ASSESSMENT OF COOLING PHOTOVOLTAIC-WIND HYBRID POWER CONTROLLER SYSTEM FOR AC LOAD APPLICATION IN TROPICAL CLIMATE CONDITION

by

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LIST OF SYMBOLS

A	An "apparent" extraterrestrial flux
A_i	Area of orientation surface,i
Ah	Capacity battery
b	The fit parameter of the PV model
e	Percentage error
f	Utilization factor
FF	Fill factor of PV module
H	Hour angle
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
n	Sample size
N	Number of elements
P_{max}	Maximum power of PV module
P_T	Theoretical power of PV module
R_S	Solar radiation
T_{max}	Maximum air temperature
T_{min}	Minimum air temperature
T_d	Difference between maximum and minimum air temperature
T_N	Nominal temperature (25 $^{\circ}$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
TD_{sqr1}	Time delay of the first pulse
TD_{sqr2}	Time delay of the second pulse
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_{rms}	rms value of the voltage waveform generated
V_n	nth voltage harmonic
β	Zero voltage angle of three level AC waveform
γ	Tilt angle of PV module
η pv	Efficiency of PV modules
η_m	Maximum efficiency of PV module
α	Maximum voltage angle of three level AC waveform
$\alpha_{\min}$	Minimum solar irradiance
$\alpha_{\max}$	Maximum solar irradiance
κ	Concentration parameter
$VM(\mu,\kappa)$	The von Mises distribution with mean direction μ and concentration parameter κ
R	Resultant length
$\overline{R}$	Mean resultant length
$I_0(\kappa)$	The modified Bessel function of the first kind and order zero.
$\overline{\theta}$	Sample mean direction

ϕ	Sample median direction
$A(\kappa)$	Ratio of Bessel functions, a measure of goodness-of-fit for circular regression model
δ_j	Circular residuals
ε_j	Circular residuals
σ^2	variance
λ	Parameter estimate
V_r	Nominal wind speed
V_f	Cut-out wind speed
ΔW	difference between generated energy and demanded energy
W_{gen}	total annual energy
K_w	the number of wind power generation
K_{pv}	the number of PV module power generation
W_{dem}	inverter demanded energy
ΔT	time between the samples
P_{dem}	inverter demanded power
V_p	peak voltage
η_i	efficiency

LIST OF ABBREVIATION

AC	Alternating Current
AIC	Akaike's Information Criteria
BJT	Bipolar Junction Transistor
CERE	Centre of Excellence for Renewable Energy
CLR	Circular-Linear Regression
CLFR	Circular-Linear Functional Relationship
CRM	Coefficient of Residual Mass
CTHD	Current Total Harmonic Distortion
DC	Direct Current
IGBT	Insulated-Gate Bipolar Transistor
ML	Maximum Likelihood
MLE	Maximum Likelihood Estimation
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PCB	Printed Circuit Board
PSHs	Peak Sun Hours
PV	Photovoltaic
PWHI	Photovoltaic/Wind Hybrid Cooling System
RMSE	Root Mean Squared Error
SE	Standard Error
SSE	Sum Square Of Error
STC	Standard Test Condition for PV module
VP2	Vantage Pro2
TNB	Tenaga Nasional Berhad
UniMAP	University Malaysia Perlis
TS	Temperature sensor

LCD	Liquid crystal display
HRES	Hybrid renewable energy systems

Penilaian Bagi Penyejukan Hibrid Fotovolta-Angin Sistem Kuasa Pengawal Untuk Penggunaan Beban AU Dalam Keadaan Iklim Tropika

ABSTRAK

Penyelidikan ini melihatkan penilaian bagi penyejukan hibrid fotovolta (PV)-angin sistem kuasa pengawal untuk penggunaan beban arus ulangalik (AU) dalam keadaan iklim tropika. Ia mempunyai empat objektif untuk memenuhi keperluan kajian ini. Pertama, kajian potensi PV dan penjanaan kuasa angin di Perlis telah dibincangkan. Data sinaran suria dan kelajuan angin di Pusat Kecemerlangan Tenaga Boleh Diperbaharui (PKTD), Universiti Malaysia Perlis di Perlis, Malaysia. Purata data sinaran suria bagi tiga tahun yang lepas (2011-2013) adalah lebih tinggi daripada 3 kWj/m^2 yang menunjukkan bahawa Perlis adalah sesuai untuk penggunaan teknologi kuasa solar. Keduanya, model baru berdasarkan data arah angin untuk menganggarkan kelajuan angin telah dicadangkan. Pembangunan teori model hubungan fungsian bulatan-lurus menggunakan model bulatan-lurus yang dicadangkan oleh Mardia (1976) apabila kedua-dua pemboleh ubah mengandungi ralat dipersembahkan. Model ini telah disesuaikan data dengan baik dengan menganggap kedua-dua pemboleh ubah model hubungan fungsian bulatan-lurus tak berulang mengandungi ralat. Ini menunjukkan kaedah yang dicadangkan boleh diterima dan bersesuaian. Ketiga, suhu PV modul meningkat apabilaia menyerap sinaran suria dan menyebabkan susutan kecekapan. Oleh itu, topologi sistem penyejukan automatik PV yang dicadangkan adalah direka bentuk, dibina dan ujikaji diteliti dalam kajian ini untuk mengatasi cabaran ini. Untuk mengurangkan suhu permukaan modul PV, arus terus (AT) sistem penyejukan telah direka bentuk mengunakan tiga kaedah yang mana kipas tanpa berus AT, pam air AT dan kacukan kipas tanpa berus AT dengan pam air AT. Mereka akan menetapkan pergerakan udara dan pusingan aliran air di bahagian belakang dan sisi hadapan modul PV, masing-masing. Empat pengesan suhu telah dipasang pada modul PV untuk mengesan suhu permukaannya. Keputusan menunjukkan bahawa sistem penyejukan kacukan AT mempunyai prestasi yang tertinggi bagi meningkatkan kuasa keluaran dan kecekapan modul PV. Ini akan menyebabkan tempoh bayaran balik sistem boleh dipendekkan dan hayat modul PV boleh menjadi lebih lama sekiranya suhu permukaannya boleh distabilkan. Akhir sekali, PV/Angin hibrid penjanaan kuasa bagi pengunaan beban AU tidak lengkap tanpa pengubah. Kerana ini, penyongsang telah digunakan dalam kajian ini untuk menukarkan kuasa AT ke dalam kuasa AU untuk menjana gelombang persegi. Walaubagaimanapun, kandungan harmonik gelombang persegi adalah agak tinggi. Juga, kecekapan gelombang ini juga menjadi agak rendah. Dalam usaha untuk mengurangkan kandungan harmonik, penyonsang hibrid PV/Angin dengan ubah suaian gelombang persegi direkabentuk. Topologi ini direka bentuk untuk mengurangkan jumlah herotan harmonik semasa (CTHD) daripada penyongsang hibrid PV/Angin. Dalam usaha untuk mengurangkan CTHD pada AU tiga tahap gelombang daripada PWHI, program dihasilkan untuk mengawal sudut voltan maksimum dengan menggunakan mikro pengawal PIC16F628A. Teknik ini boleh mengubah sudut voltan maksimum AU tiga tahap gelombang dari 20º hingga 180º. Satu beban AU digunakan kepada PWHI menunjukkan bahawa CTHD terendah diperoleh apabila sudut voltan maksimum ialah 134º. Jika PWHI berjalan dengan CTHD tinggi, ia akan mempengaruhi PWHI dan bebannya untuk bekerja dengan kecekapan yang rendah. Walau bagaimanapun, apabila CTHD menjadi paling rendah, ia akan mengurangkan kerosakan dan kerugian kuasa PWHI dan juga beban. Keadaan ini secara automatik akan meningkatkan hayat operasi mereka.

Assessment Of Cooling Photovoltaic-Wind Hybrid Power Controller System For AC Load Application In Tropical Climate Condition

ABSTRACT

This research looks at the assessment of cooling photovoltaic (PV)-wind hybrid power controller system for alternating current (AC) load application in tropical climate condition. It has four objectives in order to fulfill the requirement of this research. Firstly, the study of the potential PV and wind power generation in Perlis has been discussed. The data of solar radiation and wind speed were measured at the Centre of Excellence for Renewable Energy (CERE), University Malaysia Perlis in Perlis, Malaysia. The average of solar radiation for the past three years (2011 to 2013) is higher than 3 kWh/m^2 which indicates that Perlis is suitable for solar power technology application. Secondly, a new model based on wind direction data in order to estimate the wind speed has been proposed. The development of the theory of circular-linear functional relationship model via circular-linear regression model proposed by Mardia (1976) when both variables are subject to errors are presented. The model has fitted the data quite well by assuming that both variables of the unreplicated circular-linear functional relationship model are subject to errors. This indicates that the proposed method is acceptable and applicable. Third, the temperature of PV module increases when it absorbs solar radiation, causing the decrement of efficiency. Therefore, the proposed topology of PV automatic cooling system is designed, constructed and experimentally researched within this study in order to overcome this challenge. To reduce the PV module surface temperature, direct current (DC) cooling system was designed using three methods which are DC brushless fan, DC water pump and DC hybrid brushless fan with DC water pump. They will make the air movement and water flow circulation at the back side and front side of PV module, respectively. Four temperature sensors were installed on the PV module to detect its surface temperature. The results show that the DC hybrid cooling system shows the highest performance in order to improve the output power and efficiency of PV module. This will cause the payback period of the system to be shorter and the lifetime of PV module to be longer if its surface temperature can be stabilized. Lastly, PV/Wind hybrid power generation for AC load application is not complete without the inverter. Therefore, the inverter was used in this study to invert DC power into AC power for generating the square wave. However, the harmonic content of the square wave is relatively high. Also, the efficiency of this waveform becomes relatively low. In order to reduce the harmonic content, the PV/Wind hybrid inverter (PWHI) with modified square wave was designed. This topology was designed to reduce the current total harmonic distortion (CTHD) of the PWHI. In order to minimize the CTHD on AC three-level waveform of PWHI, the program was created to control the maximum voltage angle by using PIC16F628A microcontroller. This technique could change the maximum voltage angle of the AC three-level waveform from 20º to 180º. An AC load applied to the PWHI shows that the lowest CTHD was obtained when the maximum voltage angle was 134º. If the PWHI is run with high CTHD, it will cause the PWHI and its load to work with low efficiency.

However, when the CTHD becomes the lowest, it will reduce the malfunction and lessen the power losses of the PWHI and the load. This situation will automatically improve their operational life.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Several decades ago, renewable energy was not considered as the primary energy. It was always stated that the sources of renewable energy were not important. This is due to the fact that almost all modern countries did not want to rely on renewable energy as their main energy source. They only relied on non-renewable energy sources such as petroleum, gas, coal, crude oil and also nuclear power. All of these non-renewable energy sources could affect the environment negatively. However, today, all the modern countries have realized the importance of renewable energy sources. They gradually consume renewable energy as the main energy in their consumption power. This energy is not only for domestic use, but also for the industry. The other reason they have changed to renewable energy today is because it is known that this type of energy is environmental friendly. The mostly used renewable energy sources around the world today are photovoltaic (PV) energy, hydroelectric energy, wind energy, tidal energy, wave energy, biomass energy and geothermal.

With regard to Malaysia, its location on the South China Sea is an advantage to apply the renewable energy especially the solar power system technology. In Malaysia, the government department that is responsible for renewable energy is the Department of Energy, Green Technology and Water Malaysia (KeTTHA). Under this department, there is GreenTech Malaysia that is tasked by KeTTHA to lead the implementation of projects and activities related to renewable energy.