

Performance Analysis Of Average Model Of Boost Converter Fed From Photo Voltaic Array Using Graphical Tool

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ABSTRACT

In This Work, DC-To-DC Boost Converter Topology Is Proposed And Validated. The Proposed Topology Is Incorporated The Solar PV Array. This Paper Proposed A State Space Average Model Of Boost Converter Which Is Fed From Solar PV Array Also Circuit Model Of Boost Converter. This Paper Presents The Proposed Topology And A Detailed Analysis Of The Topology Using State Space Averaged Model And The Circuit Model In The Labview Simulation Environment. The Circuit Model Is Compared With State Space Model With Minimum Amount Of Voltage Tolerance. The Computation Time With Simulation Is Very Much Faster Than The Circuitry Model Time Of The State. An Experimental Verification Model Has Also Been Constructed To Validate The Proposed Idea And The Observations Are Presented Herein. All Studies Have Been Carried Out In The Open Loop Configuration.

Key Words: DC To DC Converters, Voltage Gain DC To DC Converters, Modeling Of DC To DC Converters, State Space Averaging.

INTRODUCTION

DC To DC Converters Are Indispensable Power Electronic Converters Which Have Numerous Applications [1]. There Are Many Configurations Of DC To DC Converters Available, Typically, The Generic Buck, Boost And The Buck Boost Converters. It Is Necessary For Certain Applications, That The Available DC Voltage Is Boosted Out With A Large Voltage Gain And That The Converter System Is Stable As Well [2] [3]. DC Buck Converters Are Widely Used In Power Supply, DC Motor Drives Etc. There

Are Many Approaches Including Stage Space, Circuitry Approach [4]. There Are Numerous [5-8] Research Focuses On Circuit Modelling And Simulation Of Boost Converter Where As Less Focus On Average Stat Space Modelling With Solar Photo Voltaic Supply. The Behaviour Of Any Electric Circuit Which Is Mainly Deals Current Through The Elements And Voltage Across The Element Can Be Modelled Using Mathematical Equations [8-12]. By Making This Simplified Mathematical Equation The Researchers Can Easily Implement Them In Any Of Simulation Software Packages. This Work Focus On Modelling And Simulation Of Solar PV Fed Boost Converter Both Circuit And State Space Model And Its Performance And Stability Is Analysed MATLAB-SIMULINK..

SOLAR PV ARRAY

The KC200GT Is Used For Simulation Purpose [12-13]. A Single Diode Model Is Used As Shown In Fig.1. Is To Model The PV Array Whose Parameters Under Standard Test Conditions Are Tabulated[8] The Process By Which The I-V And P-V Curves Are Shown N Fig. 2 And The I-V And P-V Characteristics Are Shown In Fig.3.

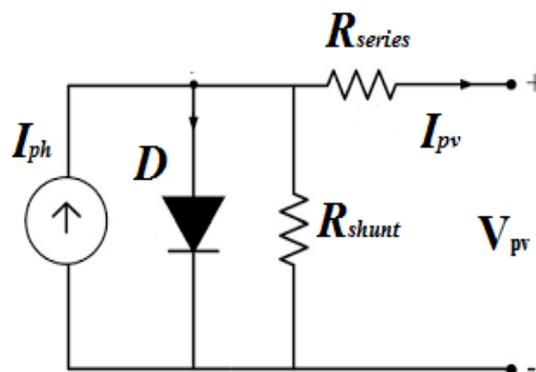


Figure. 1. Single Diode Model Of PV Array

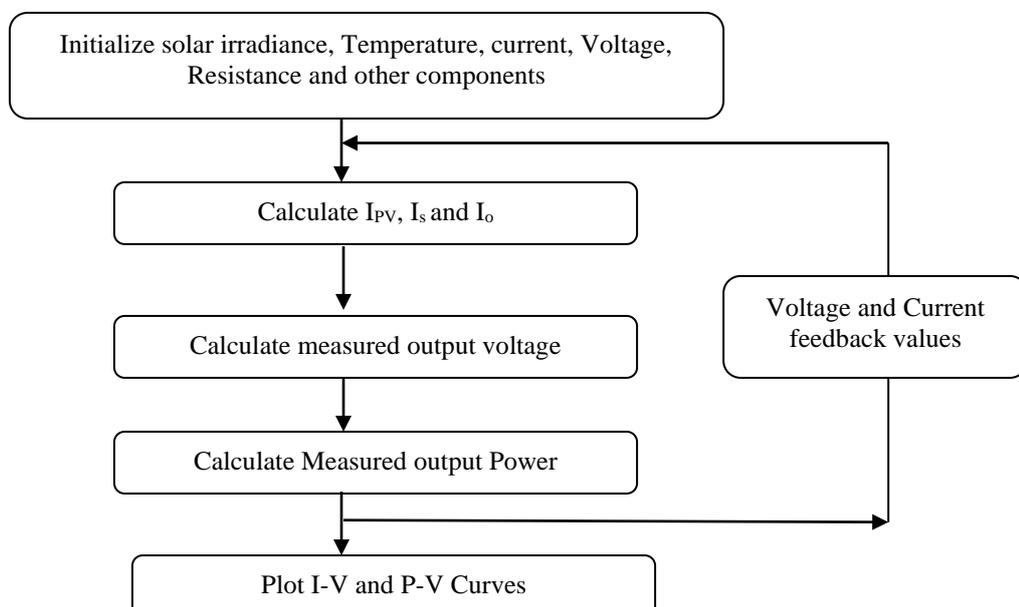


Figure 2. Process To Calculate The PV Charecteristics

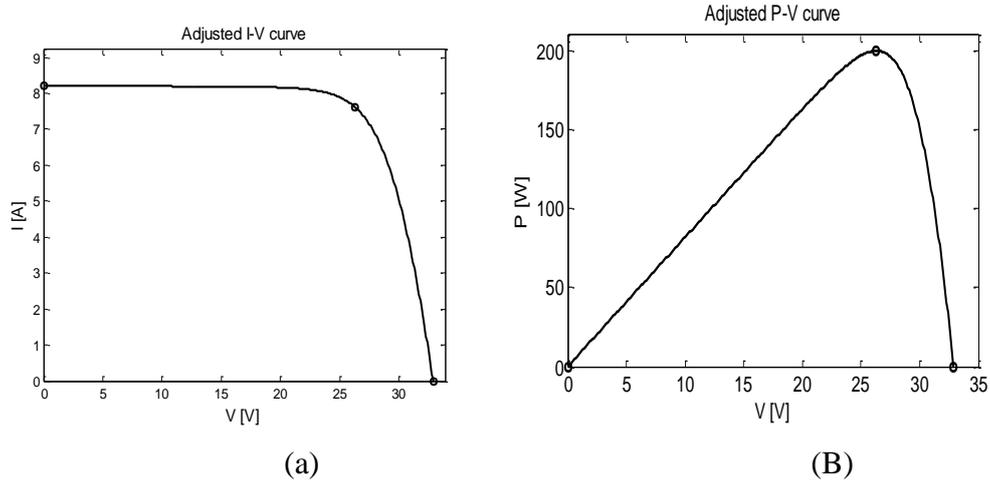


Figure.3. I-V (A) And P-V (B) Characteristics Of PV Array

MODELING APPROACH

The Basic Topology Of Any DC Converter Consists Of Combination Of Linear Elements Like Resistor, Capacitors And Inductors And Non Linear Elements Like Diode And MOSFET Or IGBT Are Oriented In Different Positions To Form Different Converters. One Of Such Converter Is Boost Converter. This Section Deals With The State Space Modeling Of The DC Boost Converter Is Modeled Using Average State Space Approach [11].

To Start With The State Space Model, The State Matrices A, B, C And D Are Related With The Equation,

$$\dot{x} = Ax + Bu \quad (1)$$

$$y = Cx = Du \quad (2)$$

Here x -State Variables, U Is The Input And Y Is The Output Of The Converter. In Modeling Of The Converter, In State Space The State Variables Are Chosen From The Energy Storage Elements In The Circuit Ie. Capacitor And Inductor.

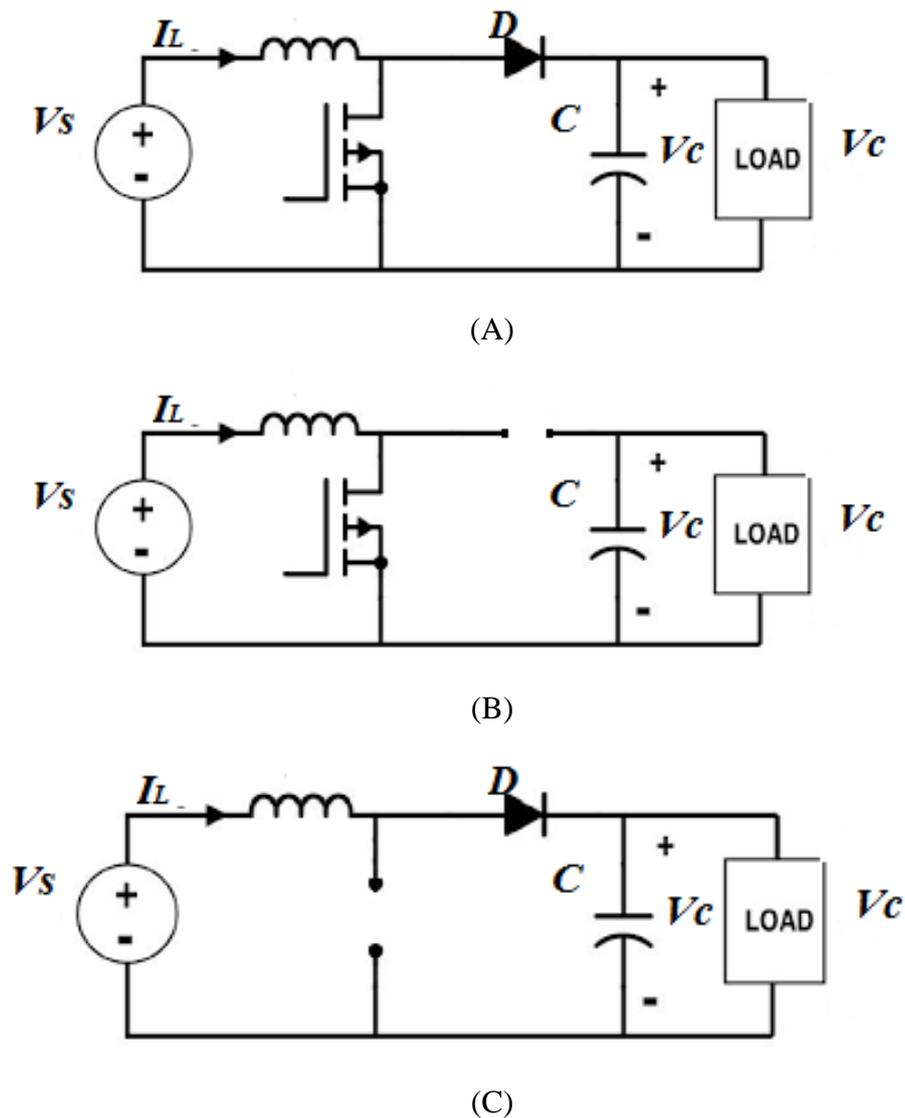


Figure.4. (A) Generic Diagram Of Boost Converter (B) ON Stage (C) OFF Stage

The Generic Boost Converter Circuit With ON And OFF Is Shown In **Fig.4.**

During ON Stage:

The Equivalent Circuit For ON Stage Is Shown In Fig. 4(B)

Capacitor Voltage V_c And Inductor Current I_L Is Chosen As State Variables, During **ON** State, There Is No Current Through The Capacitor And Resistor, The Voltage And Current Balancing Equations Are,

$$V_{pv} = L \frac{di_L}{dt} \quad (3)$$

$$0 = C \frac{dv_c}{dt} + \frac{v_c}{R} \quad (4)$$

By Replacing The Variables i_L And v_c As x_1 And x_2 And Its Derivatives Are \dot{x}_1 And \dot{x}_2 And Therefore (3) And (4) Can Be Written As

$$\dot{x}_1 = \frac{1}{L} V_{PV} \quad (5)$$

$$\dot{x}_2 = -\frac{1}{RC} x_2 \quad (6)$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} V_{Pv} \quad (7)$$

During OFF Stage:

The Equivalent Circuit For OFF Stage Is Shown In Fig. 4(B)

The Voltage And Current Balancing Equations Are,

$$v_c = -L \frac{di_L}{dt} \quad (8)$$

$$i_L = C \frac{dv_c}{dt} + \frac{v_c}{R} \quad (9)$$

By Replacing The Variables i_L And v_c As x_1 And x_2 And Its Derivatives Are \dot{x}_1 And \dot{x}_2 And Therefore (8) And (9) Can Be Written As

$$\dot{x}_1 = \frac{1}{L} x_2 \quad (10)$$

$$\dot{x}_2 = \frac{1}{C} x_1 - \frac{1}{RC} x_2 \quad (11)$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & \frac{-1}{L} \\ \frac{1}{C} & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} V_{Pv} \quad (12)$$

Now The State Matrices Can Be Calculated By Taking The Average Of ON And OFF State With Respect To The Duty Ratio K .

$$\bar{A} = A_{ON}k + A_{OFF}(1 - k)$$

$$\bar{A} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{RC} \end{bmatrix} k + \begin{bmatrix} 0 & \frac{-1}{L} \\ \frac{1}{C} & \frac{-1}{RC} \end{bmatrix} (1 - k)$$

$$\bar{A} = \begin{bmatrix} 0 & \frac{-(1-d)}{L} \\ \frac{1-d}{C} & \frac{-1}{RC} \end{bmatrix} \quad (13)$$

Similarly $\bar{B} = B_{ON}k + B_{OFF}(1 - k)$

$$\bar{B} = \begin{bmatrix} 1 \\ L \end{bmatrix} k + \begin{bmatrix} 1 \\ L \end{bmatrix} (1 - k)$$

$$\bar{B} = \begin{bmatrix} 1 \\ L \\ 0 \end{bmatrix} \quad (14)$$

Therefore,

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & \frac{-(1-d)}{L} \\ \frac{1-d}{C} & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ L \\ 0 \end{bmatrix} V_{Pv}$$

Finally To Obtain The Output Equation,

$$\begin{aligned} y_1 &= i_L \\ y_2 &= v_c \end{aligned} \quad (15)$$

RESULTS AND DISCUSSION

The Proposed Labview Model Of Solar PV Characteristics Is Shown In Figure 4 Which Contains Three Sub VI Such As I_s , I_d And I_{ph} . Single Diode Model Of Diode Current Is Developed Using Labview And Shown In Figure 5. The Photo Voltaic Current I_{pv} And Output Current I_o Are Generated Using The Figure 6 &7 Respectively. It Consists Of The Following Sub Components As Solar PV Array Whose Output Is Given Into Circuit Model And State Space Model Of The Converter. To Demonstrate The State Space Model Of The Buck Converter Circuit The Following Parameters Are Chosen $R=3$ Ohms, $L=2$ mh And $C= 220\mu$ f. Using The Figures 5, 6 And 7 The Photo Voltaic Characteristics Are Shown In Figure 8

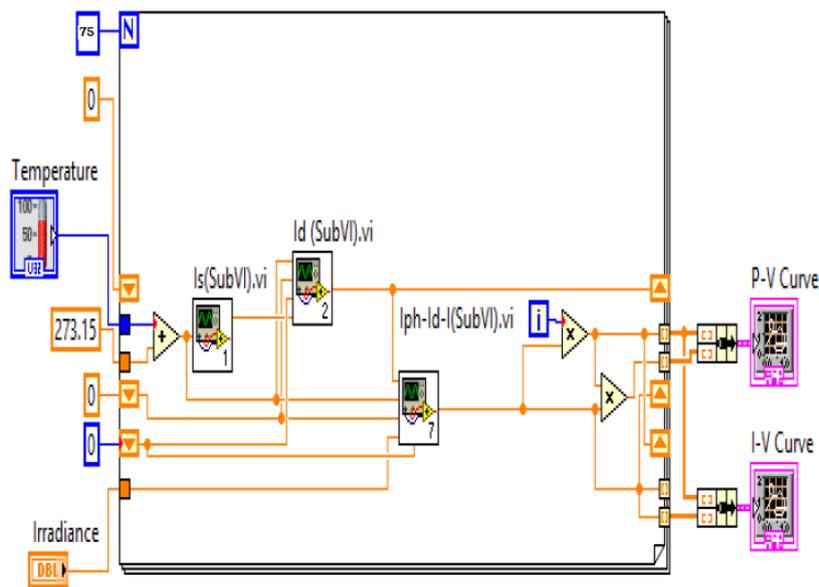


Figure.4 Labview Model Of The Proposed System

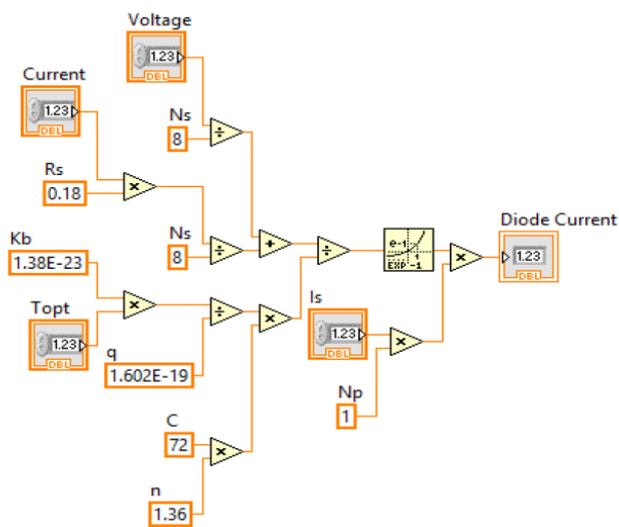


Figure.5. Single Diode Model Of PV Array

The Simulated Parameters Of Solar PV Array

- $R_{p_Min} = 42.966053\Omega$
- $R_p = 601.336801\Omega$
- $R_{s_Max} = 0.867280\Omega$
- $R_s = 0.230000\Omega$
- $P_{max,M} = 200.143000\text{ W (Model)}$
- $P_{max,E} = 200.143000\text{ W (Experimental)}$
- $I_{pv} = 8.214580\text{ A}$
- $I_{sc} = 8.210000\text{ A}$

Performance Analysis Of Average Model Of Boost Converter Fed From Photo Voltaic Array Using Graphical Tool

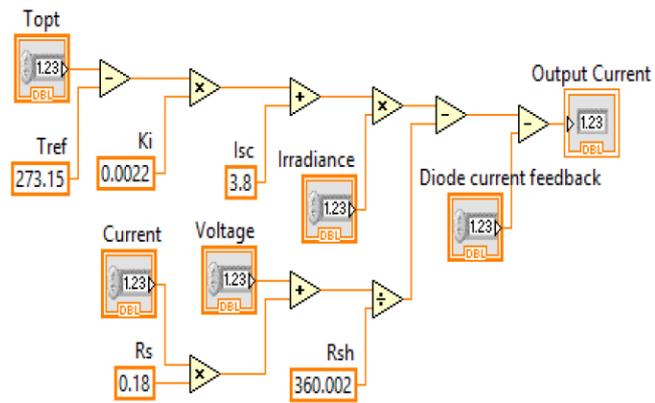


Figure.6. Calculation Of I_{pv}

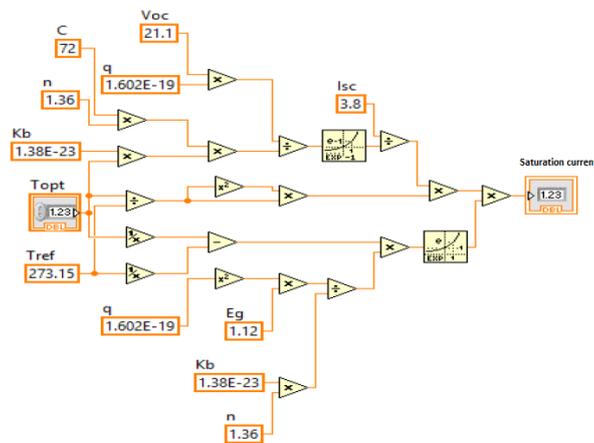


Figure.7. Calculation Of I_o

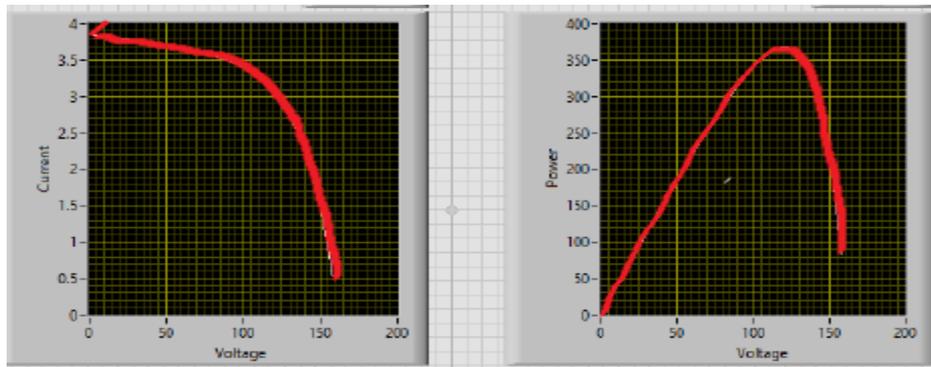


Figure.8 PV Characteristics Curves

The Variation In Solar PV Irradiance Is Achieved By Signal Builder In Labview Environment In Which The Irradiance Is Varied 700 W/M2 To 800 W/M2 At T=.02 Sec. And It Is Reduced To 700 W/M2 At T= 0.1 Sec As Shown In Figure.9. The Output Voltage Waveform Is Observed In This Interval For Both Circuit And Stat Space Model

And Shown In Figure 10. A Small Disturbance Is Noted In The Interval From 0.02 To 0.1 Sec Where Irradiance Is Made Change.

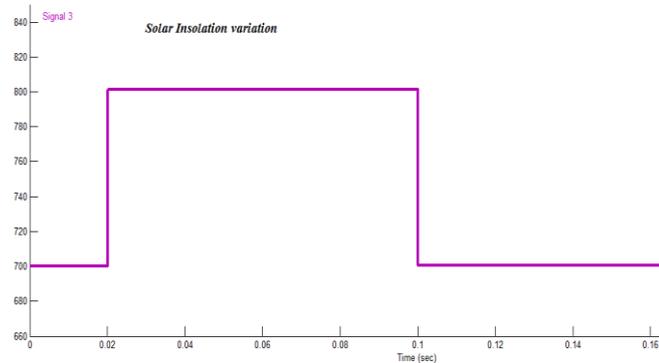


Figure.9. Variation In Solar PV Array Fron 0.02 To 1 Sec.

It Is Observed In Figure 10, There Is A Variation In Voltage Profile In Time Where The Irradiance Is Subjected To Change That Is 0.02 Sec To 0.1sec And Also Variation In The Inductor Current Also Depicted In Figure 11.

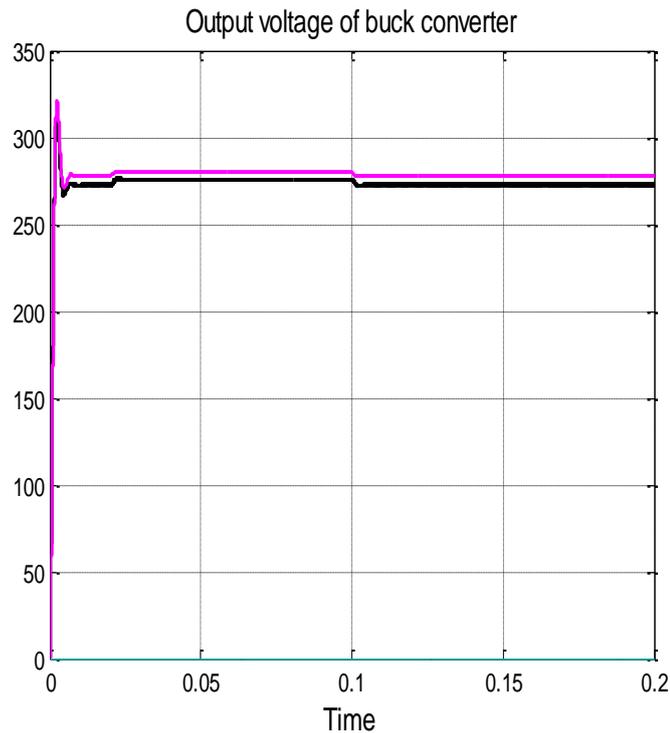


Figure 10. Buck Converter Output Voltage- For T=0.2 Secs

The Ripples Of Capacitor Voltage And Inductor Current Are Shown If Figure 12.

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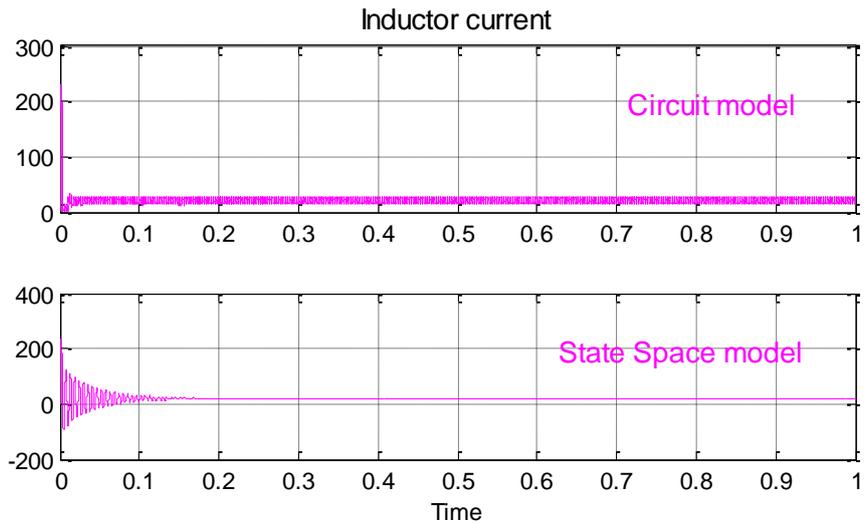


Figure.11 Inductor Current

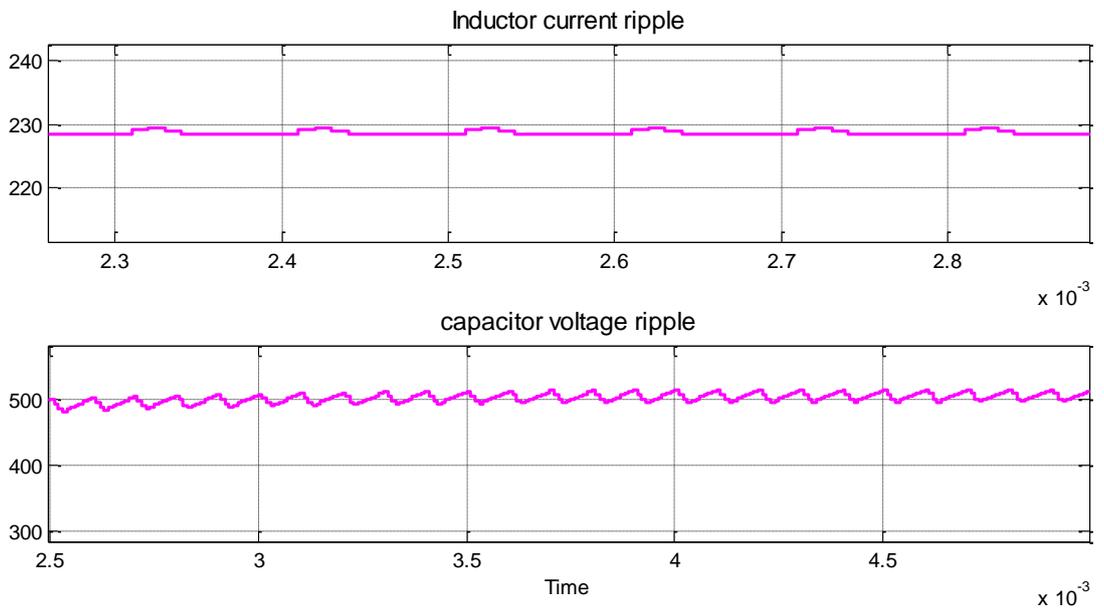


Figure.12 Ripples In Inductor Current And Capacitor Voltages

The Transfer Function Of This Buck Is Converter Is Derived As,

$$\frac{V_0(s)}{D(s)} = \frac{V_{pv}}{(1-D)^2} \left[\frac{1 - s \left(\frac{L}{R(1-D)^2} \right)}{\left(\frac{LC}{(1-D)^2} \right) s^2 + s \left(\frac{L}{R(1-D)^2} \right) + 1} \right]$$

Substituting The Values Of V_{pv} , L, C And R

$$\frac{V_0(s)}{D(s)} = \frac{-1.08s + 1128}{7.82e^{-7}s^2 + 0.001185s + 1}$$

(17)

For This Transfer Function Labview VI Is Developed To Calculate The Time And Frequency Domain Analysis And It Is Shown In Figure 13. The Transfer Function And Corresponding State Space Matrices Are Shown In Figure 14.

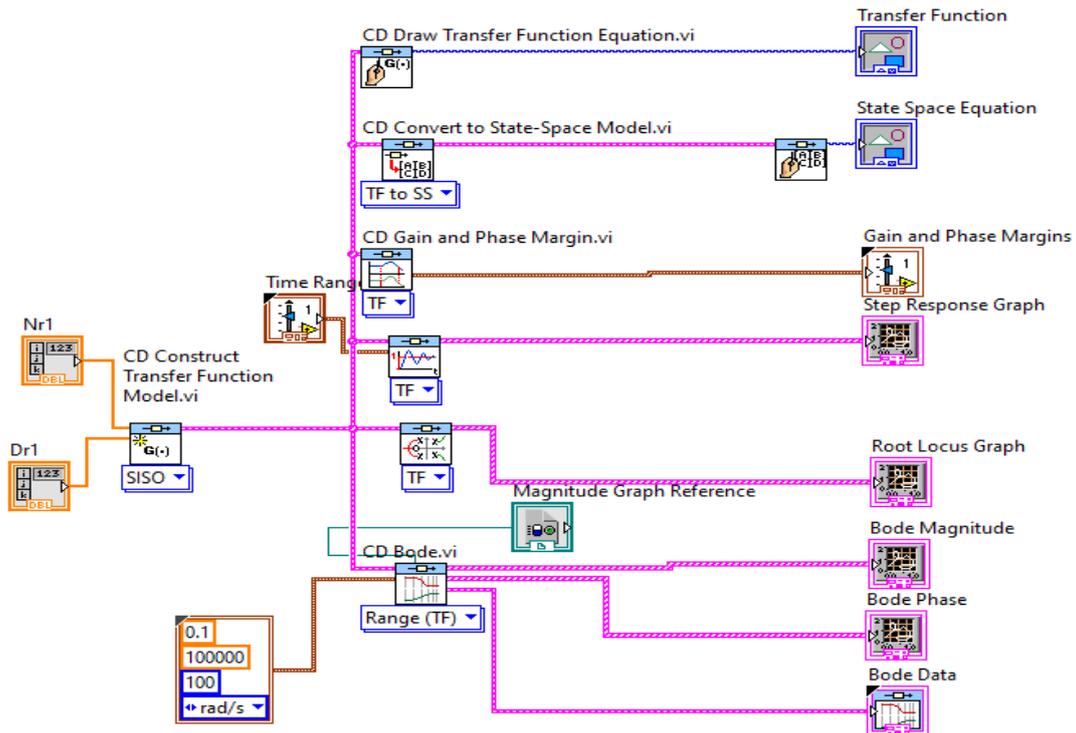


Figure.13 VI Model To Plot The Time And Frequency Domain Specification

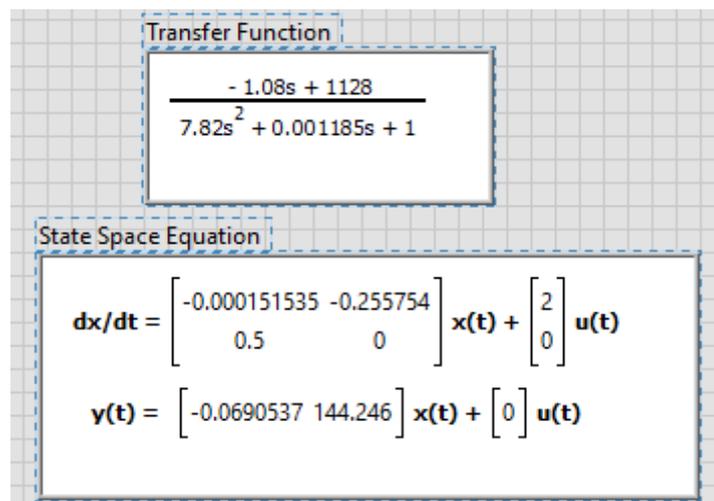


Figure.14 State Space Equation Developed From The Labview

The State Space Equation For The Transfer Function (16) Is Shown In Figure 14. The Step Response Of The Above Transfer Function Is Shown In Figure.15. The Time Domain Specification Are As Follows Peak Time =2.36msec. Setting Time 6 Msec. And Peak Over Shoot Is 31%.

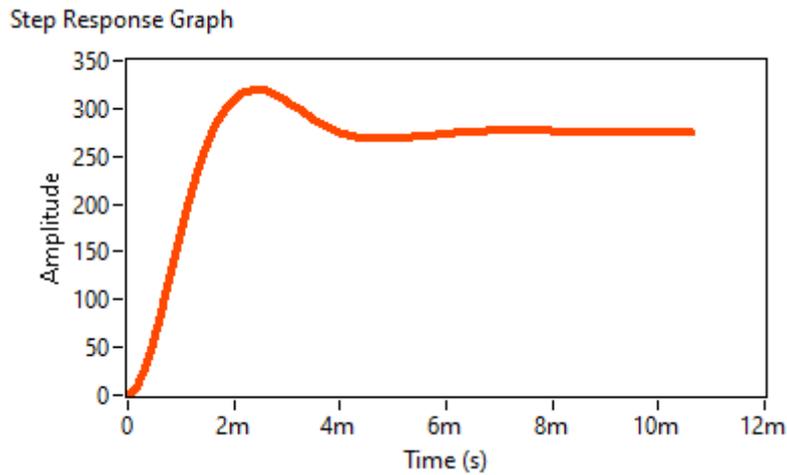


Figure 15. Step Response Of Buck Converter

The Frequency Response Curve Is Drawn For The Transfer Function Phase Margin I On Served As 10° As Shown In Figure 16 And System Is Stable System.

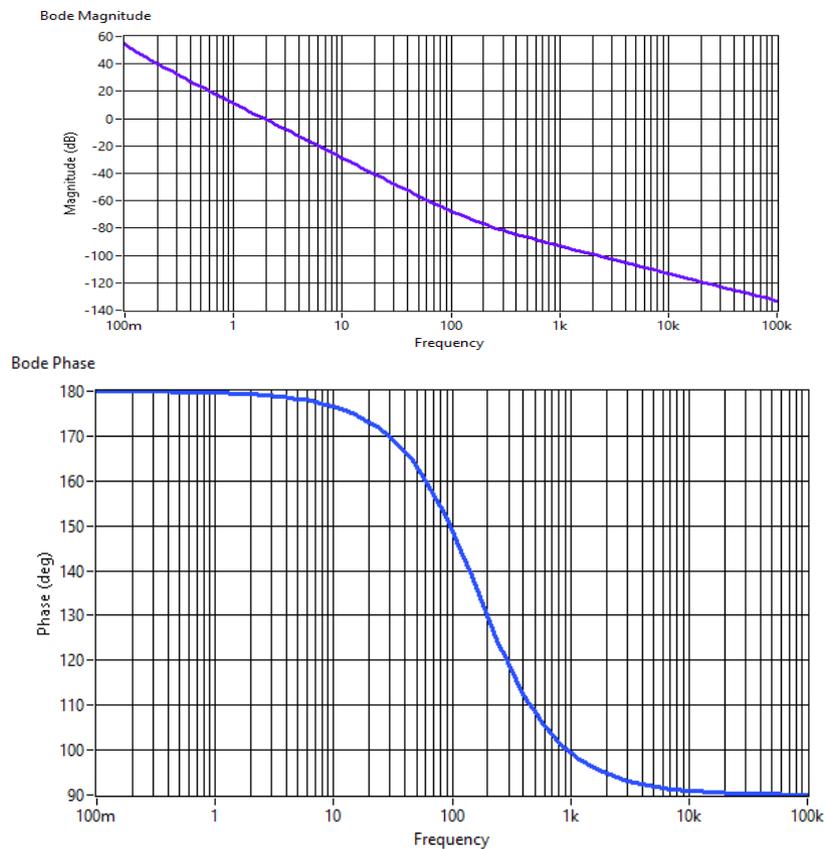


Figure.16.Bode Plot Response

CONCLUSION

A Solar Panel Simulator With A Constant Load Resistance Is Developed Using Labview. Using A Resistance Value 50Ω The Operating Point Is Analyzed. I-V And P-V Curves Are Analyzed For Varying Solar Irradiance $1000\text{W}/\text{M}^2$ And Varying Temperature From 25°C . The Front Panel Clearly Shows The Variation In The Short-Circuit Current, Open-Circuit Voltage, Maximum Output Power, And Operating Point Of The Solar Panel. A Solar PV Array Fed DC To DC Boost Converter Is Modeled And Implemented In Labview State Space Model Simulation Results Are Compared With Circuitry Model With The 5% Error. It Is Also Observed That State Space Model Reaches The State Point Quickly As Compared With Circuit Model. But It Fails To Closed Loop Operation And Also Control The Ripple Current In Inductor. It Is Also Noted That When There Is Isolation Variation In PV Array, The Corresponding Output Waveform Also Changed.

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