

Closed Loop Control of Solar Powered Boost Converter with PI Controller

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ABSTRACT: Today, the demand for energy has drastically increased as a result of which fossil fuels are consumed at a high rate. If the present state of affairs keeps, younger generations might be deprived of their use of energy. To prevent consumers from lagging of power and to fulfil their demands, solar energy system is a specific solution. Solar is available abundantly in massive amount and may be taken into consideration as dependable source of energy generation. This paper proposes the way to increase the efficiency of solar energy system by the developments in conventional boost converter. PI controller is employed to maintain a constant output voltage despite variable input voltage. Ziegler Nichol's method is used for determining the parameters of the PI Controller. PV Module and Boost Converter is modelled and simulated through MATLAB/Simulink.

KEYWORDS: Boost Converter, PV Module, PI Controller, Ziegler Nichol's Method

I. INTRODUCTION

Renewable energy source being available abundantly in nature can be considered as a better option over conventional energy sources. Solar is to be had in massive quantity and may be taken into consideration as reliable source of power era. Solar PV system is taken into consideration as a clean and eco-friendly energy system [1]. PV system is used in both standalone or grid connected configurations. PV generation system has low conversion efficiency of about 9 to 12% especially in low irradiation condition and approx. 20% at peak irradiation condition. Generated amount of electric power varies with weather condition in PV cells. Therefore, there is a need to improve the efficiency of the PV arrays [2].

Normally, the output of the PV arrays is a low level DC voltage. For higher power applications, there is a need to boost the dc voltage to the required level. The Boost converter is a dc to dc converter in which the output voltage is always greater than the input voltage. The output of the boost converter is controlled with the help of PI controller by varying the pulse width of the driving pulses of the MOSFET [3].

II. MODELLING OF PV MODULE

A solar cell converts sunlight directly into electricity using photovoltaic effect. The peak density of sun irradiations is of 1000 W/m² on this planet surface. Whenever a semiconductor material is exposed to the sun light, great range of free electrons are excited by absorbing the light photons [4]. PV module is formed by connecting the several number of solar cell in series or parallel. An ideal model of solar cell consist of a current source in parallel with a diode. Fig.1 shows the equivalent circuit of the Solar cell. Series resistance (Rs) and shunt resistance (Rsh) are the equivalent resistances of the PV cell [5].

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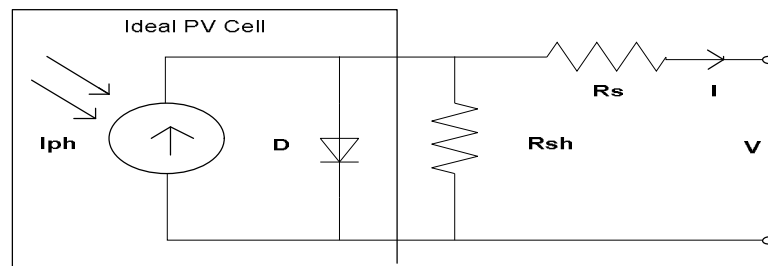


Fig1: Equivalent circuit of Solar PV cell

From the ideal equivalent circuit, the output current of the PV cell is:

$$I = I_{ph} - I_o \left[\exp\left(\frac{qV}{aKT}\right) - 1 \right]$$

Where I_{ph} is the photon generated current and its value is constant under constant temperature and constant irradiations, I_o is the diode reverse saturation current, q is the electron charge ($1.6 \times 10^{-19}C$), K is the Boltzmann constant ($1.38 \times 10^{-23}J/K$), T is the cell temperature in $^{\circ}C$ and a is an ideality factor (1.6). Practical PV module is a package of several series connected cells and their I-V characteristics equation is [6]:

$$I = I_{ph} - I_o \left[\exp\frac{q(V + IR_s)}{NsKT} - 1 \right] - \frac{V + IR_s}{R_{sh}}$$

Where,

$$I_o = \frac{(I_{sc, n} + K_i * \Delta T)}{\left[\exp\left\{ \frac{V_{oc, n} + K_v * \Delta T}{aV_t} \right\} - 1 \right]}$$

Specifications of the PV Module used in MATLAB/Simulink is given in TABLE I [1]:

TABLE I.

Each Solar cell	0.5 volts
No. of cell in Module	36
Total voltage required	18 volts
Short circuit current, I_{sc}	4.75 A
Power delivered	85.5 W
Operating temperature	25 $^{\circ}C$
Irradiation	1000 W/m 2

III. MODELLING OF BOOST CONVERTER

A. Conventional Boost Converter-

A DC-DC boost converter steps up the input voltage to a higher level voltage at the output whilst lowering the output current. Its circuit basically include an inductor, a capacitor, an electronic switch and a diode. The basic circuit of the conventional boost converter is shown in fig.2 [3].

Boost converter regulate the unregulated input voltage via controlling the switching of the switch. Both MOSFET and IGBT is used as a switch. MOSFET is used in low voltage applications also the IGBT is preferred in high voltage applications [8]. Boost converter operates in two modes.

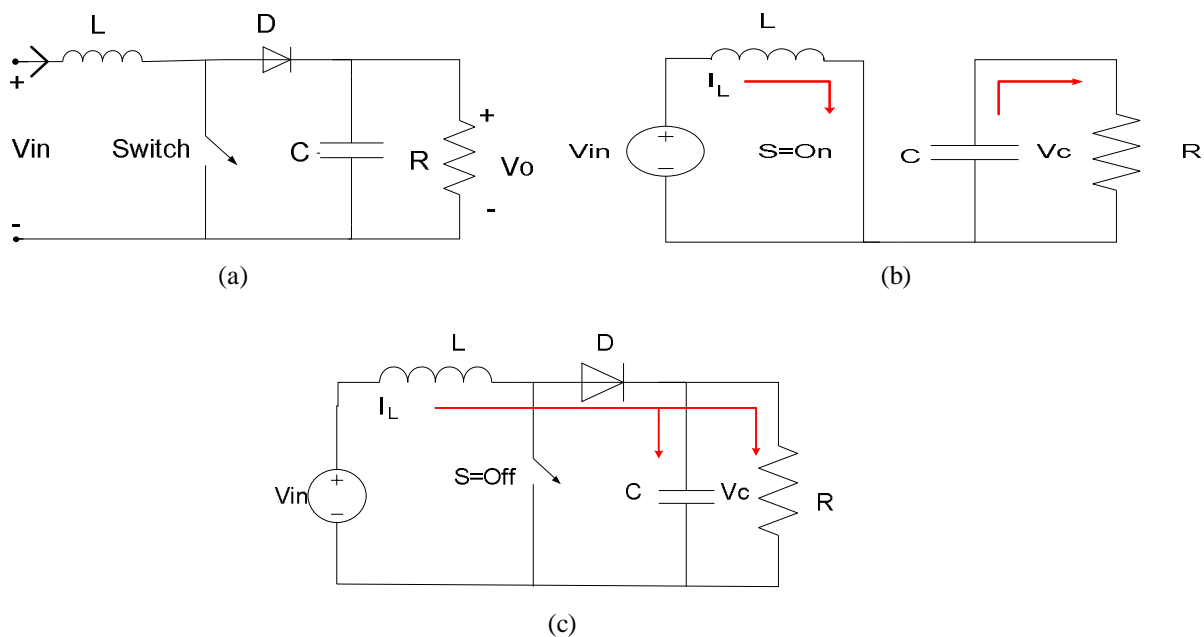


Fig2: Boost Converter (a) Block Diagram (b) Operating Mode I (c) Operating Mode II

Mode I: When the switch is on, Inductor current flows causing the inductor to store energy in it.

Mode II: When the switch is off, inductor current flows to the capacitor and load through diode D. Stored energy of inductor together with energy from the input source is transferred to the load.

Parameters of the boost converter can be calculated as follows [10]:

$$D = 1 - \frac{V_{in}}{V_o}, R = \frac{V_o^2}{P_{in}}, L = \frac{V_{in}(V_o - V_{in})}{\Delta I_o * f_s * V_o}, C \geq I_o * \frac{D}{f_s * \Delta V_o}$$

Where,

R = Load Resistance, L = Inductor, C = Capacitor, fs = Switching frequency, ΔIo = Input ripple current

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B. PI Controller-

Proportional – integral (PI) controller is broadly used and favored approach due to its simple design and easy control. Conventional boost converter gives 25% steady state error [9]. So I preferred PI controller as it eliminates the steady state error in closed loop system and also improve the efficiency of boost converter. Fig.4 shows the block diagram of PI controller [7].

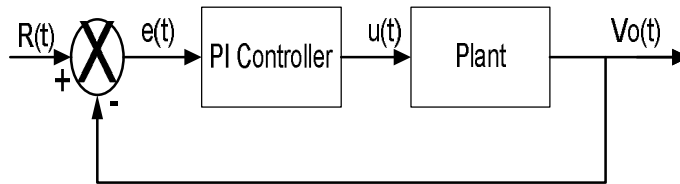


Fig3: PI Control Structure

For acquiring the steady and desired output voltage, feedback loop is used wherein output voltage is compared with reference voltage to generate a error signal. Generated error is then fed to the PI controller for generating a PWM controlled driving pulses for MOSFET [11]. Transfer function of PI is given by [8]:

$$C(s) = Kp + \frac{Ki}{s}$$

Where, Kp = proportional gain,

Ki = integral gain

The values of Kp and Ki are determined by the Ziegler-Nichols method. It is the pioneer method of tuning the PI controller. In this method, initially the integral gain (Ki) is set to zero and the proportional gain (Kp) increases until the system reaches to the stationary oscillations. After that proportional and integral gains are calculated on the basis of oscillation period. Ziegler Nichols method for PI controller is given in TABLE II [12].

TABLE II.

Controller	Kp (Proportional gain)	Ki (Integral gain)
PI (Proportional-Integral)	$0.45Kcr$	$Pcr/1.2$

Where Pcr is the period of oscillation and Kcr is the gain for that Pcr .

Impact of Controller gain on closed loop system is shown in TABLE III [8].

TABLE III.

Controller	Rise Time	Settling Time	Overshoot	Steady State Error
Proportional	Decrease	Small Change	Increase	Decrease
Integral	Decrease	Increase	Increase	Eliminates

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IV. SIMULATION AND THEIR RESULTS

Simulation of the model was done in MATLAB/Simulink Software program. For simulation 36 solar cells are connected in series and the total voltage acquired from PV Module is 17.6 Volt. Output voltage of the PV Module is directly fed to the boost converter. The parameters of boost converter considered for simulation are given in TABLE IV:

TABLE IV.

Input Voltage (dc)	17.6 volt
Output Voltage (dc)	50 volt
Boost Inductor (L)	401 μ H
Filter Capacitor (C)	106 μ F
Resistive Load (R)	30 Ω
Duty Cycle (D)	0.66

Commonly, the duty ratio of boost converter lies between 0.5 to 1. But the value of duty cycle is rely upon the supply voltage and its preferred output voltage. After making use of the Ziegler-Nichols method, the parameters are calculated as:

$$K_p = 1.3 \text{ and } K_i = 450$$

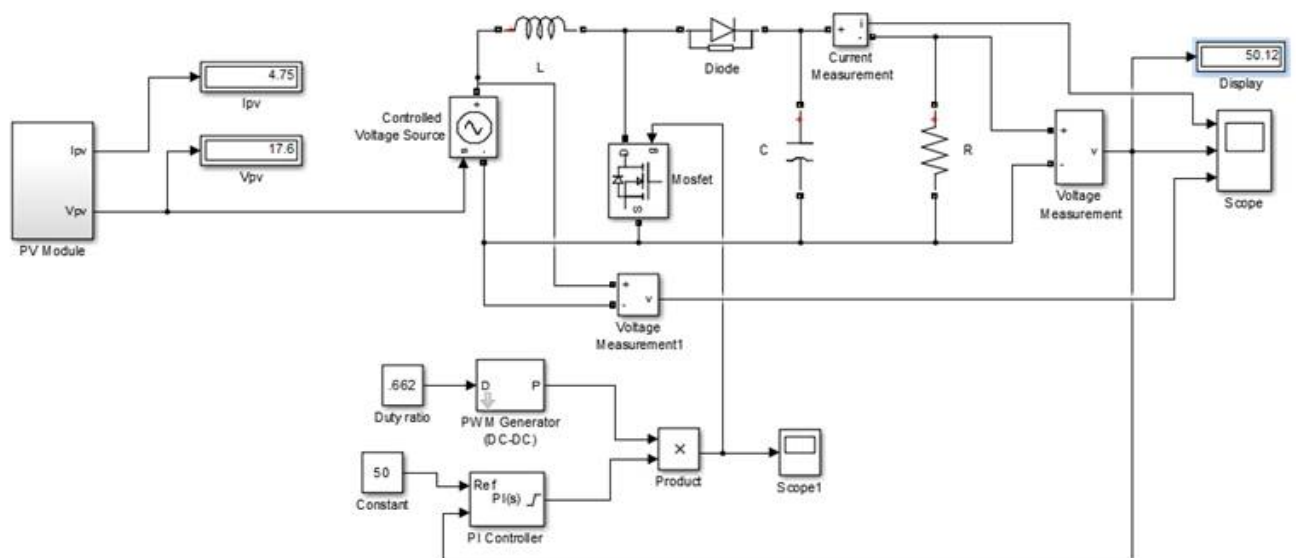


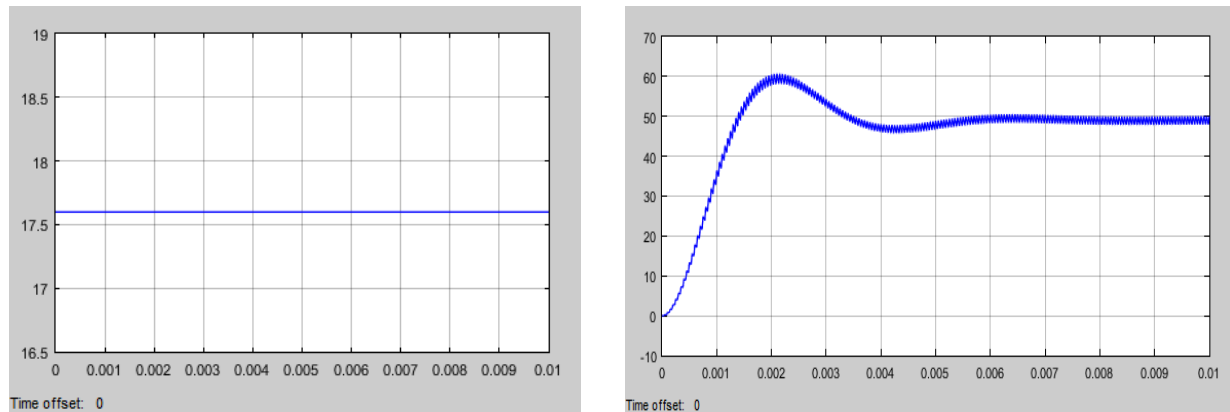
Fig4: Simulink model of PV fed Boost Converter

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(a)

(b)

Fig5: Output voltage of a (a) PV Module (b) PV fed Boost Converter

V. CONCLUSION

This paper represents the analysis of PV fed boost converter with closed loop control by means of PI controller. Often PV modules deliver very low output voltage relying on temperature and irradiance subsequently a boost converter is essential to increase the voltage and to keep the output voltage constant by means of the use of a controller. Via applying the Ziegler-Nichols approach of tuning the PI controller, for any change within the input voltage, the output stays steady.

Since the proposed boost converter with PI controller presents better voltage regulation, overshoot reduction, and improves the converter overall performance over conventional boost converter subsequently the design of the controller is most advantageous.

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