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Full paper

Implementation of IncCond Algorithm to Optimize PI Boost Converter for Maximum Power Point Tracking in Photovoltaic Arrays

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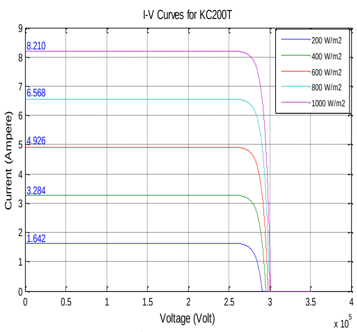
Graphical abstract



I-V Curves for varying Irradiance

Abstract

This paper presents an incremental conductance (IncCond) algorithm optimized Proportional Integral (PI) controller for maximum power point tracking (MPPT) in photovoltaic (PV) arrays. In the proposed method, Modified IncCond algorithm is used for optimizing the maximum available power in uncertainty occurs of the temperature and solar radiation. Furthermore, PI in boost converter is used to ensure the steady state conditions more quickly and eliminate the power losses in switching. Tuning method is applied for determining control parameters by using zigler-nichols and trial – error procedures. The simulation results demonstrate the excellent performance which can effectively improve in tracking speed and accuracy of maximum power. The controller response is able to achieve stable conditions around 0.01 seconds, which is three times faster to equal with the input voltage. Simulation results showed that the PV system becomes more efficient as proven by the changes in irradiance conditions by having average power efficiency is 99.35%, error is 0.65%, which is half the existing one.

Keywords: Photovoltaic; inccond algorithm; boost converter; power efficiency

Abstrak

Kertas kerja ini membentangkan satu konduktansi tambahan (IncCond) algoritma dioptimumkan dengan pengawal proporsional Integral (PI) untuk pengesanan titik kuasa maksimum (MPPT) pada photovoltaic (PV) array. Dalam kaedah yang dicadangkan itu, algoritma IncCond Modified digunakan untuk mengoptimumkan kuasa maksimum yang tersedia dalam ketidakpastian berlaku dari suhu dan radiasi solar. Selain itu, PI dalam meningkatkan penukar digunakan untuk memastikan keadaan keadaan mantap dengan lebih cepat dan menghapuskan kehilangan kuasa di switching. Kaedah penalaan digunakan untuk menentukan parameter kawalan dengan menggunakan zigler-nichols dan percubaan - prosedur kesilapan. Hasil simulasi menunjukkan prestasi yang sangat baik yang berkesan boleh meningkatkan kelajuan dan ketepatan pengesanan kuasa maksimum. Sambutan pengawal mampu mencapai keadaan stabil sekitar 0.01saat, yang merupakan tiga kali lebih cepat untuk sama dengan voltan masukan. Hasil simulasi menunjukkan bahawa sistem PV menjadi lebih efisien seperti yang dibuktikan oleh perubahan dalam keadaan radiasi dengan mempunyai purata kecekapan kuasa adalah 99,35%, kesilapan adalah 0.65%, yang merupakan separuh yang sudah ada..

Kata kunci: Photovoltaic; algoritma inccond; meningkatkan penukar; kecekapan kuasa

1.0 INTRODUCTION

Maximum Power Point Tracking, or MPPT, continuously monitors the voltage and current and updates the appropriate control signals to achieve the MPP for photovoltaic, or PV, cells, based on the load capacity. A DC/DC convertor with MPPT algorithm is used between PV module and load to extract maximum available power.[1] A large number of techniques have been proposed for MPPT. Hill climbing, Perturb and Observe, or P&O, and Fuzzy logic methods are widely used as MPPT because of their simplicity and easy implementation.[2-3] The average increasing in energy extraction is 16% to 43% by using conventional hill climbing.[4] The efficiency of P&O, and IncCond, or INC, algorithms is 96.5% and 98.2% respectively with no feedback[5] The MPPT controller response using the fuzzy-PID control is approximately 0.035s and It's has efficiency at 98.8% with feedback.[6] The optimal design of DC-DC boost Converter with closed loop control PID mechanism for high voltage

Photovoltaic application has efficiency of output power around 90% .[7] Before that is literature review the MPPT controller using a boost converter to track the MPP of PV modules has not reached the optimum conditions, and after that is new proposal make the modeling of boost converter using dynamic equation modeling, which allows the input voltage of the boost converter be controlled by the MPPT algorithm. In this paper, IncCond method and PI controller are developed as a new control techniques that results in a fast response to irradiance changes, leading to significantly higher PV system output power. Actually, the proposed MPPT controller show that by using control IncCond algorithm Optimized PI Boost Converter gives three times faster tracking response than fuzzy-PID and gives power efficiency loss half that of fuzzy-PID.

2.0 PROPOSED DESIGN OF INCCOND ALGORITHM COMBINED WITH PI CONTROLLER

Incremental Conductance (IncCond) is a more elaborate version of the dP/dV algorithm. Implementation of IncCond algorithm combined with PI controller is the most effective way. PI controller for MPPT is designed to decrease the error at the gradient value of MPPT near to zero. The following of error equation (2- 4) in PI controller can be written as:

$$G_{PI}(s) = K_P\left(1 + \frac{1}{T_i s}\right) \quad (1)$$

Where; K_p = Proportional gain
T_i = Integral time
G_{PI} = Transfer function of Proportional integral

$$error = -0 + \frac{dP}{dV} \quad (2)$$

For $P = V.I$,
Where; P = Power
V = Voltage
V_{prev} = Previous voltage
I = Current
I_{prev} = Previous current

then

$$error = \frac{dV * I + dI * V}{dV} \quad (3)$$

$$error = I + \frac{dI * V}{dV} \quad (4)$$

In discrete systems, dI and dV can be calculated as:

$dI = \Delta I$; and $\Delta I = I - I_{prev}$; In the same way,

$dV = \Delta V$; and $\Delta V = V - V_{prev}$

In accordance with the MPPT algorithm, the duty cycle (D) is calculated based on a new duty cycle setting according to the sampling time. A big change of V_{rev} will accelerate the exploration time, but difficult to achieve V_{MPP} and cause oscillations around the MPP. Modification of IncCond algorithm with combining the PI controller was employed to reduce the oscillation and able to make a big change in V_{rev} . With this changing, problem of varying weather condition will dissolve (Fig. 1). Shows the InCond algorithm optimizes PI boost converter.

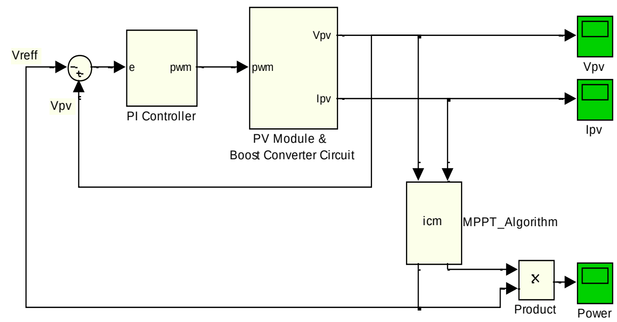


Figure 1 Block diagram of close-loop system in Matlab Simulink

3.0 RESULTS AND DISCUSSION

The main components parameters of boost converter circuit and PI controller that are implemented in Matlab Simulink are given in Table 1.

Table 1 Simulation Parameters

Boost Converter Circuit		PI controller
L	20 µH	Kp = 0.0001
fs	20 kHz	Ki = 0.7
Vc	400 Volt	Ti = 0.00015
Vd	0.62 Volt	dt = 0.0001
Rl	0.15 Ω	
C	9.4 mF	
Ns	11 cells	

A component of the reference solar cell used in this research is solar cells manufactured by Kyocera model KC200T (**Kyocera KC200T Datasheet**), where the values of specification parameters are given in Table 2.

Table 2 Specifications of KC200T
(Kyocera KC200T Datasheet)

Characteristics	Values
Maximum Power(Pmax)	+10% 200 Watt -5%
Open Circuit Voltage (V_{OC})	32.9 V
Short Circuit Current (I_{SC})	8.21 A
Temperature Coefficient of V_{OC}	$-8,21x10^{-2}$ V/°C
Temperature Coefficient of I_{SC}	$1,33x10^{-3}$ A/°C
Maximum Power Voltage (V_{MPP})	17,4 V
Number per Module	54

(Fig. 2). shows the I-V characteristic curves as a model of solar cells in exposuring on different solar radiation but temperature conditions remained at 25 °C and one cell. From the simulation results, it found that the smaller of solar radiation to the photovoltaic cells, causing I_{SC}(short circuit current) and V_{OC}(open circuit voltage) are also getting smaller.

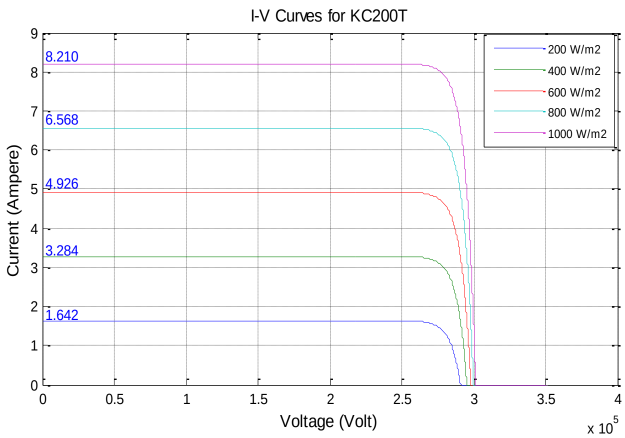


Figure 2 I-V Curves for varying Irradiance

All the parameters are obtained by tuning rule (Zigler and Nichols) method. (Fig. 3a). shows simulation results of boost converter without PI controller with the set point, V_{PVref} 50 Volt at 0 <t <0.05 and 230 Volt at 0.05 ≤ t <0.1, respectively. It shows that the output voltage response does not match to the input voltage. In contrast, (Fig. 3b). is the case with PI controller with the same as the above and the sampling time of the boost converter controller is 20 kHz. The controller response can reach stable conditions around 0.01 seconds to equal with the input voltage. We can conclude that PI controller can be used to control the input voltage (V_{PV}) of the boost converter circuit.

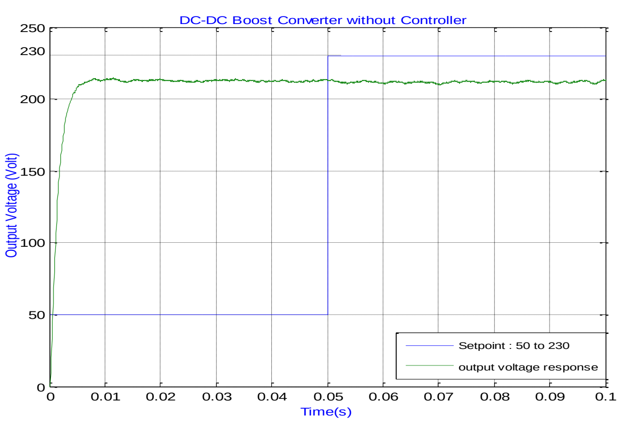


Figure 3a Output voltage without controller

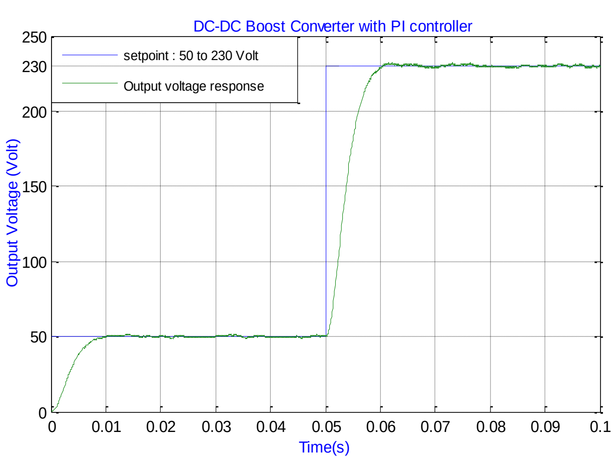


Figure 3b Output Voltage with controller

All the simulation results in (Fig. 4a), (Fig. 4b), and (Fig.4c) shows the first condition of irradiance at 400 W/m^2, output current at 3.218 Ampere, output voltage of 293.1657 volt and the output power is 938.8542 Watt, but by the calculation, the output power is 938.7760 Watt. From these values, the error is about 0.48 %, so the output power efficiency is 99.52 %. When there is changing in the irradiance about 1000 W/m^2, solar cells will change in working point and gives the output current at 8 Ampere and the output voltage at 302.8 Volt, so that the maximum output power of the solar cell is about 2402.46 Watt. Meanwhile, the results of power calculations is 2422.4 Watt, so the error is in rate of 0.82 %, that mean the output power efficiency is 99.18 %, All the average output power efficiency is 99.35 %. Based on the simulation results, it proves that the algorithm IncCond optimized PI controller can be able to find the maximum available output power although under varying uncertainty environment, and also can provide accurate and reliable in tracking to get the best performance.

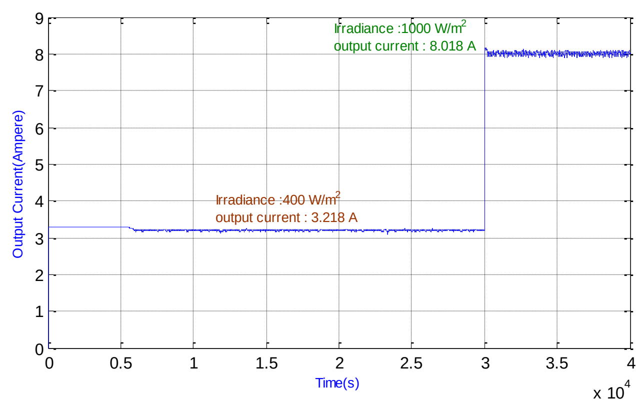


Figure 4a Output current with significantly change of irradiance from 400 W/m^2 to 1000 W/m^2

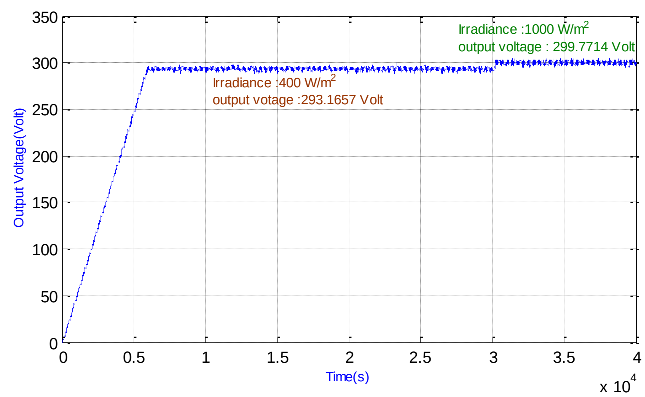


Figure 4b Output voltage with significantly change of irradiance from 400 W/m^2 to 1000 W/m^2

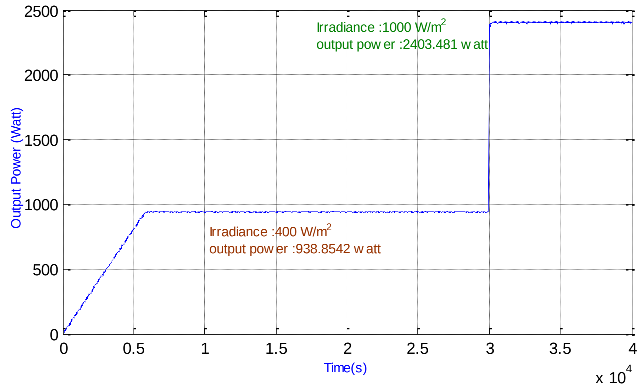


Figure 4c Output power with significantly change of irradiance from 400 W/m^2 to 1000 W/m^2

Comparison percent of energy extracted from the PV panel with the MPPT can be shown in Table 3.

Table 3 Percent of energy extracted from the PV panel with MPPT

No	MPPT Method	Power Conversion efficiency (%)	Tracking speed (s)	Feedback
1	P&O	96.5	-	No
2	IncCond	98.2	-	No
3	PID	90	-	Yes
4	Fuzzy-PID	98.8	0.035	Yes
5	**IncCond algorithm Optimized PI Boost Converter Proposed Research**	**99.35**	**0.01**	**Yes**

■4.0 CONCLUSION

The design of an IncCond algorithm optimized PI boost converter for maximum power point tracking in photovoltaic arrays has been presented. The proposed dynamic photovoltaic, boost converter and MPPT controller circuit are designed using [8] MATLAB with integrated C++ programming to form a computer simulation based. The simulation results of IncCond algorithm optimized PI boost converter are compared with the previous method. Moreover it's has been successfully implemented to give maximum photovoltaic output power, able to reach the MPP quickly and oscillation response is near to zero. Furthermore, the PV system becomes more efficient as proven by the changes in radiation conditions still have power efficiency is 99.35% with the error is 0.65%.

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