

DESIGN AND SIMULATION OF DC-DC BOOST CONVERTER FOR GRID CONNECTED PHOTOVOLTAIC APPLICATION SYSTEM

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Abstract: The main purpose of this paper is to introduce an approach to design a DC-DC boost converter with constant output voltage for grid connected photovoltaic application system. The boost converter is designed to step up a fluctuating solar panel voltage to a higher constant DC voltage. It uses voltage feedback to keep the output voltage constant. To do so, a microcontroller is used as the heart of the control system which it tracks and provides pulse-width-modulation signal to control power electronic device in boost converter. The boost converter will be able to direct couple with grid-tied inverter for grid connected photovoltaic system. Simulations were performed to describe the proposed design.

I. INTRODUCTION

Nowadays, power generation using solar power had increased dramatically because it is pollution free as compare to power generation using fossil fuel. Besides, it needs low maintenance and no noise and wear due to the absence of moving parts which make solar power attractive to the people. Solar power uses solar panel to convert sun irradiation into electric energy using photovoltaic (PV) effect. The output voltage of a solar panel is varying depending on sun irradiation and temperature [1]. As the sun irradiation and temperature changes, output voltage changing as well. Since the voltage produced is fluctuating, a lot of electronic equipments are unable to be directly connected. Therefore, a DC-DC boost converter with constant output voltage is needed. The boost converter will step up the solar panel voltage to the suitable voltage required by electronic equipments. For AC electrical equipments, the system requires an additional AC-DC inverter which converts the constant DC voltage to AC voltage. This system is called dual power processing stage system. Figure 1 shows a grid connected PV application system using dual power processing system. From the block diagram, the system does not use any batteries to store energy produced by solar panel. Any power produced by solar panel is directly deliver to the grid. Batteries are excluded from the system because battery banks need high maintenance which had to be handled

carefully in order to have a long lifetime and safe environment. Besides, batteries are the second major cost contributor for the system [2]. Therefore, the exclusion of batteries as the energy storage is economically advantageous [3].

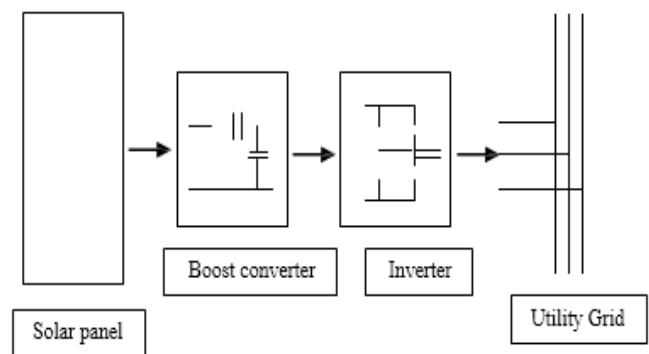


Fig. 1: Block diagram of grid connected pv application system

II. BASIC OPERATION

The boost converter is a medium of power transmission to perform energy absorption and injection from solar panel to grid-tied inverter. The process of energy absorption and injection in boost converter is performed by a combination of four components which are inductor, electronic switch, and diode and output capacitor. The connection of a boost converter is shown in Figure 2 [4]. The process of energy absorption and injection will constitute a switching cycle [5]. In other word, the average output voltage is controlled by the switching on and off time duration. At constant switching frequency, adjusting the on and off duration of the switch is called pulse-width-modulation (PWM) switching. The switching duty cycle, k is defined as the ratio of the on duration to the switching time period. The energy absorption and injection with the relative length of switching period will operate the converter in two different modes known as continuous conduction mode (CCM) and discontinuous conduction mode (DCM) [4][6].

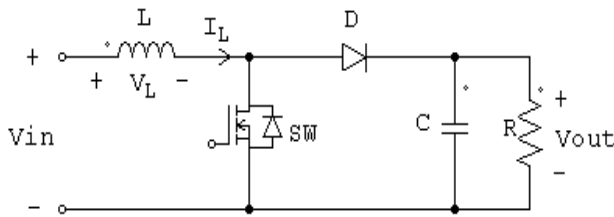


Fig. 2. Schematic of boost converter

III. BOOST CONVERTER ANALYSIS

A. Continuous Conduction Mode

Under CCM, it is divided into two modes. Mode 1 begins when the switch SW is turned on at $t = 0$ as shown in Figure 3. The input current which rises flows through inductor L and switch SW. During this mode, energy is stored in the inductor and load is supplied by capacitor current. Mode 2 begins when the switch is turned off at $t = kT$. The current that was flowing through the switch would now flow through inductor L, diode D, output capacitor C, and load R as shown in Figure 4. The inductor current falls until the switch is turned on again in the next cycle. During this time, energy stored in the inductor is transferred to the load together with the input voltage. Therefore, the output voltage is greater than the input voltage and is expressed as

$$V_{out} = 1/(1-d) V_{in}$$

Where, V_{out} =output voltage, V_{in} =input voltage, d = duty cycle.

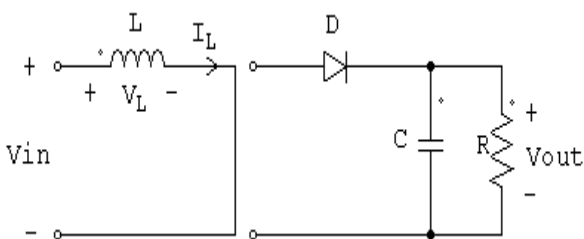


Fig. 3: Circuit diagram of boost converter during mode 1

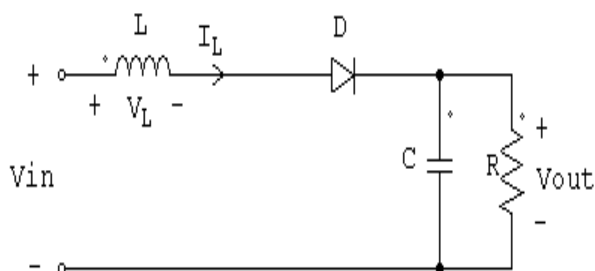


Fig. 4: Circuit diagram of boost converter during mode 2

In order to operate the converter in CCM, the inductance is calculated such that the inductor current I_L flows continuously and never falls to zero as shown in Figure 5. Thus, L is given by

$$L = \frac{V_{in} * (V_{out} - V_{in})}{\Delta I_L * f_{sw} * V_{out}}$$

Where V_{in} =input voltage, V_{out} =output voltage.

Where $\Delta I_L = 0.2$ to $0.4 * i_{out} * V_{out} / V_{in}$

Now calculation of capacitance is given by following equations:

$$C = T_{on} * i_{out} / \Delta V_o$$

Where

ΔV_o =output voltage ripple assume 20% of output voltage

i_{out} =output current

B. Discontinuous Conduction Mode

Under DCM, inductor current I_L does not flow continuously. There is an interval of time which the current is zero before the next turn on of switch SW. Taking integral of inductor voltage over one time period to zero. As the value of L_{min} calculated previously is the minimum inductance to operate in CCM, therefore any values of L_{min} below than the minimum inductance will result in the boost converter to operate in DCM. The calculation for peak-to-peak ripple in the output voltage for DCM is the same as (3).

IV. PROPOSED SYSTEM

In this paper, a boost converter operated in CCM is designed to step up a fluctuating solar panel. Output is given to dc-dc boost converter. The input voltage is fixed 36 volt and boost converter give output of 360 volt. After selection of l and c closed loop control of boost converter is done. As we if change in input voltage then duty cycle is affected and hence we must have to done close loop of converter for constant output.

In order to produce a constant output voltage, voltage feedback control system is used. In this control system, output voltage will be measured and compared with a reference voltage and the differential value is used to control flow chart produce a PWM signal. Any changes in the output voltage will lead to the changes of duty cycle in PWM signal. To produce a set of PWM signal, a microcontroller is used. PIC16F877 microcontroller is selected as it is having a successive approximation analog-to-digital converter, comparator and PWM generator. PWM signal with frequency 30 kHz can be generated when PIC16F877 is driven by a 20 MHz clock cycle. Control strategy for voltage feedback control flow chart as shown in Figure 5 is written

and load into PIC16F877 microcontroller.

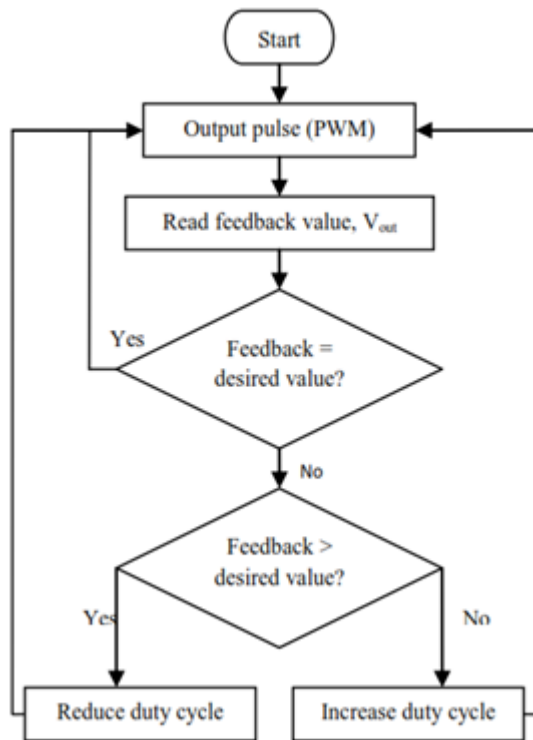


Fig. 5: Control flow chart

A. Selection of electronic switch

The electronic switch SW in Figure 2 has been chosen based on its voltage and current rating which have to be higher than the maximum input voltage and current. From the proposed system, the rating of the converter is 1050 W with an input voltage ranging from 30 V to 36 V. Therefore, electronic switch such as power MOSFET, IGBT, BJT and thyristor handling capability should meet the specification of the proposed design.

B. Selection of inductor

Equation (2) is the minimum inductance for boost converter to operate in CCM, therefore the selection of the inductor should be higher than the calculated value. Inductors with a ferrite core or equivalent are recommended.

C. Selection of diode

Diode reverse voltage rating is the main consideration for selecting the diode. Other important consideration is its ability to block the required off-state voltage stress and have sufficient peak and average current handling capability, fast switching characteristics, low reverse-

recovery, and low forward voltage drop.

D. Selection of capacitor

Equation (3) is the calculation for output voltage ripple using capacitance. The selection of capacitor should be higher than the calculated value to make sure that the converter's output voltage ripple stays within the specific range. Another important consideration is its equivalent series resistance (ESR). Since the capacitor's ESR affects efficiency, low-ESR capacitors will be used for best performance. ESR can be reduced by connecting few capacitors in parallel.

E. Boost Converter Parameters

Input voltage=36
Output voltage=360
Switching frequency=30 kHz
Inductor=0.0009H
Capacitor=0.0025f

V. SIMULATION AND EXPERIMENTAL RESULTS

A. Simulation results

Based on the proposed design, computer software PSIM is used to simulate the designed boost converter's performance. The simulation results of the boost converter with different input voltages and duty cycles are shown in Figure 6 and Figure 7

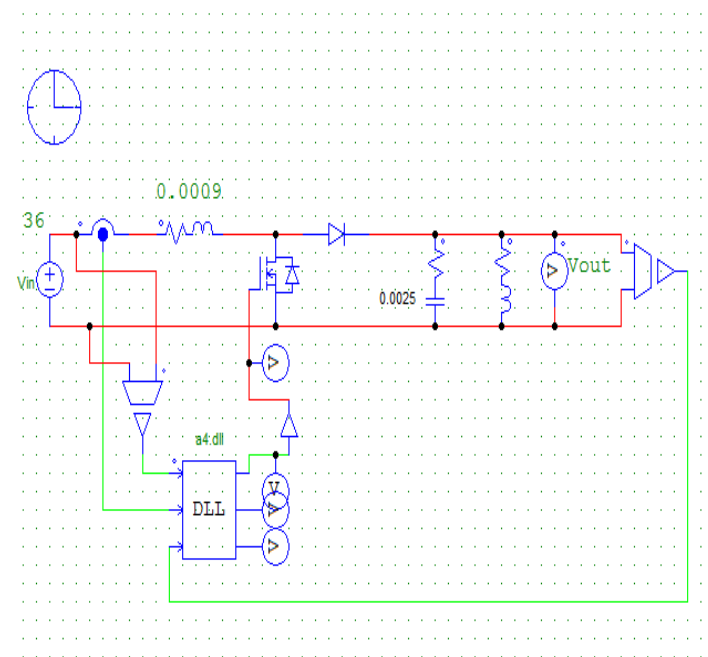


Fig. 6: Closed loop control of boost converter

VI. EXPERIMENTAL RESULTS

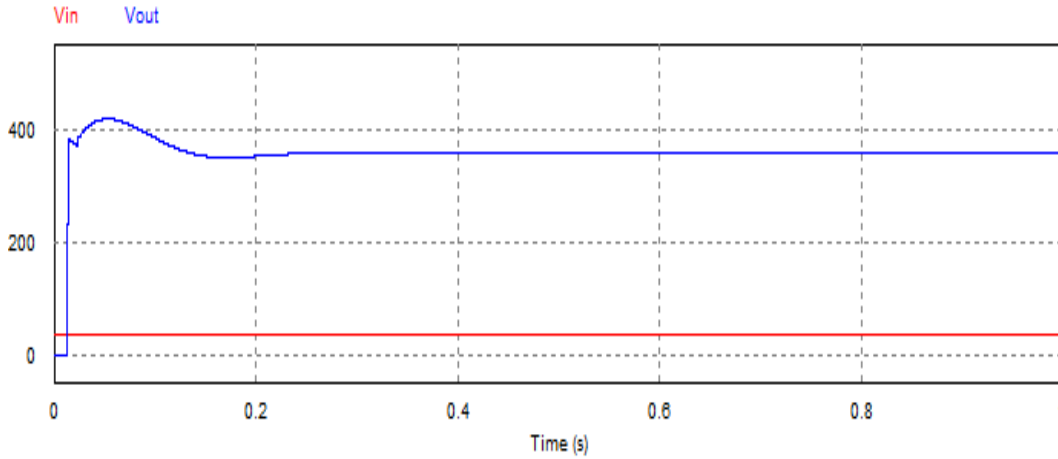


Fig. 7: Input voltage is 36 then output is 360

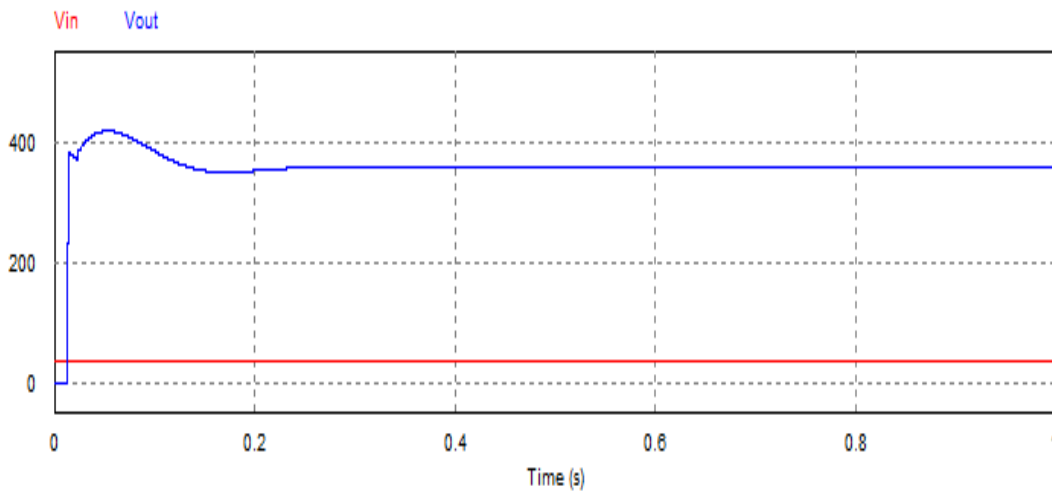


Fig. 8: Input voltage is 30 then output voltage is 360

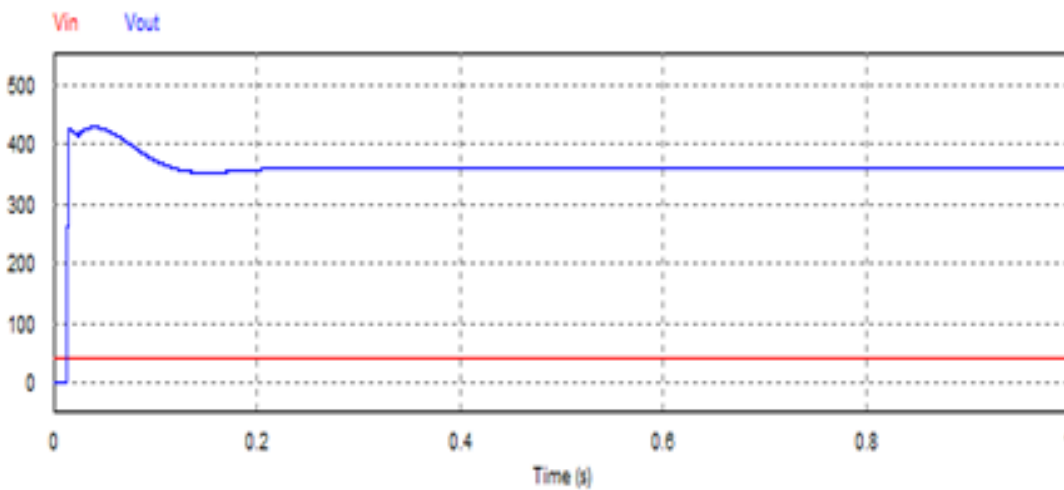


Fig. 9: Input voltage is 40 then output voltage is 360

VII. CONCLUSION

From, the proposed design the boost converter is able to boost output voltage to 360 voltage. The control of switching of switch is done by programming. The boost converter is able to deliver power with the highest efficiency of 95%. Components had been chosen based on the consideration made. PIC16F877 microcontroller is able to perform the voltage feedback control technique.

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