Faculty of Electrical Engineering

DESIGN AND IMPLEMENTATION OF PHOTOVOLTAIC WATER PUMPING SYSTEM

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Master of Electrical Engineering (Industrial Power)

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A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Electrical Engineering (Industrial Power)

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DECLARATION

I declare that this dissertation entitled "Design and Implementation of Photovoltaic Water Pumping System" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

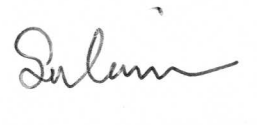
Signature : .....

Name : Maiz Hadj Ahmed Mustapha

Date : 7.9.14.....

APPROVAL

I hereby declare that I have read this dissertation and in my opinion, this dissertation is a sufficient term of the scope and quality of the award of master of electrical engineering (Industrial Power).

Signature : 

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DEDICATION

Dedicated to my Parents and Family.

ABSTRACT

The solar photovoltaic system is considered as one of the most promising applications for a future sustainable supply power notably in remote areas where the electricity is unavailable or unreliable. Due to the continuous improvement of solar cell technology and the decrease in manufacturing cost, photovoltaic powered water pumps have received considerable attention in the last few years to satisfy the basic need for a large proportion of the world's rural population. This dissertation deals with the modeling and simulation of a photovoltaic water pumping system consisting of PV panel as a generator, power conditioning unit that constitutes of a buck-boost chopper and single phase full bridge inverter to feed a single phase induction motor actuating centrifugal pump. The pump feeds the water tank in order to use it when the sun is not shining. The simulation was carried out through MATLAB/SIMULINK software using the equivalent electric circuit of each component for each subsystem then the overall system consisting of the subsystems shows the feasibility of the entire photovoltaic water pumping system. This research gives an emphasis on power electronic stage, a DC/DC buck boost chopper was designed and realized, showing its efficiency when connecting to the system. This work stresses on system sizing which is important in order to design a successful installation, HOMER software has been used to recognize the system sizing and it shows a high performance in term of sensitivity analysis of a wide range of input which may affect the system`s behavior. The system sizing has been achieved reliably and economically through two criteria which are Annual Capacity Shortage (ACS) and Levelized Cost of Energy (LCE), the results could then serve as a starting point for the designing and optimizing of a successful installation. A prototype hardware of water pumping system which can be used for domestic purposes was built and tested, the experimental results were satisfactory.

ABSTRAK

Sistem fotovoltaik suria dianggap sebagai salah satu aplikasi yang sangat berpotensi untuk membekalkan tenaga elektrik secara berterusan pada masa hadapan terutamanya ke kawasan-kawasan terpencil di mana bekalan elektrik adalah sukar untuk didapati. Oleh kerana pembangunan berterusan teknologi sel suria dan penurunan dalam kos pengeluaran, pam air berkuasa suria telah mendapat perhatian yang besar sejak beberapa tahun kebelakangan ini untuk memenuhi keperluan asas bagi sebahagian besar penduduk luar bandar di dunia. Disertasi ini adalah mengenai pemodelan dan simulasi sistem pam air fotovoltaik yang terdiri daripada panel suria sebagai penjana kuasa, unit kuasa penyaman yang terdiri daripada buck-boost chopper dan penyongsang satu fasa tetimbang penuh gelombang untuk membekal satu motor induksi satu fasa pam tersebut. Fungsi pam adalah untuk memenuhi simpanan tangki air untuk digunakan ketika tiada sinaran matahari. Simulasi ini dijalankan dengan perisian matlab / simulink menggunakan litar elektrik yang setara untuk setiap komponen bagi setiap subsistem. Keseluruhan sistem yang terdiri daripada semua subsistem menunjukkan keupayaan keseluruhan sistem pam air fotovoltaik. Prototaip telah dibina dan diuji untuk mengesahkan keputusan simulasi. Penyelidikan ini memberi penekanan kepada peringkat elektronik kuasa, dc / dc buck-boost chopper telah direka dan dipastikan, kecekapannya apabila disambungkan kepada sistem. Keputusan eksperimen adalah memuaskan apabila dibandingkan dengan kajian simulasi. Penyelidikan ini memberi penekanan kepada pensaizan sistem yang adalah sangat penting di dalam merangka sistem tenaga suria. Perisian homer telah digunakan untuk mengenal pasti saiz sistem dan ia menunjukkan prestasi yang tinggi dalam menganalisis pelbagai input yang boleh memberi kesan kepada tingkah laku sistem. Saiz sistem telah dicapai dari segi keberkesanan dan dari segi ekonomi.

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LIST OF ABREVIATIONS

RE	-	Renewable Energy
PV	-	Photovoltaic
PVWPS	-	Photovoltaic Water Pumping System
PSH	-	Peak Sun Hour
AM	-	Air Mass
DC	-	Direct Current
AC	-	Alternative Current
MPPT	-	Maximum Power Point Tracker
PWM	-	Pulse Width Modulation
PMDC	-	Permanent Magnet Direct Current
SPIM	-	Single Phase Induction Motor
PI	-	Proportional Integrator
Mi	-	Modulation Index
HOMER		Hybrid Optimization and Modeling of Energy Renewable
Voc	-	Voltage Open Circuit
FiT	-	Feed in Tariff
WMO	-	World Meteorological Organization

GUI	-	Graphical User Interface
Isc	-	Current Short Circuit
CMSe		Coronal Mass Ejections

LIST OF SYMBOLS

η	-	Efficiency
f	-	Frequency
A	-	Area
V	-	Voltage
I	-	Current
P	-	Power
ρ	-	Water density
□	-	Wavelength
L	-	Inductance
C	-	Capacitance
T	-	Period
t	-	Time
Ns	-	Synchronous speed
H	-	Height
Q	-	Water Flow
g	-	Acceleration of gravity
Tref	-	Reference temperature

A	-	Factor of ideality
K	-	Coefficient of Boltzmann
q	-	Charge of electron
ω	-	Rotational speed
Rs	-	Series resistance
Rp	-	Parallel resistance
β	-	Tilt angle
Jm	-	Inertia of the motor
G	-	Solar radiation

CHAPTER 1

INTRODUCTION

1.1 Introduction

The world energy demands are basically met by fossil fuels such as oil, coal and natural gas. The fact that these fossil fuels are in rapid depletion and environmental concerns has given awareness on the generation of renewable energy resources. The energy consumption is steadily increasing and the deregulation of electricity has caused that the amount of installed production capacity of classical high power stations cannot follow the demand. A method to replenish the gap is to make incentives to encourage investing in alternative energy sources known as renewable energy.

Renewable energy is any energy source that is continually replenished, such that derived from wind, solar, geothermal or hydroelectric action and photosynthetic energy stored in biomass. Which produces through its utilization neither noxious waste nor greenhouse effect gas. There is a necessity to explore these renewable energy sources for sustainable growth.

Using renewable energy sources is not only highly beneficial from an energetic point of view but also from an ecological point of view because by utilizing the renewable energy we can save our environment for our future generations. Early Malaysia has stressed on renewable energy and the RE target is 5.5% of Malaysia's total electricity generation mix by 2015 (Bakhtyar et al., 2005). Harnessing these clean energies appears to be a propitious key for improving both the power supply and the life quality of rural villagers.

Among these renewable resources, the solar energy has demonstrated its effectiveness and holds great promise as an alternative source of energy in many applications. With today's advancement technology, we are able to capture this radiation and turn it into two principal forms of solar energy which are heating and electricity (Robert and Ghassemi, 2009). Photovoltaic (PV) is an emerging technology, it can be seen as the symbol for future sustainable energy supply system, no other RE sources receive such enormous appreciation by the public. Photovoltaic is the direct transformation of sunlight into electricity at the atomic level.

Nowadays photovoltaic (PV) modules can be used, especially in stand-alone power systems for residential houses, emergency telephones, street lighting, refrigeration, telecommunications and water pumping.

Water is considered as the primary source of life for mankind and one of the most basic requirements for rural development. Water pumping, which requires energy, is a basic need for a large proportion of the world's rural population, the suitability of this technology for covering the daily water needs in these zones had been launched over many pilot projects implemented mostly in South America, Africa and Asia, where it has been estimated that two billion people are affected by water shortages in over forty countries, and 1.1 billion do not have sufficient drinking water (Malki, 2011).

In this dissertation, a photovoltaic water pumping system (PVWPS) is presented. It consists of PV panel, buck-boost chopper, single phase full bridge inverter, single phase induction motor and water tank for storage. This study provides a mathematical model of each component based on its equivalent electrical circuit from where the block diagram has been built using MATLAB/SIMULINK software in order to be transferred into a computer simulation. In addition, an experimental setup of the photovoltaic water pumping system through prototype hardware was performed to show the feasibility of the system.

The sizing task takes into account in this work due to its importance because the size of the components of the installation should be balanced and respect certain proportions to guarantee the best investment with an optimized and full use of the PV system and system storage as well. This system sizing is performed through a user friendly software which is HOMER, it performs optimization according to different assumption of input factors to give a wide view about their effect in the system, two criteria have been chosen to achieve technical and economic requirements of a system which are Annual Capacity Shortage (ACS) and Levelized Cost of Energy (LCE).

1.2 Literature Review

1.2.1 Solar Energy

Solar energy characterized by its abundance and free of charge, it exists in most parts of the world, has proven to be an economical source of energy in many applications. It can be a main source of power, indeed its potential is estimated around 178 billion MW which is about 20,000 times the world's demand (Chandrasekaran, 2011).

In appropriate climatic condition the sun's radiation on the earth can reach easily 3000 watts per square meter depending on the location. The sun is replenished and clean source, which produces neither greenhouse effect gas nor noxious waste through its utilization.

(Narbel, 2011) gave an overview about a solar energy technologies and their classification, he claimed that Solar energy technologies can be classified as:

- Passive and active.
- Thermal and photovoltaic.

Passive solar energy technology simply refers to collects the energy without transforming it into other forms. It includes, in instance, maximizing the use of daylight or heat through building design.

Active solar energy technology in the other hand is the harnessing of solar energy to convert it for other applications or stores it. Active solar energy in turn is classified into two categories:

- Solar thermal
- Solar photovoltaic

The sun is a star among many others. Its diameter is 1.39×10^{6}Km, almost 50 times that of the earth and a mass of 2×10^{30} Kg with luminosity of 4×10^{26}W, note that the average distance Sun-Earth is estimated to 1.5×10^{11}m. The sun is composed of three components: the core, the radiation and the convection zone and its atmosphere. The core is the source of all sun`s energy, it contains the half of the sun`s mass. It is composed of 70% hydrogen, 28% helium and 2% of a mixture of 100 elements. This changes over time as every second 700 million tons of hydrogen is converted into helium by thermo- nuclear reaction which is taken place in the core (Robert and Ghassemi, 2009).

The sun emits energy in two major forms:

- A plasma, which is a mixture of ions, electrons, and neutral atoms, is emitted along perturbations in the Sun's magnetic field, and causes solar flares and coronal mass ejections (CMEs).
- Radiation (heat energy) travels at the speed of light and takes about 8 min to reach the earth and has no mass.

The solar spectral distribution of the air has a maximum for a wavelength of about 0.5μm; the black body temperature at the surface of the sun is about 5780 ° k [pv s].