with literature review for concept of photovoltaic energy conversion and some previous work through papers, journal, and article on current issue in Malaysia. Collect information and data of climatology for past five years until current year from MMD. The climatology data included temperature, solar radiation, rainfall and evaporation for Chuping Station, Perlis. While the paddy information such as paddy plantation areas, irrigation areas and other facilities supplied by MADA and Lembaga Pertubuhan Peladang (LPP). Paddy fields in granary areas are monitored by MADA while outside the granary areas are monitored by LPP.

Climatology data is used to obtain solar radiation using Hargreaves method. Hargreaves method is one of the methods most accurate to obtain the solar radiation falls in Perlis. Draft an experiment for different tilt angle of PV, solar tracking device, direct current (DC) and alternating current (AC) water pumping systems. Test the set up experiment to collect the data and analyzed. The data is analyzed to get achieved the objective of the research project. This process takes into several times until the results fulfil the objective requirement. The experiment results is analyzed and discussed once the process is complete.

1.6 Thesis Synopsis

The dissertation of thesis is divided into five chapters. Chapter one introduces project overview, objectives, scope of research and the problem statement.

Chapter two consist a review of current solar energy development and demand in power usage. The review focuses on energy and water usage in Malaysia for agriculture sector and the aspect of research involve the paddy field in Malaysia. In this chapter, the review of previous work in solar energy for water pumping system.

Chapter three explain the detail description of the methodologies used in this research. This chapter presents the design, development and implementation of hardware to build a photovoltaic water pumping system for paddy field. Through this

research by using the water pumping system able to improve the paddy crops for paddy field located at outside the granary area in Perlis, Malaysia.

Chapter four perform the verification of some of the models presented in chapter three by examining the preliminary test results obtained the mock-up of the hybrid solar water pump and the actual Solar Photovoltaic Powered Water Pump which were tested at paddy field.

Chapter five presents conclusion of the research. The conclusion in this study is made based on the results and discussion that obtain in the previous chapter 4. Recommendation for future work also presented in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Critical Reviews of Previous Work

In this section, a critical review is presented on the research of other researchers in relating to this study. A few critical reviews of previous works are given below:

Abdolzadeh, M., and Ameri, M. (2009), discussed about improving the effectiveness of a photovoltaic water pumping system by spraying water over the front of photovoltaic cells. The purpose of this paper is to investigate the possibility of improving the performance of a PV water pumping system. From the experimental results showed the cells power is increased due to spraying water over the PV cells and had compared with traditional systems. In order to utilize PV power and increase PV water pumping system efficiency, it is necessary to keep PV cell temperature and cell reflection as low as possible. Loss of efficiency due to a raised temperature of PV arrays can be reduced by heat removal from the front surface into the water spray across the cells which absorb the heat generated by the cells during the day. It is found that spraying water over the PV cells strongly improves the system and subsystem efficiency where when the module are working closely at the temperature of maximum power generation, the motor pump can receive most of the cells power. Decreasing the cell's temperature and reflection loss can also reduce the threshold radiation of starting motor pump torque during the hot days and result in increasing the customer requirement in the early morning.

Yesilata, B., and Firatoglu, Z. A. (2008), discussed the effect of solar radiation correlations on system sizing PV pumping case. In this paper, the precise determination of solar radiation intensity is important for accurate system sizing in PV pumping system since inaccurate solar radiation data nonlinearly reflected to calculation. The differences in power output of a PV pumping system due to using some solar radiation correlation and the results compared with those long term solar radiation measurements. From this paper had developed an algorithm to demonstrate nonlinear propagation of the errors in power output of a DC-PVPS due to using the empirical correlation instead of the long-term solar radiation measurement.

Glasnovic, Z., and Margeta, J. (2007) had discussed about systematically methods which this system elements and analyzed the photovoltaic water pumping system, local climate, boreholes, soil, crops and method of irrigation. The result approach is the new mathematical hybrid simulation optimization model for optimal sizing of PV irrigation water pumping systems that uses dynamic programming for optimizing. The model testes on two areas in Croatia and has successfully established in consideration all characteristic values and the relation in the integrated system. The optimal nominal electric power of PV generator is obtained in the manner presented are relatively smaller than when the usual method of sizing is used. This paper presented method for solving the problem has paved the way towards the general model for optimal sizing of all stand-alone PV systems that have some type of energy storage.

Saadi, A., and Moussi, A. (2006), presented an optimization study of a photovoltaic pumping system using maximum power point tracking technique (MPPT). The optimization is based on new reference voltage criterion, which is the addition of the open circuit voltage of PV generator and a segment of solar radiation. This technique is developed to ensure an optimum chopping ratio of a Back-Boost

converter. This paper proposed technique was experienced on PV water pumping system in order to optimize the PV generator output power instead of an easy direct connection or using a complex MPPT technique. This paper showed the efficiency of the maximum power tracking technique for PV pumping systems; buck-boost DC/DC converters and separately excited DC motor were found to give a good match to PV generator. Although the MPPT with variable reference based on percentage of open circuit voltage, is approximate to the true MPPT for its results, the proposed optimization technique make it with a finite precision, in order to reach maximum power instead of the optimal power. The chopping ratio values for DC/DC converter are derived easily, quickly and with high precision.

Ghoneim, A. A. (2006), presented the results of performance optimizing of a photovoltaic powered water pumping system in the Kuwait climate. The journalist considered the PV water pumping system consists of PV array, DC motor, centrifugal pump, a storage tank, battery storage and maximum power point tracker for improving the efficiency of the system. In this paper, the pumped water is desired to satisfy the domestic needs of 300 people in a remote area in Kuwait. A computer simulation program is developed in determine the performance of PV array with maximum power point tracker of amorphous silicon solar cell modules. Size of PV array orientation and the pump motor hydraulic system characteristics varied to achieved an optimum performance. The life cycle cost method is implemented to evaluate the economic feasibility of the optimized PV powered water pumping systems. Through this paper, the cost of the PV powered water pumping system is found to be less expensive than the cost of the conventional fuel system at the current prices of PV modules.

Bione, J., Vilela, O. C., and Fraindenraich, N. (2004) focused on performance of photovoltaic water pumping systems driven by fixed, tracking and V-trough generator. From this paper, PV pumping systems with solar tracking coupled to low concentration cavities used as viable alternative in reducing cost of pumped water volume. While V-trough concentrators are particularly appropriate for photovoltaic applications because combinations of the concentration ratio (C) and vertex angle (Ψ), which provide uniform illumination on the region. The water pumping systems are operated when the irradiance is larger than a minimum irradiance level (I_C). Through this solar tracking increased, the average collected irradiance ($\bar{I}_{coll}$) and, for a system operated with critical irradiance level (I_C) which verified the smaller the relationship ($I_C/\ \bar{I}_{coll}$). Thus, the gain, in terms of pumped water volume provided by solar tracking systems is larger than the gain in collected solar radiation. Combination of devices, tracking and concentration provides an additional increase of the benefits resulting from the use of solar trackers. From this paper, ‘‘Utilizability Method’’ used to estimate the long-term gains of pumped water volume, for tracking systems, with and without concentration, against fixed systems. From the result calculated from characteristic curve of tested PV pumping system with tracking V-trough concentrator for climate of city of Recife (PE-Brazil) showed that tracking system is 1.41 times of pumped water value compared to fixed system. This paper concluded that cost reduction of the order of 19% for the tracking system and of 48% for the concentrating system when compared to fixed configuration.

Cuadros, F., Rodriguez, F. L., Marcos, A., and Coello, J. (2004) discussed a procedure to estimate the required dimension of a photovoltaic installation designed to power a pumping system for the drip irrigation of an olive tree orchard in SW Spain. The method consists of three main stages, firstly is to determine the irrigation requirements of the specific estate according to the characteristics of its soil-type and climate. Secondly is a hydraulic analysis of the pumping system is made according to the depth of the aquifer and the height needed to stabilize the pressure in the water

distribution network. Finally, determines the peak photovoltaic power required to irrigate a 10 ha sub-plot of the estate taking into account the overall yield of the photovoltaic-pump-irrigation system. This system called ‘‘photoirrigation’’, and can be of great utility to improve the output of such socially significant crops as olives and wine grapes, optimizing the use of water and solar energy resources at the same time as preserving the environment.

Pande, P. C., Singh, A. K., Ansari, S., Vyas, S. K., and Dave, B. K. (2003), discussed on design development and testing of a solar PV pump based drip system for orchards. From this paper, they focused the solar PV pump to operated drip irrigation system designed and developed for growing orchards in arid region in considered design parameter such as pumps size, water requirements, and the diurnal variation in pressure of the pump due to changes of irradiance and pressure compensation in drippers. The system comprising a PV pump with 900W_p PV array and 800W of DC motor pump mono-block with micro filter, main, sub mains, and three open-able low-pressure compensating drippers on each plant in tested field. The system could irrigate 1 ha area within 2hour with discharged of 3.8 l/h in the pressure 70-100 kPa of range which is 92-94% of emission uniformity observed. This system can effort about 5 ha area of orchard based on the performance of PV pump and the drip system. From the overall, this paper project benefit is cost ratio for growing pomegranate orchards with such a system was evaluated to be above 2 even with the costly PV pump and the system was considered appropriate technologies for the development of arid region.

Kaunmuang, P., Kirtikara, K., Songprakorb, R., Thepa, S., and Sumannakum, T. (2001), discussed about one decade experience assessment of photovoltaic pumping systems in Thailand. This paper reports the surveyed results 489 photovoltaic water pumping systems and 45% of the systems are failed. Lack of adequate supervision during installation caused the systems fail and most failures are due to blockage of pumps and pipe which are because of water plants, sediments and inverter breakdown. Major cases occur because of villagers not been equipped, prior to and after installation to manage and maintain the pumping units. 35% of important sources damages are motor/pump units and 19% are inverters.

Kou, Q., Klein, S. A., and Beckman, W. A. (1998), had proposed a method is developed to predict the long term performance of direct coupled PV pumping systems. The method used only the information from the PV module and pump motor manufacturers and weather data are generated from monthly averages of horizontal radiation and ambient temperature using well known weather data statistic. The method predicts monthly pumped water to within 6% of TRNSYS predictions based on hourly weather data. Single monthly average day showed to under predict monthly pumped water at low monthly average radiation levels and over predict monthly pumped water at intermediate radiation levels. Only at high radiation level does the used of single monthly average day provide a reasonable estimation of monthly pumped water.