JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Design of Closed Loop Buck – Boost Converter For a Standalone PV System With Incremental Conductance MPPT Tracking

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***Abstract*— This paper presents the design and simulation of a standalone photovoltaic (PV) system utilizing a DC-DC Buck-Boost converter, implemented in MATLAB/Simulink. The system comprises a solar PV array, the Buck-Boost converter, and both resistive (R) and resistive-inductive (RL) loads. Recognizing the intermittent nature of solar PV power output due to variations in cell temperature and solar irradiance, an Incremental Conductance (INC) Maximum Power Point Tracking (MPPT) algorithm is employed with the Buck-Boost converter to ensure maximum power extraction from the PV panels. Three distinct simulation cases are investigated: i) a closed-loop Buck-Boost converter with a DC supply, ii) the solar PV array integrated with the system, and iii) the complete system incorporating the INC MPPT algorithm. Simulation results consistently demonstrate that a stabilized and regulated output voltage is achieved for both R and RL loads, irrespective of fluctuations in the input voltage.**

Key Word : PV system , INC MPPT , DC-DC Converter , Closed loop control system.

1. Introduction

Due to the Environmental concerns, There is strong demand to increase the penetration level of renewable energy globally[1,2].The photovolatic (PV)technology has a great potential to become a major renewable source for clean electricity generation in the near future[3-4].

MPPT algorithms are necessary because PV arrays have a non - linear voltage - current characteristics with a unique point where the power produced is maximum[5,6,7]. This points depends on the temperature of the panels and the irradiance conditions[3]. Temperature and irradiance changes during the day and are also depending on the season of the year(i.e. winter,rainy,summer), and also Irradiance can change,rapidly due to changing atmosphere condition such as clouds.It is very important to track the maximum power point accurately under all atmospheric condition the most popular, INC mppt analysed in depth and simulated using standard test conditions[10].

Closed Loop Control Technique

The Closed Loop Control technique is implemeented to maintain the load volatge constant ,the sensing volatge on the load side compared with the constant refernce voltage (PV volatge).The error produced is further amplified and fed back to the PI controller . The output of PI controller is then compared with the high frequency sawtooth signal,the generator pulse given to the IGBT

2. CLOSED LOOP DESIGN:

2.1 Closed loop design

The basic elements of the closed-loop control system include error detector, controller, feedback elements & power plant.

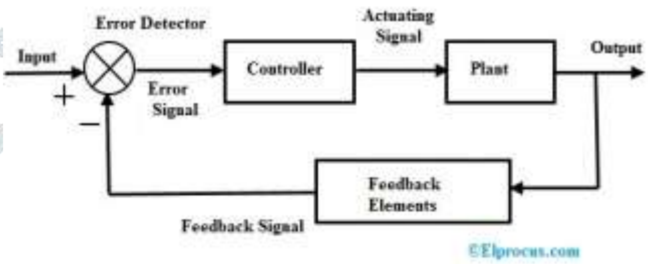


Figure 1 Block diagram of closed loop system

When the control system includes a feedback loop, then the systems are known as feedback control systems. So the output can be controlled accurately by providing feedback to the input. This type of control system can include more than one feedback.

In fig 1 the error detector generates an error signal, which is the difference of the input as well as the feedback signal. This feedback signal can be obtained from the elements of feedback in the control system by considering the system output as an input. As an alternative of the input, this error signal can be given as an input of a controller.

Consequently, the controller generates an actuating signal to control the plant. In this arrangement, the control system output can be corrected automatically to get the preferred output. Therefore, these systems are also named as automatic control systems.

3. DC-DC CONVERTER

DC to DC converter is very much needed nowadays as many industrial applications are dependent upon DC voltage source. The performance of these applications will be improved if we use a variable DC supply. It will help to improve controllability of the equipments also. Examples of such applications are subway cars, trolley buses, battery operated vehicles etc. We can control and vary a constant DC voltage with the help of a chopper. A chopper is a static device in power electronics that changes a fixed DC voltage into a variable one. Essentially, it's a high-speed switch that rapidly connects and disconnects the load from the source to produce a variable voltage output.

4. MPPT

The main goal of MPPT are to ensure fast , precise maximum power tracking and reduce oscillation . Recent research has seen several popular MPPT algorithm techniques, such as P&O, incremental conductance ,and particle swarm optimization. Voltage , Current and duty cycle are the control variable that canbe used in the MPPT technique . Among all the currently used MPPT algorithm perturn and observe and incremental algorithms are commonly used algorithm . A drawback of P&O MPPT technique is that ,at steady state ,the operating point oscillates around the MPP giving rise to the waste of some amount of available energy .Several improvement of the P&O algorithm have been proposed in order to reduce the number of oscillation around the MPP in steady state , but they slow down the speed of response of the algorithm to changing atmosphere conditions and lower the algorithm efficiency during cloudy days.The INC algorithm seeks to overcome such limitations.

5. Incremental conductance algorithm

The time complexity of the perturb & observe algorithm is much less but on reaching very close to the MPP it does not stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm . However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPPT.

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by INC method . The INC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPPT and positive when it is to the left of the MPPT.

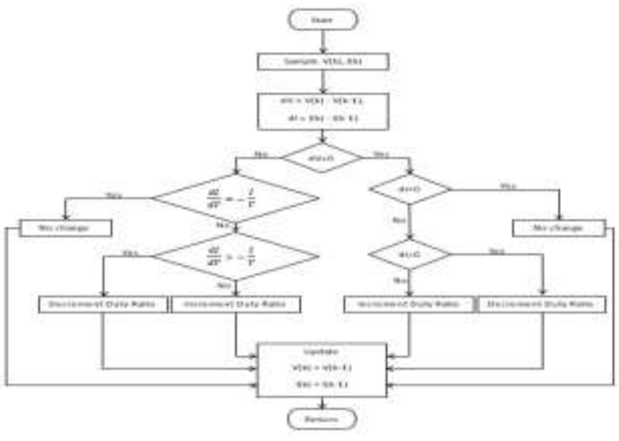


Figure 2 Block diagram of Incremental conductance

PV Array Data

Parameter	Value
Parallel strings	6
Series connected modules per string	8

PV module data

Parameter	Value
Module	TSMC Solar TS-110C
Maximum power (W)	5kW
Calles per module (Ncell)	100
Open circuit volatage,Voc (V)	51.6
Short circuit volatage ,Isc(A)	3.36
Voltage at maximum power point , Vmp (V)	39.1
Current at maximum power point , Imp (A)	2.81
Temperature coefficient of Voc (%/°C)	-0.33
Temperature coefficient of Isc (%/°C)	0.063797

6. Design of Buck-Boost Converter

Inductor Design

$$L_{min} = \frac{(1-D)^2R}{2f}$$

Capacitor Design

$$C = \frac{1-D}{R\left(\frac{\Delta V_o}{V_o}\right)f}$$

Duty Cycle

$$D = \frac{V_o}{V_{o+VI}}$$

Parameter	Value
Input voltage (V)	312
Output Voltage (V)	230
Duty ratio	0.42
Switching Frequency (kHz)	10
Load resistor(Ω)	10
Inductance (μH)	$199*10^{-4}$
Capacitance (μF)	$200*10^{-6}$

SIMULATION CIRCUITS

Buck-Boost Converter closedloop with DC supply

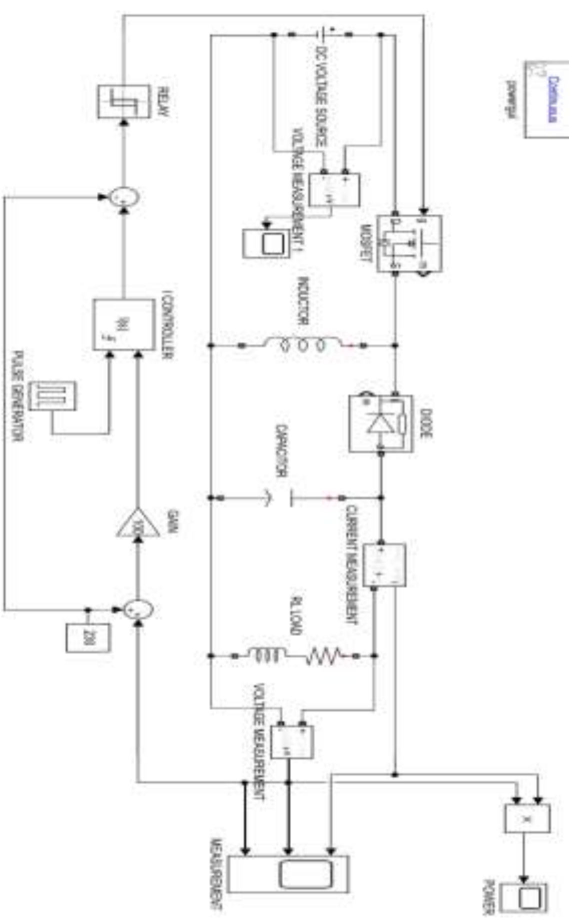
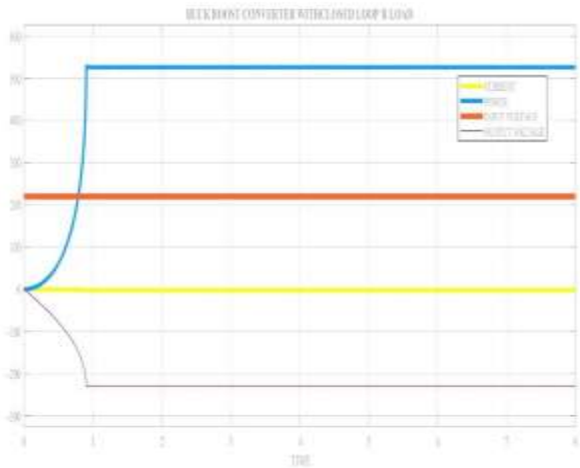


Fig 2 : Buck -Boost converter with closed loop R load



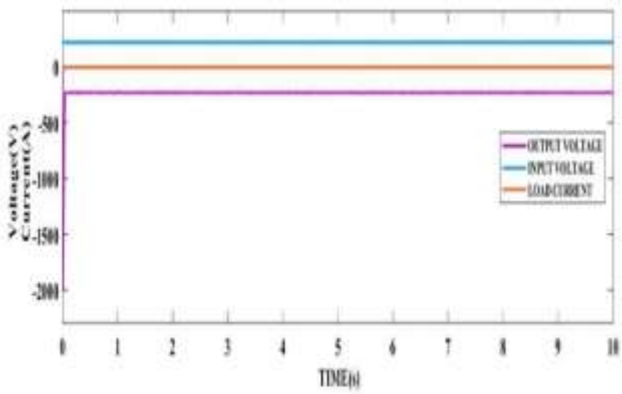


Fig 3: Buck -Boost converter with closed loop R L load

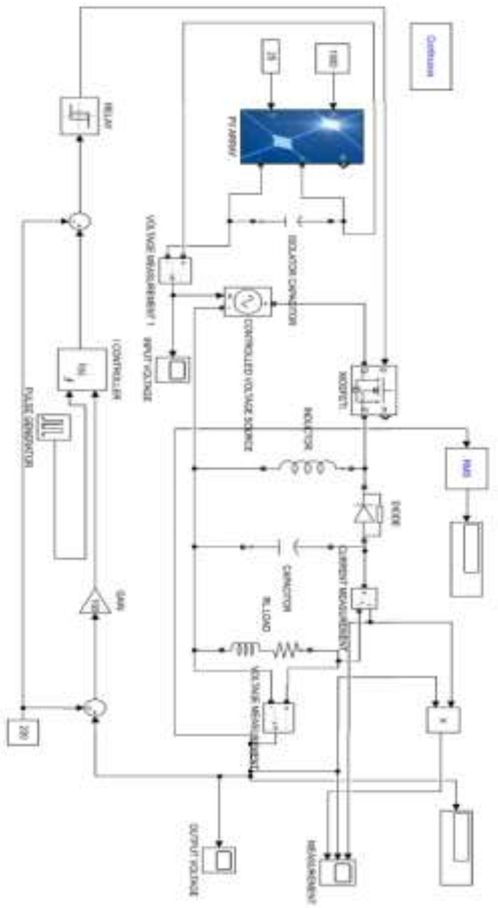
Results And Analysis

R-Load				RL Load			
Vin	Vout	Io	Po	Vin	Vout	Io	Po
220	-229	-2.29	526	220	-227	-2.2	515.29
230	-229	-2.3	526	230	-227	-2.2	515.29
240	-229	-2.3	526	240	-227	-2.2	519.83
250	-229	-2.29	526	250	-227	-2.3	522

7. BUCK BOOST CONVERTER WITH CLOSED LOOP WITH PV ARRAY

In a closed loop Buck Boost converter with PV array, instead of DC supply, we used PV system for considering different irradiations and input voltage is varied. It is observed that for change in the value of input voltage, desired output voltage is obtained

Simulation Circuit



Waveforms

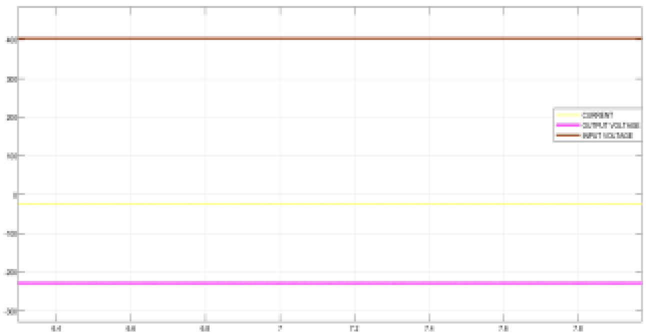


Fig4 : Buck-Boost converter with PV array for R Load

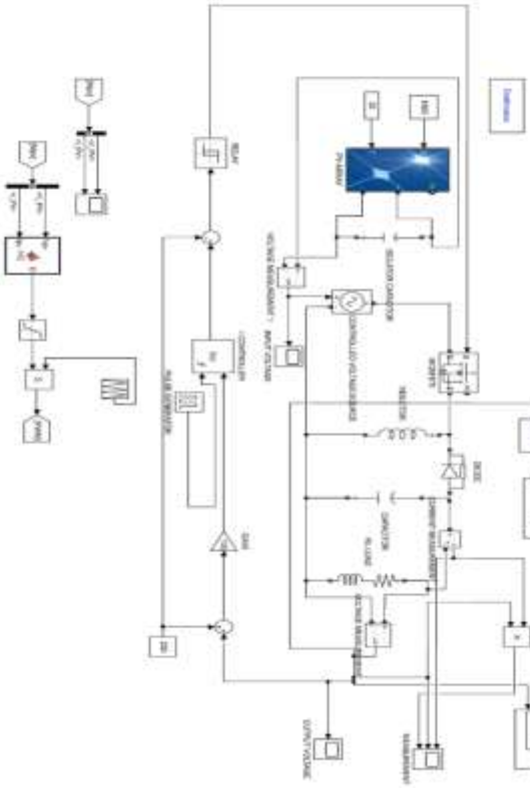
R-Load				RL Load			
Vin	Vout	Io	Po	Vin	Vout	Io	Po
403	220	22	$1.0*10^3$	403	-225	-25	$5*10^3$
408	220	22	$1.0*10^3$	408	-225	-24	$4.9*10^3$
412	220	23	$0.5*10^4$	412	-225	-24	$5*10^3$
415	220	24	$0.6*10^4$	414	-225	-23	$5.2*10^3$

8.BUCK BOOST CONVERTER CLOSED LOOP WITH INC MPPT

By applying INC MPPT technique to the closed loop Buck-Boost converter it is observed that maximum power is obtained with any change in the value of irradiations and also change in the input voltage

Simulation Circuit

Waveforms



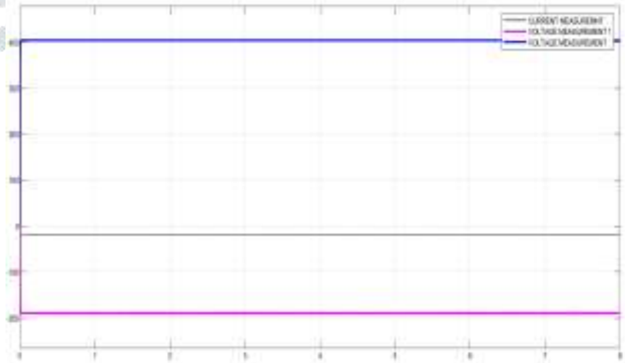


Fig 5 : Buck-Boost converter for INC MPPT with R-L load

R-Load					RL Load				
Irradiance	Vin	Vout	Io	Po	Irradiance	Vin	Vout	Io	Po
600	404	314	20	$4*10^3$	600	403	244	20	$4*10^3$
800	410	314	21	$4.3*10^3$	800	408	244	22	$4.5*10^3$
1000	412	315	20	$5*10^3$	1000	412	244	21	$5*10^3$
1200	415.3	316	23	$5.1*10^3$	1200	415	244	23	$5.2*10^3$
1400	419	315	20	$4.9*10^3$	1400	418	245	20	$5.2*10^3$

9. Results Analysis and Conclusion

In this research work, three cases of a closed-loop buck-boost converter were analyzed using different input conditions, including a i)DC supply ii) PV array iii) incremental conductance (INC) MPPT.

In Case 1, a varying DC input from 200 V to 220 V was applied to the converter. The system successfully maintained regulated output voltage and power across both resistive (R) and resistive-inductive (RL) loads.

In Case 2, the converter was fed by a PV array output with input voltage varying from 400 V to 415 V. Here too, a constant output voltage was achieved for both R and RL loads.

In Case 3, the PV array with INC MPPT was tested under varying irradiation levels. The converter consistently delivered a constant output for both R and RL loads, demonstrating its robustness under different environmental conditions.

These results confirm the effectiveness of the closed-loop buck-boost converter design in maintaining stable output performance across various input scenarios and load types

10. REFERENCES

1.Francisco M .Gonzalez-Langatt "Model of photovoltaic module in MATLAB"

2.Ariya Sangwongwanich , "Mitigation of Interharmonics in PV systems With Maximum Power Point Tracking Modification" , IEEE Trans. Power Electronics, Vol 34, NO.9, Sept.2019.

3.Mohammad Alqarni , Mohammad K Darwish " maximum PowerPoint tracking for photovoltaics system modified perturb and observe algorithm" 2012 47th International Universities Power Engineering Conference . Publisher : IEEE . Date of Conference : 4-7 Sept 2012.

4.Ahmed M Atallah ,Almoataz Y .Abdelaziz ,and Raihan S. Jumah, " Implementation Of Perturb And Observe MPPT Of PV system with direct control method using Buck and Buck-Boost converters" ,Emerging Trends in electrical , Electronics &Instrumentation Engineering . An international Journal (EEIEI) ,Vol.1 ,No 1, Feb.2014.

5.B.Pakkiraiah and G.Durga Sukumar, " Reasearch Survey on various MPPT Performance Issues to Improve the solar PV system efficiency " Journal of solar energy, Feb 2016.

6 . Tekeshwar Prasad Sahu , T.V.Dixit and Ramesh Kumar, " Simulation and Analysis of Perturb and Observe MPPT Algorithm PV Array Using CUK Converter".Vol 4 ,NO 2 ,pp,(2014)

7. Omar Diouri , Najia Es-Sbai, Fatima Errahimi , Ahmed Gaga , and Chakib Alaoui, " Modelling and Design of Single-Phase PV Inverter with MPPT Algorithm Applied to the Boost Converter Using Back -Stepping Control in Standalone Mode ", Hindawi, International Journal of Photoenergy, Vol 2019

8. Saeed H Hanzab , Samana Gori and Mehran Ektesabi, "A Scheme-Based Review of MPPT Techniques with Respect to Input Variables Including Solar Inradiance and PV Arrays Tempreature",Sept 2020.

9. Ajay Patel, Vikas Kumar , Yogendra Kumar , " Perturb and Observe Maximum Power Point Tracking for Photovoltaic Cell ",Innovative Systems Design and Engineering , Vol.4 ,NO.6, 2013.

10. Manel Hlaili and Hfaiedh Mechergui "Comparision of Different MPPT algorithm with a proposed One using a power Estimator fore grid Connected PV Systems " Hindwai Publishing Corporation ,International Journal of Photoenergy ,Vol 2016 , Received 4 April ; Accepted 17 May 2016.

11. Saeed H . Hanzer , Saman A.Gorji ,Mehran Ektesbi " A Scheme -based review of MPPT techniques with respect to input variables including solar irradiance and PV array Temperature" IEEE Access , Date of publication :October 5

12. Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo , Massimo Vitelli, "Optimization of Perturb and Observe Maximum Power Point Tracking Method", IEEE Trans. Power Electronics,Vol.20 ,NO.4,July.2005.