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TITLE: LOW COST MICROCONTROLLER BASED OPTIMAL CONTROL ON PHOTOVOLTAIC ENERGY OPTIMIZATION

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Bachelor of Electrical Engineering
(Control, Instrumentation & Automation)

June 2014

"I hereby declare that I have read through this report entitle "Low Cost Microcontroller Based Optimal Control on Photovoltaic Energy Optimization" and found that it has comply the partial fulfilment for awarding the degree of *Bachelor of Electrical Engineering (Control, Instrumentation and Automation)*"

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LOW COST MICROCONTROLLER BASED OPTIMAL CONTROL ON PHOTOVOLTAIC ENERGY OPTIMIZATION

TO SHU ZI

This report is Submitted in Partial Fulfillment of Requirement for the Degree of Bachelor in Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle “Low Cost Microcontroller Based Optimal Control on Photovoltaic Energy Optimization” 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 other degree.

Signature : .....

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ABSTRACT

The energy consumption in the world was increasing due to the increase of residents and high factory development. Solar energy has becoming a potential resource to generate energy because it is renewable energy. This research is about the modeling and simulation of optimal control on solar photovoltaic to optimize the power output. During the high irradiance of the sun, the temperature of the photovoltaic panel will be increase and the output power generated by the photovoltaic system will be decreased. Thus, the control system is applied to find an economic optimum to control the temperature of the solar photovoltaic and optimize the energy generated by the system. To overcome the problem, a fan was installed on the solar photovoltaic for the cooling on surface of solar photovoltaic. However, the used of the fan is also consumed energy from the system. Hence, the optimum operating point which is used to control the switching of fan is found to produce optimal power. Microcontroller PcDuino is used in designing the control system of this project. The algorithm of optimization, numeric integration and input-output will be exploited toward the success of the optimal control system. The data from the simulation and program are obtained for comparison and analysis. The results show that the output power with using optimal control is higher than the conventional condition. The percentage of improvement in output power is about 9% to 13%.

ABSTRAK

Penggunaan tenaga di dunia telah meningkat disebabkan oleh peningkatan penduduk dan pembangunan industry kilang yang pesat. Tenaga solar telah menjadi satu sumber yang berpotensi untuk menjana tenaga kerana tenaga ini adalah tenaga yang boleh diperbaharui. Kajian ini adalah tentang pemodelan dan simulasi kawalan optimum pada photovoltaic solar untuk mengoptimumkan output kuasa. Semasa sinaran matahari tinggi, suhu panel photovoltaic akan meningkatkan dan kuasa output yang dijana oleh sistem photovoltaic akan berkurangan. Oleh itu, sistem kawalan digunakan untuk mencari optimum bagi mengawal suhu photovoltaic solar dan mengoptimumkan tenaga yang dihasilkan oleh system photovoltaic. Untuk mengatasi masalah ini, kipas telah dipasang pada photovoltaic solar untuk penyejukan permukaan photovoltaic solar. Walaubagaimanapun, kipas juga menggunakan tenaga dari system apabila kipas dihidupkan. Oleh itu, titik operasi optimum yang digunakan untuk mengawal penukaran kipas didapati menghasilkan kuasa optimum. Micropengawal PcDuino telah digunakan untuk mereka cipta sistem kawalan dalam projek ini. Algoritma pengoptimuman, integrasi berangka dan input-output akan dieksploitasi untuk mencapai sistem kawalan optimum. Data yang diperolehi daripada simulasi dan program untuk perbandingan dan analisis. Keputusan menunjukkan bahawa kuasa yang dihasilkan dengan menggunakan kawalan optimum adalah lebih tinggi daripada keadaan konvensional. Kawalan optimum tersebut telah menyebabkan peningkatan dalam kuasa yang dihasilkan, iaitu sebanyak 9 % hingga 13 %.

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PV	-	Photovoltaic
USB	-	Universal serial bus
DC	-	Direct current
DSP	-	Digital Signal Processing
SISO	-	Single input and single output
TOMP	-	Direct optimal control method
GPP	-	General purpose preprocessor
V	-	Voltage
I	-	Current
MPPT	-	Maximum power point tracker

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CHAPTER 1

INTRODUCTION

1.1 Research Background

In the last century, fossil fuel was one of the most important energy resources. Due to increasing use of the fuel, it is predicted that the fuel will be depleted soon. Consequently, renewable energy such as Solar PV energy is becoming a prime interest of many researchers as an alternative energy source for human being in the near future. Solar energy was started to be explored and used in this modern century. Most of the homes today use the solar collector and solar PV for their auxiliary energy supplied.

Solar PV system is the system used to collect the solar irradiance to generate energy for home and industry application. Its energy is abundant and free, and relatively has no negative impact on the environment which is made this energy leading to the fossil fuel such as oil.

Solar photovoltaic (PV) cell is a semiconductor device which is used to convert solar radiation into electrical energy directly. Combination of series and parallel of the PV

cells to generate a large power is called by Solar PV array. Solar PV array power stations are the best alternative energy sources in rural areas. The PV systems generate power for applications such as in residential appliances, telecommunication, and calculator. The power generation of the photovoltaic is reliable and the cost for maintenance is low. PV system operates in a silent and clean condition but the capital cost of the system is high.

The PV system has been recognized and proved as the device which is used to produce energy for long duration and high reliability. However, the uncontrollable of the weather and radiation of sun have affected the continuity and efficiency of the energy delivery. During sunrise and sunset moment, the temperature of the solar PV plate increases non-linearly. The uncontrollable increase of temperature will decrease at the output power of the PV cell.

To solve the problem of the increasing of the solar PV temperature, optimal control theory was used to optimize the energy produced by the PV system. A fan was installed on the PV panel to cool the surface of the PV panel. However, the utilization of fan also needs to consume energy. To save the energy usage, the optimal controller had to be implemented to control the switching of the fan. A performance function had to be identified for the purpose of the optimal control. When the PV temperature increases, output power will decrease. To cooling the surface of PV panel, the fan is turned ON and the decrease of PV temperature will increases the output power of PV panel. However, fan is consuming energy when the fan is turn ON. When the fan is consuming energy more than the margin of output power, the performance function is negative, the fan must be turned OFF. Thus, the optimization of energy in this PV system can be obtained.

In this system, the implementation of the optimal control theory is very important to upgrade the performance of the PV system. The factors of ambient temperature, PV

temperature, maximum power point (MPP) current and MPP voltage are also will affect the performance of the PV system.

The PcDuino is used to control the operation of the system in order to have an optimal solution of the output power produced by the PV system from time to time. The use of PcDuino is due to its speed performance, memory size and relatively low cost compared to Digital Signal Processing (DSP) board. [1]

1.2 Problem Statement

PV system is a system that converts solar energy into the electricity energy. In this system, the solar radiation is very important. However, the solar radiations and weather are uncontrollable, and this can cause the temperature of the PV system increased dramatically during afternoon. The rise in temperature of the solar PV plate will decrease the efficiency of the energy harvesting from the solar PV. To solve this problem, optimal control is applied to adjust the temperature at predefined value or not to do anything at all such that the control system will make the PV system able to produce power as maximum as possible.

1.3 Objective of Research

The aim of the project is to design a low cost microcontroller based optimal control on photovoltaic energy optimization. There are three objectives to achieve in this project which are:

1) To simulate optimal control for optimize the output power generated by the PV system.
2) To design a microcontroller based optimal control in PV system.
3) To develop a C++ computer code on PcDuino to solve the control system tools subroutine and system simulation.

1.4 Scope of Research

The project deals with the performance and effectiveness of PV cell model. The PV system was used to convert solar irradiance into electrical energy. The solar PV system must be effective, reliable and low energy usage. The microcontroller used was PcDuino. The PcDuino and the theory of optimal control will be concerned. In this project, the software and the hardware of the system were implemented. The scope of this research is voltage, current and temperature measurement, fan, and software development for optimal control and system modeling. Some devices such as MPP Controller, current and voltage transducer, and fan controller are provided.

1.5 Contribution of Research

The project was contributed to solve the problem of power decrease at the solar PV due to the raising of the PV temperature during high irradiance. To implement such optimal control system, some standard tools such as Runge-Kutta integration and optimization algorithm must be developed for the PcDuino's environment.

1.6 Report Outline

Overall of this project is related to the design of optimal control on photovoltaic energy optimization. There are five chapters in this report.

Chapter 1 is explained the introduction of the project briefly. The research background, problem statement, objective, and scope, contribution of research and report outline were discussed in this chapter.

Chapter 2 is related to literature review and the information was come from the journal, newspaper, books and other materials that have been studied.

Chapter 3 explained the methodology of the research in details. The method of simulation, collect data and analysis data were discussed.

Chapter 4 presents the results that collected from the research. The discussion also contains at this chapter to discuss and analysis the data collected.

Chapter 5 presents the conclusion and recommendation of the research.