PHOTOVOLTAIC POWERED UNINTERRUPTED POWER SUPPLY BASED ON PIC MICROCONTROLLER

by

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LIST OF ABBREVIATION

AC	Alternating Current
CERE	Centre of Excellence for Renewable Energy
CRM	Coefficient of Residual Mass
CTHD	Current Total Harmonic Distortion
DC	Direct Current
NSE	Nash-Sutcliffe equation
PCB	Printed Circuit Board
PIC	Peripheral Interface Controller
PSHs	Peak Sun Hours
PV	Photovoltaic
RMSE	Root Mean Squared Error
STC	Standard Test Condition for PV module
TNB	Tenaga Nasional Berhad
UPS	Uninterrupted Power Supply

LIST OF SYMBOLS

A	An "apparent" extraterrestrial flux
A_i	Area of orientation surface, i
e	Percentage error
E_{out}	Total Electricity Energy
$E_{solar,\ i}$	Available solar radiation on different orientation surfaces
f	Utilization factor
I_{SC}	Short circuit current of PV module
$I_{\max}$	Maximum current of PV module
I_{MPP}	Current of PV module in the maximum power point STC
$I(\alpha, T, V)$	The circuit current as function of solar irradiance, temperature
J_s	The saturation current density
k	Optical depth
$P_{\max}$	Maximum power of PV module
P_{mea}	The measured power of PV module
P_{MPP}	Maximum Power Point
P_{sim}	The simulated power of PV module
R_S	Solar radiation

R_a	Extraterrestrial radiation
T_d	Difference between maximum and minimum air temperature
T_N	Nominal temperature (25 ^{0}C)
TC_i	Temperature coefficients of the short circuit current of PV module
TC_v	Temperature coefficients of the open circuit voltage of PV module
V_{OC}	Open circuit voltage of PV module
$V_{\min}$	Minimum voltage of PV module
$V_{\max}$	Maximum voltage of PV module
V_{MPP}	Voltage of PV module in the maximum power point STC
$V_{oc}(\alpha, T)$	The open circuit voltage as function of solar irradiance and temperature
V_{rms}	rms value of the voltage waveform generated
β	Zero voltage angle of three level AC waveform
η_{pv}	Efficiency of PV modules
α	Maximum voltage angle of three level AC waveform
$\alpha_{\min}$	Minimum solar irradiance
$\alpha_{\max}$	Maximum solar irradiance
τ	The minority lifetime

Bekalan Kuasa Tanpa Gangguan Dikuasakan Fotovolta Yang Diasaskan Pada PIC Mikropengawal

ABSTRAK

Tesis ini mengemukakan sistem bekalan kuasa tanpa gangguan dikuasakan fotovolta yang menggunakan PIC mikropengawal. Kajian upaya sinaran suria adalah amat penting untuk mengetahui upayanya guna membina sistem bekalan kuasa tanpa gangguan dikuasakan fotovolta. Sistem bekalan kuasa tanpa gangguan dikuasakan fotovolta tersebut harus memilki satu pengecas suria yang boleh cas bateri degan cepat, satu suis pindah ambil-alih yang memenuhi piawai IEC 62040-3 dan satu penyongsang yang memilki herotan harmonik jumlah arus (CTHD) terendah. Untuk alasan-alasan ini, objektif-objektif tesis ini adalah untuk menganalisis keupayaan sinaran suria guna membina sistem bekalan kuasa tanpa gangguan dikuasakan fotovolta, untuk merekabentuk satu pengecas suria, satu suis pindan dan satu penyongsang. Data upaya sinaran suria diukur pada Stesen Pusat Kecemerlangan untuk Tenaga Boleh Diperbaharui, Universiti Malaysia Perlis di Kangar, Perlis, Malaysia Belahan Utara. Pengecas suria, suis pindah dan penyongsang dibina oleh PIC mikropengawal. Hasil-hasil menunjukkan bahawa sinaran suria bulanan ialah 4824.81 Wh/m^2. Ianya lebih besar dari 3000 Wh/m^2 dan menunjukkan bahawa langit di Perlis cerah dan keamatan sinaran suria potensi sangat tinggi. Ianya menunjukkan bahawa sinaran suria di Perlis memberikan upaya yang besar untuk sistem bekalan kuasa tanpa gangguan fotovolta. Pengecas suria yang dicadangkan boleh menghantarkan arus pengecasan sehingga 20 A. Ini kerana arus tersebut boleh dibagi dalam nilai yang sama oleh litar arus berbilang. Teknik penyongsang yang dicadangkan beloh merubah sudut voltan maksimum dari bentuk gelombang tiga aras dari 20^0 sampai 180^0. Satu beban ulang alik yang dikenakan ke penyongsang dikuasakan fotovolta menunjukkan bahawa herotan harmonic jumlah arus terendah (CTHD) diperolehi ketika sudut voltan maksimum adalah 134^0. Satu kajian perbandingan (CTHD) antara penyongsang fotovolta tanpa pengubah satu fasa tiga aras dan penyongsang tiga aras pasaran (2000 W power inverter, 2000 W Charger 10A SUVPR Series DY 2000C and 1000 W Charger 10A SUVPR Series DY 1000C) juga telah dilakukan. Hasil tersebut menunjukkan bahawa CTHD dari penyongsang fotovolta tanpa pengubah satu fasa tiga aras lebih rendah berbanding CTHD dari penyongsang-penyongsang tiga aras pasaran.

Photovoltaic Powered Uninterrupted Power Supply Based on PIC Microcontroller

ABSTRACT

This thesis presents the photovoltaic (PV) powered uninterrupted power supply (UPS) system based on PIC microcontroller. The study of solar radiation is very important to know its potential to develop the PV powered UPS system. The PV powered UPS system should have a solar charger that can charge the battery fast, a change over of transfer switch that fulfill the standard of IEC 62040-3 and an inverter that has a lowest current total harmonic distortion (CTHD). For these reasons, the thesis objectives are to analyze the solar radiation potential to develop PV powered UPS system, to design a solar charger, a transfer switch and an inverter. The data of solar radiation are measured at the Renewable Energy Excellence Centre (REEC) Station, Universiti Malaysia Perlis in Kangar, Perlis, Northern Malaysia. The solar charger, transfer switch and inverter are constructed by PIC microcontroller. The results show that the average monthly solar radiation is 4824.81 Wh/m^2. It is greater than 3000 Wh/m^2 and indicates that the sky in Perlis is clear and the solar radiation intensity is very high. It indicates that the solar radiation in Perlis gives big potential for PV powered UPS system. The proposed solar charger can flow the charging current up to 24 A. It is due to the current can be divided in same value by the multiple current circuits. The proposed inverter technique is able to change peak voltage angle of the AC three-level waveform from 20^0 to 180^0. An AC load applied to the PV powered inverter shows that the lowest CTHD is obtained when the peak voltage angle is 134^0. A comparative study of CTHD between the proposed three level single phase PV inverter and the market three level inverters (2000 W power inverter, 2000 W Charger 10A SUVPR Series DY 2000C and 1000 W Charger 10A SUVPR Series DY 1000C) are conducted. The result shows that the CTHD of proposed three level single phase PV inverter is lower than the CTHD of the market three level inverters.

CHAPTER 1

INTRODUCTION

1.1 Background

Since the conventional energy reached its crisis, it has given a bad effect on the economical growth and energy demand. Due to the reduction of conventional energy, the transportation and power plant systems that use the fossil fuel can be stopped. The effects have motivated the researchers to find the alternative energy. The renewable energy has been obtained and applied as an alternative energy which produced continuity and it is widely used in the world (Alam & Manfred, 2010).

Solar energy is one part of the renewable energy, it is a fusion process of the sun that produces solar irradiation and reaches the surface of earth. The study of solar irradiation in one area of the earth surface is very important. The daily, monthly and annual data collection of solar irradiation are useful to give information in the one area that it is suitable or not to develop a photovoltaic (PV) power generation. By knowwing the area of orientation surface, efficiency and utilization factor of the PV module, thus the annual potential electricity generating capacity from the PV systems for the area can be estimated.

PV performance depends on the solar irradiation and temperature. If the solar irradiation increases and the temperature is constant, thus the PV performance will increase. Inversely, if the temperature increases and the solar irradiation is constant, thus the PV performance will decrease. The PV performance affects the capability of the charging system in the PV application. A high PV performance will produce a high charging current. It is important to reach the fast fully charging condition of the battery (Hussein & Fardoun, 2014).

The battery charged by the PV can be applied into an uninterrupted power supply (UPS). The UPS is used as a back up power source for emergency electrical loads in case of main power source failure. Usually, it is applied directly from the main power source, until the main power source fails. After the failure, inverter operated by a battery will turn on to supply electric power to the electrical loads. The battery is charged when main power source is available. The life time of the inverter depends on the battery capacity. The battery powered inverter is charged by the main power source can not be applied in the rural area.

Normally, the inverter is constructed by some switching electronic components. The components decide the output voltage waveform of the inverter. It will produce harmonic and affects the life time of the electrical loads. If the harmonic of the inverter is poor, thus the life time of the electrical loads are long. Inversely, if the harmonic of the inverter is reach, thus the life time of the electrical loads are shorten. A harmonic reduction technique of the inverter is important to be studied. The general technique is how to drive the switching electronic components and produce the output voltage waveform of the inverter with poor harmonic.

This thesis presents the daily, monthly and annual solar irradiation in Perlis. They are observed and analyzed to obtain the potential of PV powered UPS system application. A PV powered UPS system using PIC microcontroller is developed. It is a backup UPS whereas if the main power source fails to supply power to the electrical loads, inverter operated by a battery will turn on to supply electric power continuosly. The PV module charges the battery using solar charger and the transfer switch is controlled by PIC microcontroller.

1.2 Problem Statement

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

1. The solar irradiation data are the most important component to estimate output of photovoltaic systems. The information of daily, monthly and annual solar irradiation are important to know the potential of solar irradiation for PV powered UPS system. Shijun and Hongxing (1997) states that the area requirement should be fulfilled to generate the photovoltaic is that the area has solar irradiation above 3 kWh/m^2. Markvart (1994), Itagaki et al. (2003) and Mellit et al. (2007) also state that the area has peak sun hours (PSHs) is above 3 hours. Laleman et al., 2011 states that the solar irradiation can be classified into four categorizes. They are low solar irradiation (below 2.6 kWh/m^2), moderate solar irradiation (between 2.6 – 3 kWh/m^2), high solar irradiation (between 3-4 kWh/m^2) and very high solar irradiation (above 4 kWh/m^2). It is important to know the sky condition and its potential towards PV application, especially the PV powered UPS system in Perlis, Northern Malaysia.

2. UPS system needs batteries to run it. Usually, the battery is charged by the main power source using a rectifier circuit. It means that the UPS only can be operated in the main power source area or it can not be operated in the rural area (no utility grid). A design of UPS completed by solar charger is important in case of its application. It can be operated in both of the main power source area and also the rural area. The batteries are charged by PV module using solar charger. A higher current of the solar charger will charge the batteries fast. Karami et al., 2012 states that the power consumed by the batteries is related to their states of charge (SOC) which is charged by PV module. The PV current at different solar irradiance should be compatible with charging current required to charge the batteries. A critical situation occurs at high solar irradiance when the PV module delivers a high current that exceeds the tolerated charging current. If it is not controlled, the batteries can be damaged. In this case, a design of solar charger controller is important to maintain the batteries safety condition.

3. UPS system needs a transfer switch to transfer electrical energy from failed main power source to inverter source. The transfer switch needs high speed accuracy to detect the failed main power source. Normally, the transfer switch is developed by static transfer switch, it is DC relay (Alam et al, 2013). It has lower speed accuracy compared to the PIC microcontroller. Thus, it is very important to develop a transfer switch in the Photovoltaic powered UPS system which has high speed accuracy.

4. Inverters installed in the UPS system are developed by using electronic components which produce harmonic. The simplest technique to invert DC power into AC power is to generate a square wave. However, not only the harmonic content of the square