Design of Photovoltaic system using Buck-Boost converter Based on Incremental Conductance MPPT with PID Controller

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Abstract—Different complete models of the PV system containing many techniques of DC-DC converter are applied in this paper like, buck converter, boost converter and buck- boost converter which are placed to be closest to the power between PV array and load by changing its duty cycle which is named maximum power point tracking (MPPT). This paper presents four different techniques of the DC-DC converter controlled by MPPT. The first configuration is proposed as composing PV module connected to buck-boost converter controlled via incremental conductance MPPT algorithm, the system includes PID controller to reduce the error of output voltage. The second model likes the first without PID controller. The last two systems comprise from boost converter with MPPT control and with PWM technique. All studied techniques are simulated by using Matlab/Simulink.

Keywords- PVsystem; DC-DC converter;PID controller; MPPT algorithm

I. INTRODUCTION

Renewable energy sources are the most widely studied electric power sources like wind turbine and photovoltaic cells which are the most popular renewable sources. The photovoltaic model gains a great attention in the last decades as it has not a moving part and produces less pollution to environment. The output characteristic of PV array depends on parameters radiation intensity and temperature [1, 2]. Increasing the temperature is decreasing the power generated by PV module at MPP. While, an increase in radiation intensity can cause increasing in the generated power in the maximum power point of PV module [3, 4].

The PV cells operate with maximum output power and tracks the maximum available output power of PV array and make PV system more efficient. The MPPT algorithm adopt criteria dv/dt =0 at maximum points to extract the maximum power. Many different techniques are implemented based on MPPT, which are different in their efficiency, speed response, implementation, cost and popularity [3, 5, 6]. Different algorithms like conductance are applied to the MPP tracking to control the duty cycle of the converter [7].

II. EQUIVALENT CIRCUIT OF PV MODULE

The equivalent circuit of PV general model composes photon current source in parallel with a diode and shunt resistance, all in series with a series resistor. the equivalent circuit is shown as in Fig. 1 [4, 8, 9].

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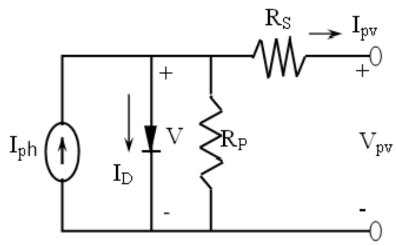

Fig.1: The equivalent circuit of PV module

$$I_{PV} = N_p I_{Ph} - N_p I_o \left[e^{\frac{V_{PV}+I_{PV}R_S}{N_S V_{th}}} - 1 \right] - \frac{V_{PV}+R_S I_{PV}}{R_p} \quad (1)$$

I_{ph} : light generated current , Is :panel saturation current, Ns: number of cells connected in series , Np : number of cells connected parallel, T : cell working temperature , A : ideal factor , Rp: shunt resistance and Rs : series resistance.

III. DC-DC CONVERTER BASED ON MPPT

DC-DC converter was a vital part of alternative and renewable energy conversion, portable devices, and much industrial process. It is essentially used to achieve a regular DC voltage from DC source with may be the rectifier output or a battery or a solar cell and fed to DC-DC converter [10].

A. Perturb and Observe (P&O) MPPT Algorithm

The P &O method is most used in MPPT because of its simple technique and it requires only few parameters. It perturbs the terminal voltage of PV array and compares the generated output power of PV with the last cycle of perturbation. When generated power of PV and voltage is increased or decreased, a perturbation step size, the system is oscillating toward the MPP and this oscillation is minimized and the step size perturbation is reducing and it slows down the MPP tracking system. This MPPT algorithm is introduced to provide gate pulses to the MOSFET switch used in the boost converter [10, 11, 12].

B. PV System Boost Converter with PWM

The block diagram is introducing the technique of the feed forward control is shown in Fig. 2. It composes of a Solar panel, boost converter, MPPT and a lighting load. The current – voltage characteristics of this panel is tested initially before connecting it to the load [11, 13].

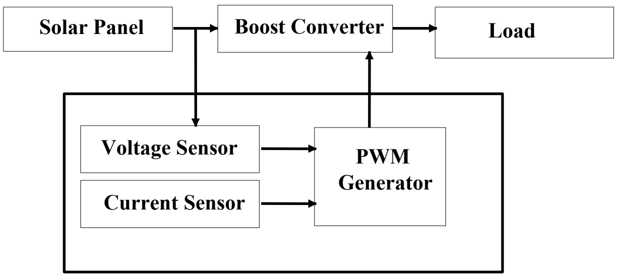

Fig. 2 Block diagram of PV system PWM control technique

C. PV System Boost converter with MPPT

A DC-DC boost converter is used to convert the input dc voltage value to the different dc voltage value at the output. The circuit diagram of the boost converter. It consists of a electronic switch which is controlled by PWM signal. The inductor is storing energy from the panel until T_{ON} period when the electronic switch is switched on. Meanwhile, when diode is in the reverse biased it isolates the output from the circuit and the load current supplies from the capacitor. When the electronic switch is switched off, the inductor is discharging and the current flows through the diode.. The output voltage composes of the discharged voltage and instant panel voltage; hence it is always higher than the input voltage. The ON and OFF of the switch is controlled by the PWM signal [10, 11, 14].

D. PV System Buck-Boost converter with MPPT

Buck-Boost converter is combination of a buck and boost converter. It is a combination of the buck converter case and a boost converter case in cascade. The ratio for the output to input voltage is equal to a product of ratios in buck converter and the boost converter. [11, 12, 15]. The block diagram presenting the technique of the PV system buck-boost converter with MPPT technique is shown in Fig. 3.

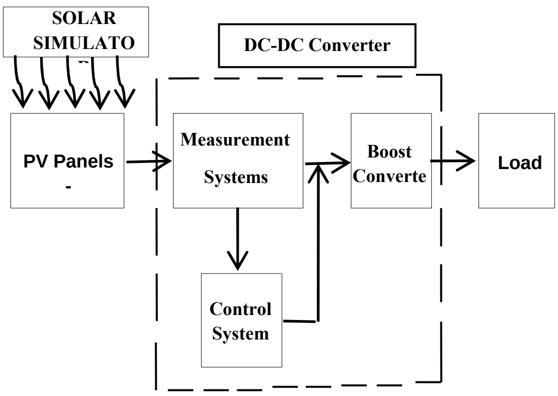

Fig. 3: The block diagram of PV system with DC-DC Converter

E. Incremental Conductance Algorithm for MPPT

The output power of the solar PV module changes with change in direction of the sun, change in solar insulations level and change in temperature. There is a single MPP in the PV characteristics of the PV module for normal operating condition. It is desired the PV module to operate around to this point, i.e., output of the PV module reaches near to MPP. The process of operating PV module at this condition is called as maximum power point tracking (MPPT). Maximization of PV power improves the utilization of the solar PV module [8,15]. The most common algorithms are the P& O and the IC method. The conductance method presents the advantage of giving high efficiency under changing atmospheric conditions, so it has been introduced in the model. This method is based on the slop of the PV array power curve is zero at the MPP, and is increasing on the left of the MPP and is decreasing on the right side of MPP.

The algorithm of this technique starts by obtaining values of I(k) and V(k) and using former values stored at the end of the cycle, I(k-I) and V (k-I), then the voltage variable is zero and the current variable equals zero so the PV is operating on the MPP [10, 16].

When the PV array are not operating at the MPP; thus the change in the atmospheric Conditions is detected using ($dI \neq 0$) . In this case, the control is depending on dI is positive or negative, if the incremental change in current is positive, the voltage is increased, otherwise is decreased. While the voltage variable is unequal zero, and is comparing dI/dV with I/V..

The configuration of MPPT controller is composed of the inputs for MPPT controller are voltage, current of the PV module to control the duty cycle of the DC-DC converter.

Therefore, the problem of the maximized output power can be solved effectively using the duty cycle of DC-DC converter as a control variable with perturbation and observation (P&O) as the following control law [10, 11,12]:

$$\mathrm{D}_k = \mathrm{D}_{k-1} + C_1 \frac{\Delta P_{k-1}}{\Delta D_{k-1}} \quad (2)$$

D_k and D_{k-1} are duty cycle values in K and K-1 intervals, respectively. $\Delta P_{k-1}/\Delta D_{k-1}$is the power slope of PV in step K-1 and C_1 is the step change [13, 14, 17,18].

IV. THE PROPOSED MODEL WITH PID

The output power from PV module is fed to DC-DC converter by using Incremental Conductance (IC) algorithm MPPT with PID controller to obtain the point of maximum power as shown in Fig. 4. The proposed model depends on the slope of the derivative of the current to the voltage to reach MPP from measurements of the voltage, V, and the current, I, and the algorithm determines the photovoltaic output power and its derivative as in terms of the voltage. The difference between actual voltage signal and generated voltage signal are compared and fed to PID controller to reduce error and generate the duty cycle to operate DC-DC converter.

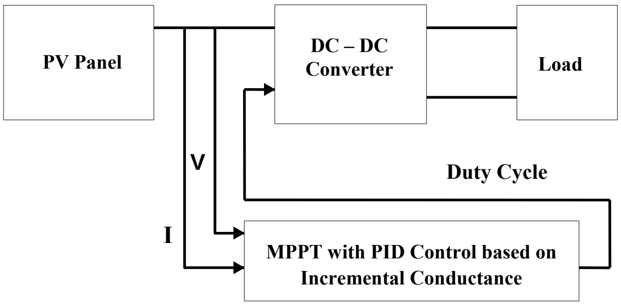

Fig. 4: The block diagram of proposed PV system

The flow chart of the proposed model of MPPT method is implemented in Fig, 5. The operation of this algorithm can be given by the following mathematical equations, [16, 17, 18]

$$\left.\begin{array}{ll} \frac{dp}{dv} = 0 & \text{At MPP} \\ \frac{dp}{dv} > 0 & \text{At the left of MPP} \\ \frac{dp}{dv} < 0 & \text{At the right of MPP} \end{array}\right\} \quad (3)$$

Since,

$$\frac{dp}{dv} = \frac{d(IV)}{dv} = I + V\frac{dI}{dV} \quad (4)$$

$$\left.\begin{array}{ll} \frac{\Delta I}{\Delta V} = \frac{-I}{V} & \text{, at MPP} \\ \frac{\Delta I}{\Delta V} > \frac{-I}{V}, & \text{at the left of MPP} \\ \frac{\Delta I}{\Delta V} < \frac{-I}{V}, & \text{at the right of MPP} \end{array}\right\} \quad (5)$$

V. NUMERICAL ANALSIS

The proposed PV module is simulated by Matlab/Simulink as shown in Fig. 6 and compared with three others model. The specification of the PV array and optimized ratings are illustrated in Table 1. Fig.7.a and Fig.7.b show the characteristics curve of PV module and PV which it used array. The output voltages, current and power for the proposed model PV system usage buck-boost converter based on MPPT with PID controller are shown in Fig. (8.a, 9.a, 10.a), the PV system usage buck-boost converter based on MPPT controller is shown in Fig. (8.b, 9.b, 10.b), while the PV system usage boost converter based on MPPT are shown in Fig. (8.c, 9.c, 10.c) and PV system usage boost converter based on PWM are shown in Fig. (8.d, 9.d, 10.d) It is illustrated from Fig. 8.a to Fig. 8.d which are shown the wave form of output and input voltage for the proposed technique are the best wave because it has a low harmonics and has a high value of the output voltage when is comparing with the other three techniques.

Also, from Fig. 9.a to Fig. 9.d which are shown the wave form of output ant input current of all four techniques ant it clears the wave of the proposed model has no ripple and output current is not excesses the range of PV array maximum current .

While, from Fig. 10.a to Fig. 10.d are presented the output and input power and it is concentrated of wave form from 0.8 sec to 0.805 sec to show the ripple in the each wave for each technique, thus the wave form of the proposed model has a low ripple with less oscillation value about 1.7 watt and the best wave compared with the other techniques.

The comparison simulation results such as output power (Po), ripple in output power (ΔPo), output voltage (Vo) are in Table 2.

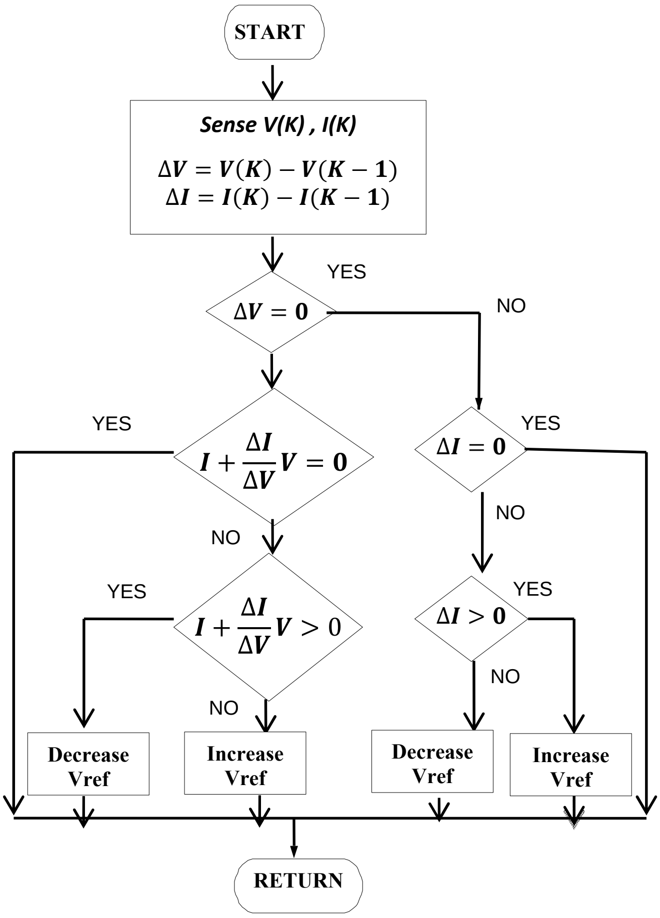

Fig. 5: The flowchart of IC algorithm

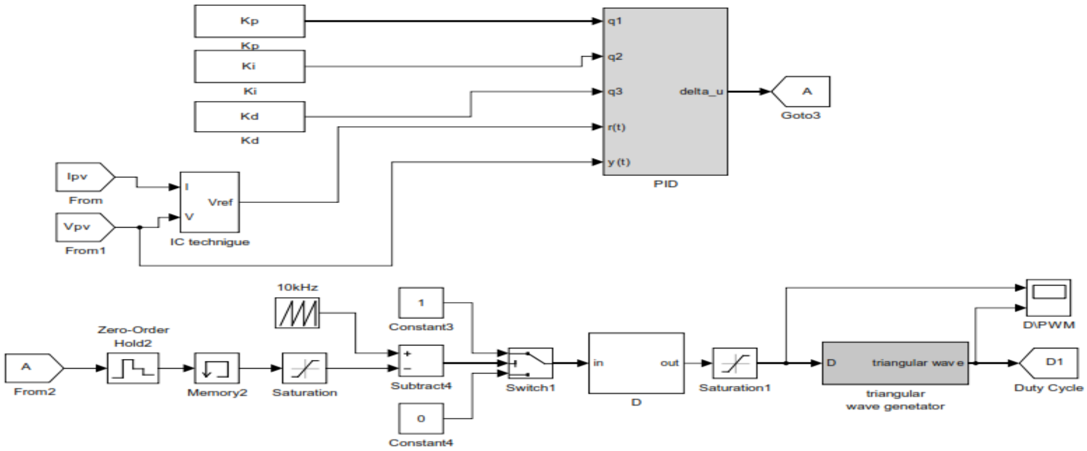

Fig. 6: Simulink model of proposed control model

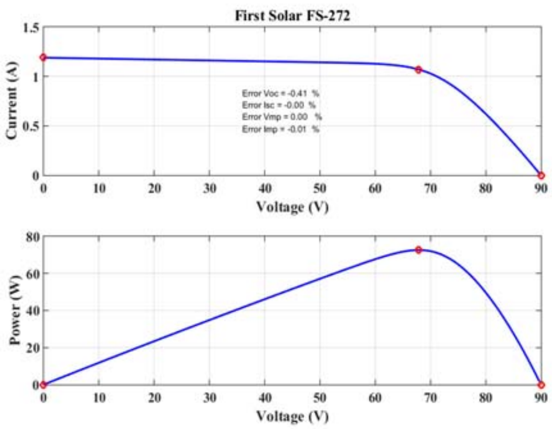

Fig. 7.a PV module characteristics

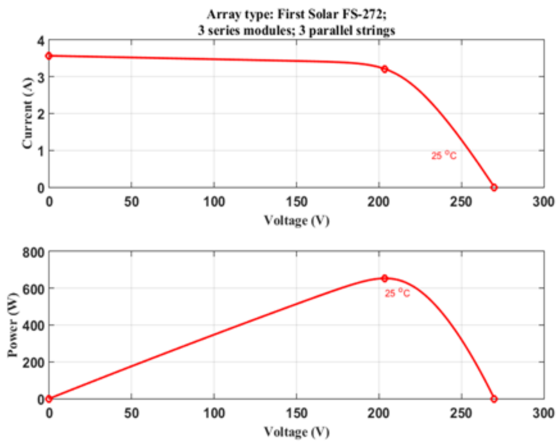

Fig. 7.b PV array characteristics

TABLE1: Specification of PV array and ratings

Electrical specifications of PV array	
Module type	First Solar FS - 272
Ns	3
Np	3
Maximum power(W)	680
Voltage at max. power (V)	37.3
Current at max. power (A)	8.31
Open circuit voltage (V)	45.22
Short circuit current (A)	8.9
Cell temperature, in deg.C.	25
Sun irradiance, in W/m2	1000

TABLE 2: Output results of PV system for different models

Results / **Model**	**Po (watt)**	**ΔPo Ripple (watt)**	**Vo (volt)**
PV system usage buck-boost converter based on MPPT with PID	690	1.7	360
PV system usage buck-boost converter based on MPPT	675	3.8	350
PV system usage boost converter based on MPPT	620	7.5	325
PV system usage boost converter based on PWM.	535	20.2	315

VI. CONCLUSION

Converter and MPPT system based on incremental conductance algorithm conclude that the MPPT controller deliver maximum power possible by using proposed model and give adjustment duty cycle of the DC-DC converter at any change in the irradiance.

In This paper the performance of different models for PV system using MATLAB/Simulink are implemented. The maximum power is obtained using proposed model method. It is observed that the characteristics obtained based on this method is closest to the theoretical and simulations. Also from this proposed model, maximum values of voltage, maximum value of current and maximum value of power are developed and have a low ripple compared with the three other models. Thus the proposed simulation model of DC-DC converter with PID-MPPT algorithm can be used as a reference for presentation of actual system.

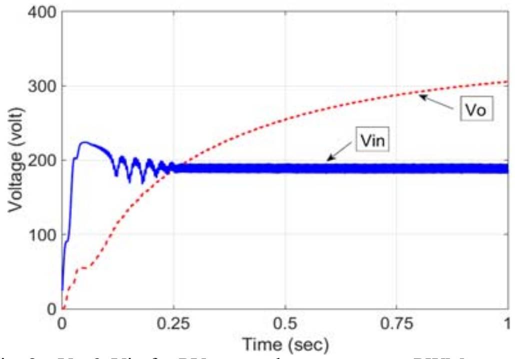

Fig. 8.a Vo & Vin for PV system boost converter PWM

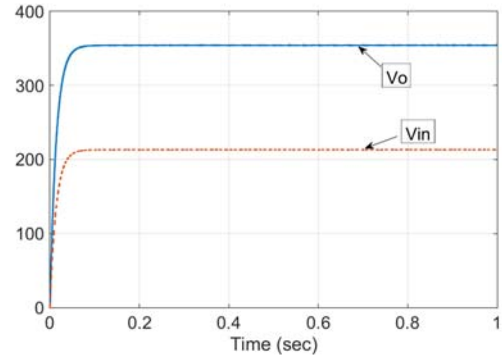

Fig. 8.b Vo&Vin for PV system boost converter MPPT

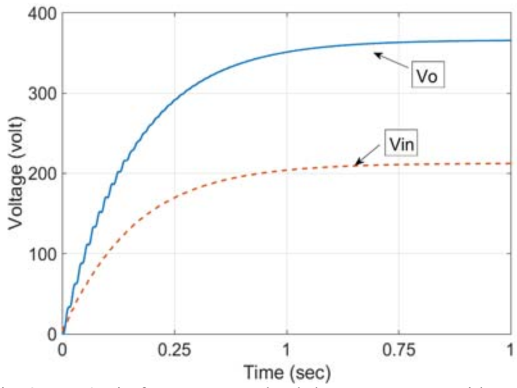

Fig. 8.c Vo&Vin for PV system buck-boost converter with MPPT

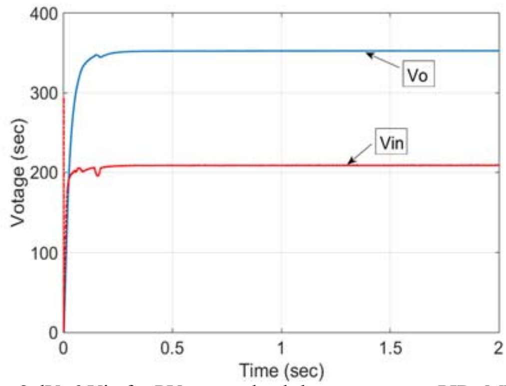

Fig. 8.dVo&Vin for PV system buck-boost converter PID- MPPT

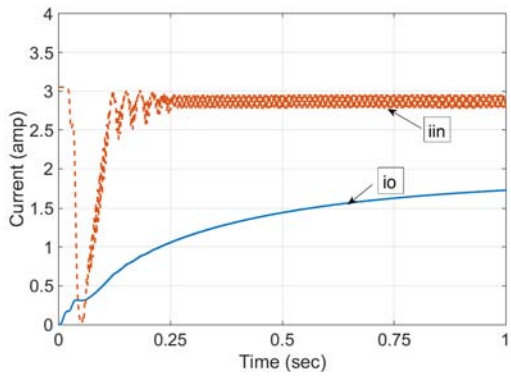

Fig. 9.a Io & Iin for PV system boost converter with PWM

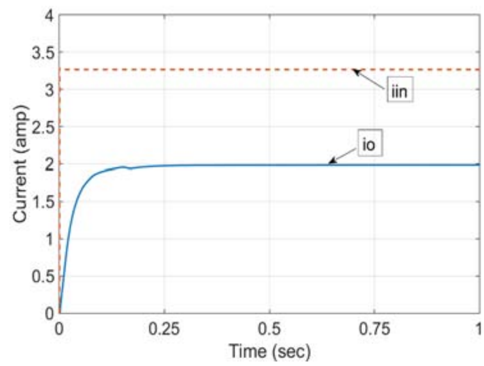

Fig. 9.b Io&Iin for PV system boost converter with MPPT

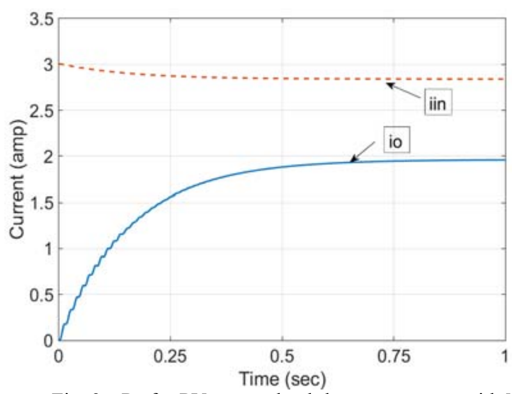

Fig. 9.c Po for PV system buck-boost converter with MPPT

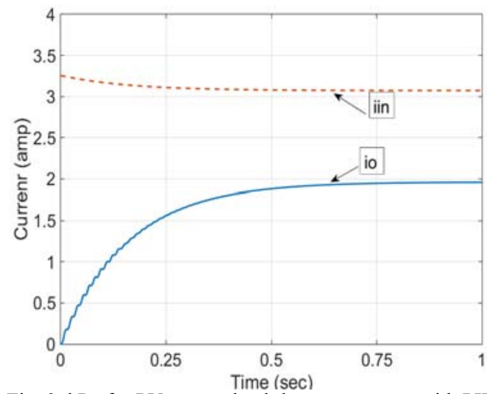

Fig. 9.d Po for PV system buck-boost converter with PID-MPPT

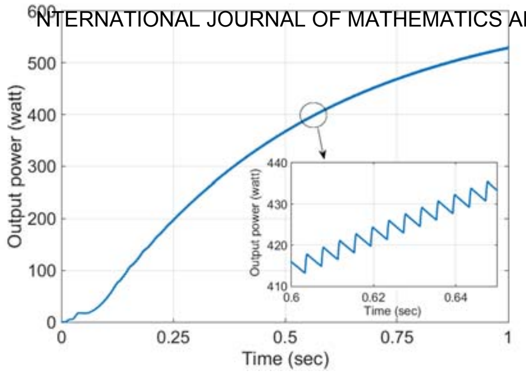

Fig. 10.a Po for PV system buck-boost converter with PWM

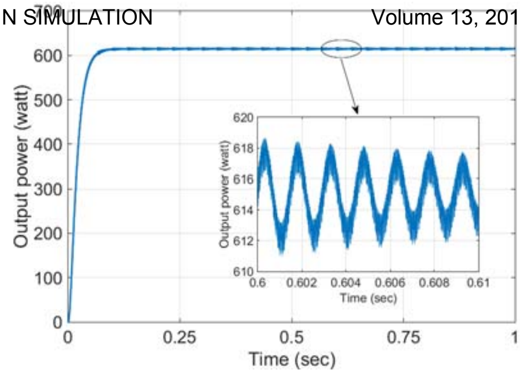

Fig. 101.b Po for PV system boost converter with MPPT

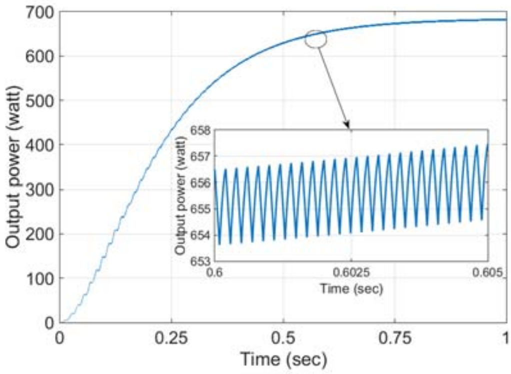

Fig. 10.c Io&Iin for PV system buck-boost converter with MPPT

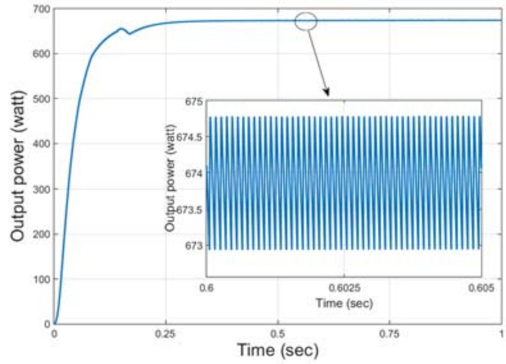

Fig. 10.d Po for PV system buck-boost converter with PID – MPPT

REFERENCES

[1] Irtaza M.Sayed, Kaamran Raahemifar, "Model Predictive Control of [1]. Irtaza M.Sayed, Kaamran Raahemifar, "Model Predictive Control of Three Phase Inverter for PV Systems". Intera national Journal of Electrical , Computer, Energetic, Electronic and Communication Engineering IEEE Trans. Energy Conversion, vol. 9, no. 10, pp. 1126-1131, 2015.

[2] I. H. Altas, A. M. Sharaf, " A Photovoltic Array Simulation Model for Matlab-Simulation GUI Environment". IEEE International Conference on Clean Electrical Power. pp. 341-345, May. 2007.

[3] Chen Qi, Zhu Ming , "Photovoltic Module Simulink Model for a Stand-alone PV Systems". International Conference on Applied Physics and Industrial Engineeerig, pp. 94-100. February. 2012.

[4] Chouki Balakishan, N. Sandeep, M. V. Aware, " Design and Implementation of Three-Level DC-DC Converter with Golden Section Search Based MPPT for the Photovoltic Applications". Hindawi Publication Corporation Advances in Power Electronics, vol. 2015, pp. 1-9, 2015.

[6] Gudimetla Ramesh, Kari Vasavi, S. Lakshmi Sirisha, "Photovoltic Cell Fed 3-Phase Induction Motor Using MPPT Technique". International Journal of Power Electronics and Drive System (IJPEDS), Vol. 5, No2, pp. 203-210, October 2014. (2008) 453 – 464.

[7]. N. A. Kamarzaman, C. W. Tan," A comprehensive review of maximum power point tracking algorithms for photovoltaic systems," Renew Sustainable Energy Rev, Vol 37, pp. 585-598, Sept.2014.

[8] M. H. Moradi, and A. R. Reisi, "A Hybrid Maximum Power Point Tracking Method For Photovoltaic Systems," Journal of Solar Energy, Vol. 85, No.11, pp. 2965-2976, November 2011.

[9] MD.SAFIA, T V V PAVAN KUMAR, " Design and Simulation of Grid Connected PV system Using Multilevel Inverters". International Journal of Electrical and Electronics Engineering (IJEEE), vol 4, Issue 2, pp. 52-59, 2013.

[10] Zaghba Layachi, A ,Borni, A .Bouchakour, N.Terki, " Buck-Boost Converter System Modeling and Incremental Inductance Algorithm for Photovolyic System via MATLAB/Simulink". The 2nd International seminar on New and Renewable Energies, pp. 1-6, Algeria, October 2014.

[11] A. Bouchakour, L. Zaghba, M. Brahami, A. Borni, " Study of a Photovoltic System Using MPPT Buck-Boos Converter". International Journal of Material, Mechanics, Manufacturing, vol.3, No.1, pp. 65-68, February 2015.

[12] Lijun Qin, Xiao Lu, "Matlab/Simulink-Baswd Research on Maximum Power Point Tracking of Photovoltic Generation". ". International Conference on Applied Physics and Industrial Engineeerig, pp. 10-18, February. 2012.

[13] M. T. Ullah, M. H. Uddin, M. Quamruzzaman, "Performance analysis of DC/DC Boost Converter with Maximum Power Point Tracking for Grid connected Photovoltic Systems". International Conference on Physics sustainable Development & Technology (ICPSDT-2015), PP. 133-139, August 2015.

[14] Syed Enam Reza, A. S. M. Kaikobad, Abd-AI- Fattah-Ibne Mahabub, Md. Mehadi Hassan Nahid, Arif Ahammad , Md. lakaria Rahimi, "A study on the Reactive Power Control Mechanism of Current source Boost Inverter for Photovoltaic Power System". IEEE 2nd Int'l Conf on Electrical Engineering and Information & Communication Technology (ICEEICT) , 21-23 May 2015.

[15] K. Mahsa Ghapandar, M. Maziar, B. Subhashish, "Variable interleaving technique for photovoltaic cascaded DC–DC converters". 40th Annual Conference of the IEEE Industrial Electronics Society, IECON 2014, pp. 5612–5617,2014.

[16] lunation of new FLC controller based MPPT for a DC to DC buck-boost zeta converter" WSEAS TRANSACTIONS on POWER SYSTEMS, volume 11, pp. 27-34, 2016.

[17] Gomathi B Sivakami P, "An Incremental Conductance Algorithm based Solar Maximum Power Point Tracking System". International Journal of Electrical Engineering, volume 9 Number 1, pp. 15-24 , 2014.

[18] Nur Atharah Kamarzamana, Chee Wei Tanb, "A comprehensive review of maximum power point tracking algorithms for photovoltaic systems". Renewable and Sustainable Energy Reviews, volume 37, pp. 585–598,2014.