IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Modeling and Small Signal Analysis of Boost Converter for PV Applications

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Abstract— **one of the significant aspects in the power electronics technology is small signals models. By Using Small-Signal analysis, the transfer function of a given DC-DC converter can be achieved easily. The small signal model helps in identify the deviation around steady state operating point. This helps in ripple reduction and acheiving more stable and regulated output. It can be demonstrated by using the non-linear properties. They can contribute the access to the stabilized and also assists to optimize the controllers. In many literatures, small signal models are presented for power electronics converters. Nevertheless, in some specified applications such as photovoltaic (PV) systems, at the addition of capacitor for PV panel is used to stabilize the issues. The connected capacitor between PV terminal and power converter input, may be called as input capacitor. So far, many researchers are not investigated the cause of adding of capacitor(C) in the Photovoltaic system. Based on the earlier studies, small signal models are utilized for the PV step up converter with proportional integral and derivative (PID) controller in discontinuous conduction mode (DCM) and continuous continuous modes (CCM) of operations. In this paper the conventional Perturb and observe (P&O) MPPT algorithm is applied to track continuously to the maximum power point, which is not dependent on the capacitance. Moreover, purely resistive load is considered for examining the system under diverse operating conditions modes. As per the simulation results, the proposed PID controller based small signal models shows greater response in all CCM and DCM conditions as compared with other previous studied models.**

Keywords—small signals models, PV systems, PID controller, MPPT, CCM, DCM.

I. INTRODUCTION

Quite possibly the most helpless of the large amount of sustainable power sources which are regularly arranged as the economical-proficiency types of power transformation is photovoltaic (PV) frameworks. Subsequently, now a day's examines center around enhance the productivity of energy utilize by focusing as well as maximum power point procedures. These maximum power point tracking (MPPT) procedures constantly include controlling the panel voltage also, current make use of a power electronic converter dependent on the stages temperature and isolation [1][2]. Any framework which is being expected to be controlled requires input. The input framework should meet explicit prerequisites like stability, properties such as settling time, overshoots, consistent steady state regulation [3]. To plan a steady criticism framework, its dynamic model is required. The inductors and capacitors are concentrated with the help of small signal models.

meet explicit prerequisites like stability, properties such as settling time, overshoots, consistent steady state regulation [3]. To plan a steady criticism framework, its dynamic model is required. The inductors and capacitors are concentrated with the help of small signal models.

Accuracy models for power electronic converters in yield voltage (V) and input current control modes can be broadly found in literature. In any case, the power models for PV driven frameworks with extra input capacitor(C) are only from time to time covered. The criticism controller configuration issues for MPPT with a step down [4][5] and step up[6] converters can be found in recent work. The investigation thinks about the input capacitor into modeling. In any case, the impact of input capacitor on the stability isn't specifically examined. It is likewise uncertain, if the input capacitor has a similar impact on security for all the power electronic converters or slightly it is converter explicit. **A**lternating **C**urrent small signal displaying for conveyed **M**aximum **P**ower **P**oint **T**racking with a step up converter as an illustration is determined in [7].

It's seen that the dynamic interaction among every one of self controlled PV modules isn't responsible for any instability issue. Small signal models for double current mode controllers [8] and yield voltage (V) principle modes [9][10] are likewise introduced in the present literature. With the previously mentioned analysis, now a few focuses to be observed. Stability models, particularly for Photovoltaic fed of frameworks, are rarely covered. The impact of input capacitance on the framework dependability has not been talked about only. It is seen that the great majority of the models accept that the converter works in CCM. In any case, **P**hoto**v**oltaic frameworks are now and then found to go into DCM [11]. In this way, dependability models for Discontinuous Conduction Mode should be explored. The contributions of this paper are

From side to side detailed derivations, stability models for a non-ideal step up converter in both Continuous Conduction and Discontinuous Conduction modes. It also contains enticing findings such as pole-zero cancellation in both modes, which leads to a significant conclusion. It also includes scientific evidence to support the presented definition.

It also includes enticing findings such as pole-zero cancellations in both modes, which contributes to a substantial conclusion. It also includes experimental proof to support the presented definition.

2.0 Modeling of small signal analysis

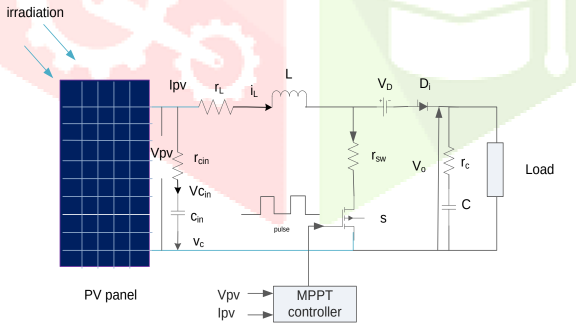

Fig.1: circuit diagram of PV fed DC-DC step up converter in Maximum Power Point tracking mode sustain a load [2].

Fig.1 shows that, circuit diagram of a PV fed step up converter sustain a load. The load might a basic resistive load or a complex load like an inverter operates of motor. Here $v_{c_{in}}$,V_{pv} and V_c the input capacitor(C), voltage, Photovoltaic panels and yield capacitors separately. IL and Ipv are the current through the inductor & Photo Voltaic limits. Cin, inductor and C are the Input capacitor, inductor and yield capacitor of the step up converter individually and Vo is the yield voltage of the step up converter. $r_{c_{in}}$, r_L, r_{sw}, r_c are the effective series resistance of input capacitor(c), inductor (L), switch and yield capacitor separately, V_D is voltage drop across the diode (D_i).In a large portion of the PV operate of frameworks, it is compulsory to work the system in MPPT mode. The MPPT controller accepts the V_{pv} and I_{pv} as input sources and produces duty cycle (d) to such an extent that greatest power is transferred from PV to stack.

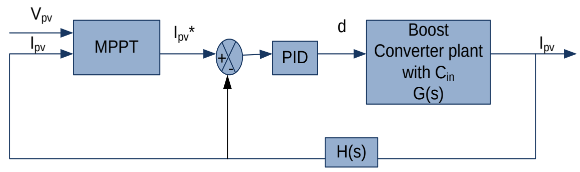

Fig.2: Functional Block diagram of PV fed step up converter with feedback loop [2]

The practical circuit diagram of PV fed step up converter is appeared in Fig.2 and with feedback loop is appeared in Fig.2. Any **M**aximum **P**ower **P**oint **T**racking calculation usually accepts V_{pv} and I_{pv} as data sources and produces a reference called $v_{pv_{ref}}$ or $I_{pv_{ref}}$. The estimation of V_{pv} or I_{pv} should be managed at these reference respect to maximum power on the load To achieve this, the MPPT controller's voltage and current references are compared to their true value, and the error is passed on to a PI controller, which produces pulses for the step up converter switches(s) ,G(s) is the step up converter's transfer function of the analysis along with C_{in} as input capacitor and the feedback system H(s) carrying the voltage and current sensors are added to the system and PI controller.

The first and most step in designing any controller, such as P, PI and PID is deciding the transfer function of the plant. The controller poles and zeroes are selected based on the characteristic of the plant, change transfer function. In this case, the step up converter is used to form the plant with d. as the control data, and i_{pv} as the output under control. The step up converter will operate in both DCM and CCM, and the aim at this point is to deduce the transfer function, $i_{pv}(s)/d_1(s)$, for both cases, which shows that the exchange work is open loop steady state in both cases.

Ease of Use

2.1 CCM

The ON and OFF states inconsistency conditions for the non ideal step up converter implemented in Figure (1) are given by[1 to 6]. R is the load associated with the step up converter's yield at this stage, and all the factors in small characters indicate that they are time shifting. The middle value of with requirement period (d) is found and linearized [3] to produce the small signal models given by [1 to 6], respectively. We will see the effect of wear i_{pv} to consider the impact of maximum power point on converter steadiness. As a result, $i_{pv}(s)$ d(s) is obtained.

ON state:

$$\frac{dv_{c_{in}}}{dt} = \frac{1}{c_{in}}(i_{pv} - i_L) = \frac{1}{r_{c_{in}} c_{in}}(v_{pv} - v_{c_{in}}) \qquad (1)$$

$$\frac{di_L}{dt} = \frac{1}{L}(v_{pv} - i_L(r_L + r_{sw})) \qquad (2)$$

$$\frac{dv_c}{dt} = -\frac{v_0}{r_c} = -\frac{v_c}{R + r_c} \qquad (3)$$

OFF state:

$$\frac{dv_{c_{in}}}{dt}=\frac{1}{c_{in}}(i_{pv}-i_L)=\frac{1}{r_{c_{in}}c_{in}}(v_{pv}-v_{c_{in}}) \quad (4)$$

$$\frac{di_L}{dt}=\frac{1}{L}(v_{pv}-i_L(r_L+\frac{Rr_c}{R+r_c})-v_d-\frac{Rv_c}{R+r_c}) \quad (5)$$

$$\frac{dv_c}{dt}=\frac{1}{c}\{i_L(\frac{R}{R+r_c})-\frac{v_c}{R+r_c}\} \quad (6)$$

$$\begin{bmatrix}\overleftrightarrow{v}_{c_{in}}\\ \overleftrightarrow{i}_L\\ \overleftrightarrow{v}_c\end{bmatrix}=\begin{bmatrix}a_{11}&a_{12}&a_{13}\\a_{21}&a_{22}&a_{23}\\a_{31}&a_{32}&a_{33}\end{bmatrix}\begin{bmatrix}v_{c_{in}}\\ i_L\\ v_c\end{bmatrix}+\begin{bmatrix}b_{11}&b_{12}&b_{13}\\b_{21}&b_{22}&b_{23}\\b_{31}&b_{32}&b_{33}\end{bmatrix}\begin{bmatrix}v_{pv}\\ v_d\\ d\end{bmatrix} \quad (7)$$

$$\begin{bmatrix}v_o\\ i_{pv}\end{bmatrix}=\begin{bmatrix}c_{11}\,c_{12}\,c_{13}\\c_{21}\,c_{22}\,c_{23}\end{bmatrix}\begin{bmatrix}v_{c_{in}}\\ i_L\\ v_c\end{bmatrix}+\begin{bmatrix}e_{11}\,e_{12}\,e_{13}\\e_{21}\,e_{22}\,e_{23}\end{bmatrix}\begin{bmatrix}v_{pv}\\ v_d\\ d\end{bmatrix} \quad (8)$$

$$\frac{i_{pv}(s)}{d(s)}=\frac{b_{23}(s-a_{11})((s-a_{33})+\frac{a_{23}b_{33}}{b_{23}})}{(s-a_{11})((s-a_{22})(s-a_{33})-a_{32}a_{23})} \quad (9)$$

2.2 DCM

The different conditions managing the step up converter activity in DCM are given. The different conditions are earliest arrived at the midpoint of with duty cycle (d and d1). at Each time ‘d' is the ratio of the switch's on time (s) to the total switching period, and d1 is the ratio of the time, it takes the inductor current to reach zero during the switch's OFF state (S) to the total switching period. They arrived at the midpoint of model containing d and d1 should now be adjusted to wipe out d1 [12].

$$\frac{dv_{c_{in}}}{dt}=\frac{1}{c_{in}}(i_{pv}-i_L)=\frac{1}{r_{c_{in}}c_{in}}(v_{pv}-v_{c_{in}}) \quad (10)$$

$$\frac{di_L}{dt}=\frac{1}{L}(v_{pv}-i_L(r_L+r_{sw})) \quad (11)$$

$$\frac{dv_c}{dt}=-\frac{v_0}{r_c}=-\frac{v_c}{R+r_c} \quad (12)$$

$$\frac{dv_{c_{in}}}{dt}=\frac{1}{c_{in}}(i_{pv}-i_L)=\frac{1}{r_{c_{in}}c_{in}}(v_{pv}-v_{c_{in}}) \quad (13)$$

$$\frac{di_L}{dt}=\frac{1}{L}(v_{pv}-i_L(r_L+\frac{Rr_c}{R+r_c})-v_d-\frac{Rv_c}{R+r_c}) \quad (14)$$

$$\frac{dv_c}{dt}=\frac{1}{c}\{i_L(\frac{R}{R+r_c})-\frac{v_c}{R+r_c}\} \quad (15)$$

$$\frac{dv_{c_{in}}}{dt}=\frac{1}{c_{in}}(i_{pv}-i_L)=\frac{1}{r_{c_{in}}c_{in}}(v_{pv}-v_{c_{in}}) \quad (16)$$

$$\frac{i_{pv}(s)}{d(s)}=\frac{b_{23}(s-a_{11})((s-a_{33})+\frac{a_{23}b_{33}}{b_{23}})}{(s-a_{11})((s-a_{22})(s-a_{33})-a_{32}a_{23})} \quad \frac{di_L}{dt}=0 \quad (17)$$

$$\frac{dv_c}{dt}=-\frac{v_0}{r_c}=-\frac{v_c}{R+r_c} \quad (18)$$

We realize that the most extreme inductor current $i_{l_{max}}$ and normal inductor current $i_{l_{max}}$ and $\overline{\overline{i}}_L$ Of a step up converter are given by

$$i_{l_{max}}=\frac{v_{pv}dT_s}{L} \quad (19)$$

$$\overline{\overline{i}}_L=\frac{i_{l_{max}}}{2}(d+d_1) \quad (20)$$

Substituting eq (20) in eq (21) we get,

$$d_1=\frac{2L\overline{\overline{i}}_L}{dT_s(v_{pv}-\overline{\overline{i}}_L(r_L+r_{sw}))}-d \quad (21)$$

Where Ts = 1/f_s and fs is the switching frequency of the converter. The condition (21) which communicates d1 as an element of d is more substituted in arrived at the midpoint of model to produce it self-control of d_1. The model as a result (7) and (8) and the co-operative points provided in sequel are linearized to obtain the small signal model (for DCM, the co-operative points available in Capital letter sets). Whenever the small-signal analysis is completed, it's time to obtain the transient response $i_{pv(s),}$ which is given by (22).

$$\frac{i_{pv}(s)}{d(s)}=\frac{B_{23}(s-A_{11})((s-A_{33})+\frac{A_{23}B_{33}}{B_{23}})}{(s-A_{11})((s-A_{22})(s-A_{33})-A_{32}A_{23})} \quad (22)$$

3.0 Proposed PID controller

A proportional integral derivative (PID controller or three term regulator) is a control loop component utilizing evolution that is generally makes use of modern control frameworks and an collection of different applications requiring constantly modulated control. A PID controller with determination find out a error values the contrast between an ideal set point (SP) and a calculated process variable (PV) and applies an modification dependent on proportional-integral-derivative terms (indicated P, I, and D separately).

In useful terms it naturally applies an exact and responsive correction to a control work. A controller model is the trip control on a vehicle, where climbing a slope would bring down speed if just steady motor force were applied. The controller PID algorithm reconciles the required speed to the ideal speed with negligible delay and overshoot by getting higher the power output of the motor. The main hypothetical analysis and functional application was in the field of automatic directing frameworks for ships, created from the mid 1920s onwards. It was then utilized for programmed measure control in the manufacturing industry, where it was broadly actualized in pneumatic and afterward electronic, controllers. Today the PID idea is utilized generally in applications requiring exact and advanced automatic-control.

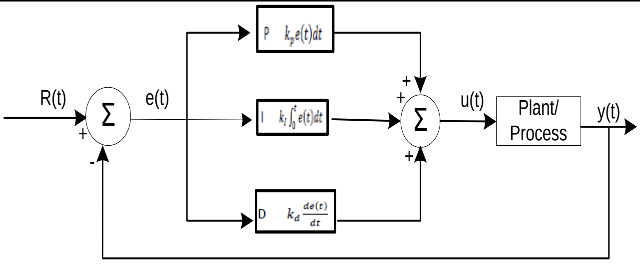

Fig .3: representation of PID controller

Consistently computes a error values the compare between an ideal setpointand a calculated cycle variable, and applies an rectifying dependent on proportional, integral, and derivative terms. The controller activities to limit the error over the long time by change of a control variable, like the beginning of a control valve, to another worth controlled by a weighted amount of the control terms.

4.0 Simulation results:

The simulation circuit consists of a pv system which act as a pv source and supplies DC output. A total of 4 panels are connected in series. a step up converter with c_{in}=2000 μF, $r_{c_{in}}$

$r_{c_{in}}$ 11e^(-3)Ω,L=0.5H,rL=35Ω,rsw=0.1smΩ,

V_d =1.63v, c=1000μF,f_s =25 kHz & r_c=0.0032 Ω is used as power electronic interface between simulator to load. At load side a variable rheostat is used on the output of the step up converter. The gating pulse essential to triggered the MOSFET switch is developed using a simulation.

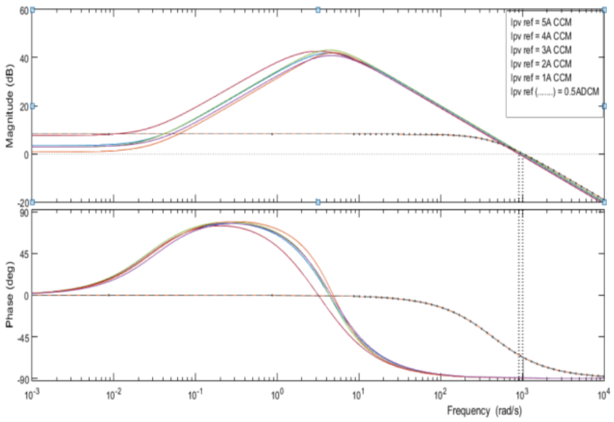

Fig.4: Bode plots showing open circle steadliness in both DCM and CCM cases under constant current mode.

Both DCM and CCM cases of step up converter bode plots were plotted for the respective transfer function (i_{pv} / d) to demonstrated open loop stability of the plant, which is shown in fig.4. For i_{pv} = 5A, 4A, 3A, 2A, and 1A CCM, the photovoltaic device is operated in constant current mode. The simulation results are presented in acquire gain margin (G.M) is infinity (∞) and the phase margin (P.M) is near 90.5° , suggesting that the system is stable. For DCM case transfer function is plotted for i_{pv} = 0.5A in MATLAB simulation then the system verified as open loop stability at gain margin (G.M) is infinity (∞) and the phase margin (P.M) is near 90.

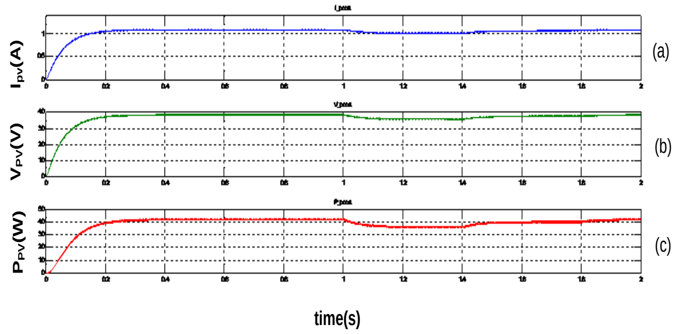

Fig.5: System output under constant current mode (CCM)

For reference PV currents i = 4 A, 2 A, 3 A, and 1 A, the pv system run at first, which shown in figure 5a It is seen from Fig.5a.from the figure it is clear that the verified PV current tracks the reference current values in all cases. The associated PV voltage and power is shown in Fig.5b and Fig.5c sequentially.

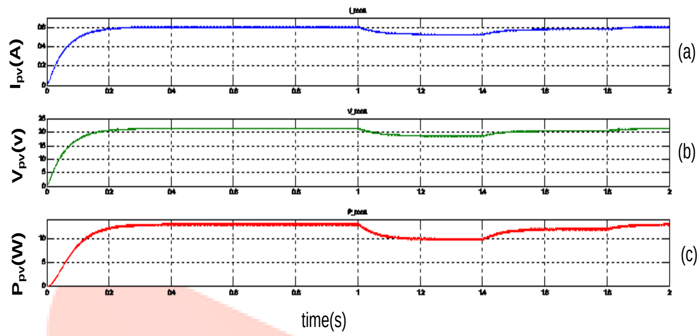

Fig.6: System output under constant current mode (DCM)

The load resistance R is now increased to 120 Ω, and inductor L was cut down to 270 μ H then the converter enters into DCM and the system is tested for i = 0.7A at t=14s.It is seen from fig.6a.it is clear that also in DCM the actual pv curve would track the reference current. The associated pv voltage and power is shown in fig.6b and fig.6c sequentially. Additionally the pv system is tested for the MPPT using P&O, then the value of i_{pv} obtained from the MPPT algorithm as shown in fig.1.

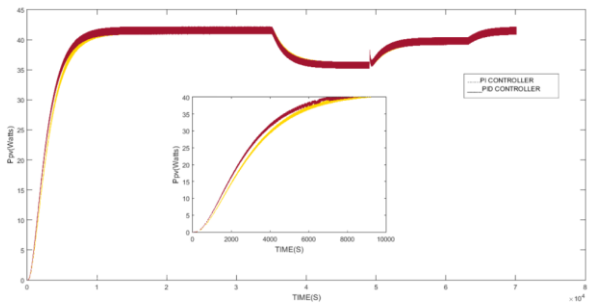

Fig.7: power output Comparison of PV fed of DC-DC step up converter consistent conduction mode by utilizing PI and PID

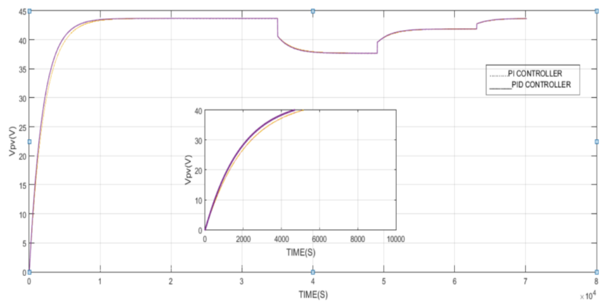

Fig.8: Voltage output Comparison of PV fed of DC-DC step up converter continuous conduction mode (CCM) by utilizing PI and PID

The PV system Power and voltage Tracked by using conventional algorithm along with PI and PID controller under unshaded condition for CCM are shown in above fig.7 and 8.

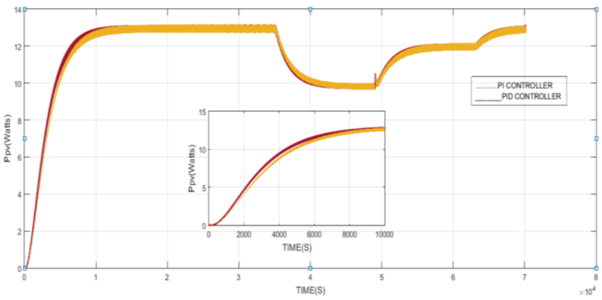

Fig.9: Power output Comparison of PV fed of DC-DC step up converter discontinuous conduction mode (DCM) by utilizing PI and PID

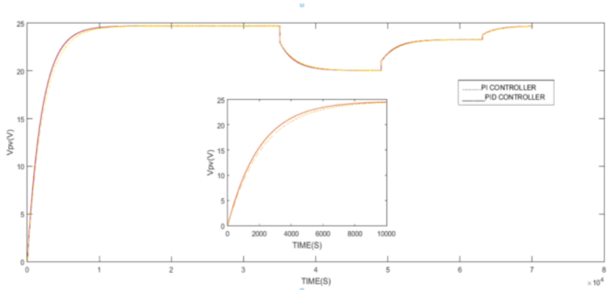

Fig.10: Voltage output Comparison of PV fed of DC-DC step up converter discontinuous conduction mode (DCM) by utilizing PI and PID

The PV system Power and voltage Tracked by using conventional algorithm along with PI and PID controller under unshaded condition for DCM are shown in above fig.9 and 10.From observing the above four graphs, it is clear that the PV system has been examined with P&O algorithm based MPPT method along with PI and PID controller under unshaded condition in both CCM and DCM cases, the simulation results reveal the superiority of the proposed control schemes.

5.0 Conclusion

The impact of the production of capacitor(c) at Photovoltaic terminals on device protection has been investigated in this paper using small signal models. In light of the organism, models are proposed for both Continuous Conduction Mode and Discontinuous Conduction Mode. There is a unclear load of the action techniques. And are initiate to be the components of information capacitor(c) and its effective series resistance. The system has been developed in the MATLAB/Simulink environment. The PID controller based small signal models shows the experimental results appeared in all CCM and DCM conditions as compared with other studied approaches.

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