IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 3 Ver. II (May – Jun. 2015), PP 08-15
www.iosrjournals.org

Power Management analysis and Coordination Control of Standalone Photovoltaic (PV) System

Kailash Krishna Prasad.B[1]
[1](*Assistant Professor, Department of EEE, BITS-KURNOOL, AP, INDIA,)*

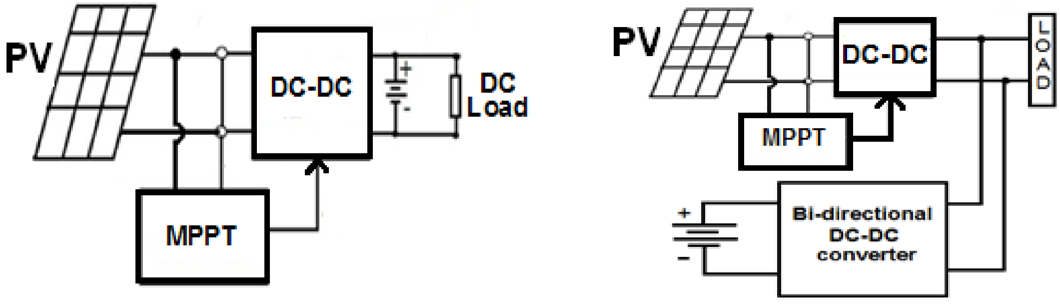
Abstract : This paper mainly emphasizes and explains about the two possible topological configurations which plays a vital role in designing and ensuring the coordination control of a standalone PV system. The development of hybrid power generation systems is of major concern because of its controlling complexity. By comparing the topologies of series and parallel connected PV systems, one can assess the importance of parallel connected PV system over the series connected. The state diagram which is proposed in this paper helps in understanding the concept of coordination control between the generating source and load. Simulation results illustrates about the power flow aspect and operational characteristics of parallel connected PV system.
Keywords – Coordination control, Hybrid systems, Power Management, Standalone PV system, State diagram.

I. Introduction

Renewable energy sources have been attaining the maximum concern of interest today to compensate the conventional power generation through fossil fuels. Usually, the hybrid power generation systems will facilitate an environmental friendly alternative solution for standalone based applications [12]. The major confronting issue is to develop an eco-friendly, reliable, cost effective renewable energy based hybrid system to mitigate the problem of load management. Moreover, solar energy based energy harvesting can be served as a highest power density source, which makes it as a preferable option for power flow operations [6]. Section I gives a brief introduction about hybrid systems. Section II explains about the system architecture of hybrid system. Section III presents the component wise description. Section IV illustrates the power management state diagram. Section V shows the simulation results of topology considered and Section VI summarizes the conclusion part followed by references.

II. System Architecture

The system structure is designed such that, it inherently helps in combining the functions of both maximum power point tracking (MPPT) and battery charge regulation without compromising its overall efficiency. The most popular architectures of standalone PV systems proposed and implemented so far are mainly based on series connection of MPPT and battery between PV source and load as depicted in Fig: 1(a), as explained in [1],[2],[3],[4],[5],[16],[17], series-parallel combination of MPPT and battery shown in Fig: 1 (b) as described in [6],[7],[8],[9]. But such systems have few demerits like high power loss, reduction in overall system efficiency, involves high cost in hardware realization with increased complexity. Also, there is necessity of adding battery charge regulation circuitry to the series connected MPPT circuits [15].Thus, in order to overcome such aforementioned drawbacks, it is highly necessary to choose a topology which specifically facilitates multiple functions.



(a) (b)

Fig: 1(a) Series connected MPPT structure; **Fig: 1(b**) Series-Parallel combination of MPPT structure

The authors in [10] has already proposed and implemented a parallel connected MPPT system as shown in Fig: 2, which exactly resembles a hybrid system since it consists of an energy source namely PV and an energy storage unit called battery as mentioned in [11], [13]. It is basically a simple architecture that can be employed as a step-up/down converter, MPPT and battery bank charger respectively. The most important feature of this parallel structure is that, it needs only a single converter structure to realize the operation of both MPPT and battery charge/discharge regulation, thus reducing the energy processing stages.

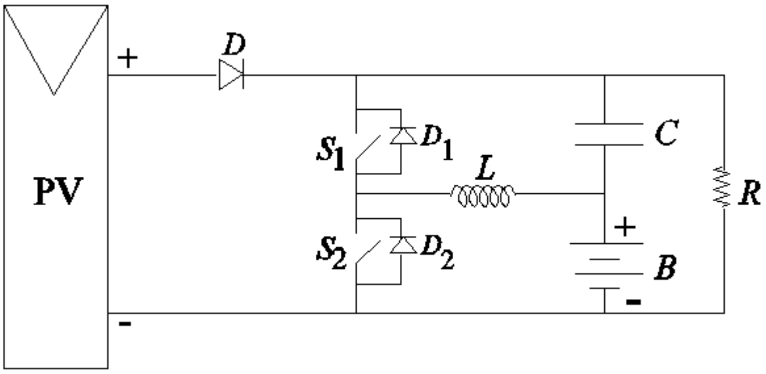


Fig: 2 Parallel connected Bi-directional DC-DC converter Topology

III. Component Wise Description

The following are the components simulated in MATLAB/SIMULINK environment.

1. PV array: The photovoltaic array has been modeled and simulated in MATLAB/SIMULINK. A single-Diode model of PV array [14] has been considered for the sack of simplicity reasons as shown in Fig: 3.

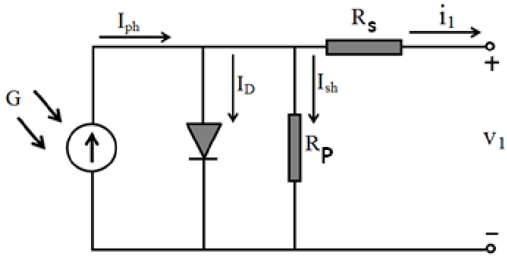


Fig: 3 PV Array Single-Diode model

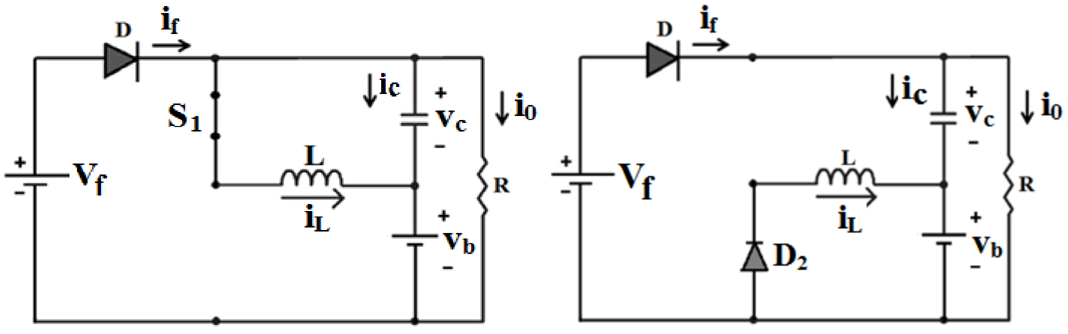
The basic equation of the PV array can be represented as:

$$i_1 = I_{ph} - I_0\left[\exp\left(\frac{v_1 + R_s i_1}{v_t a}\right) - 1\right] - \frac{v_1 + R_s i_1}{R_p}$$

where i_1 and v_1 are the output current and voltage of the PV module.

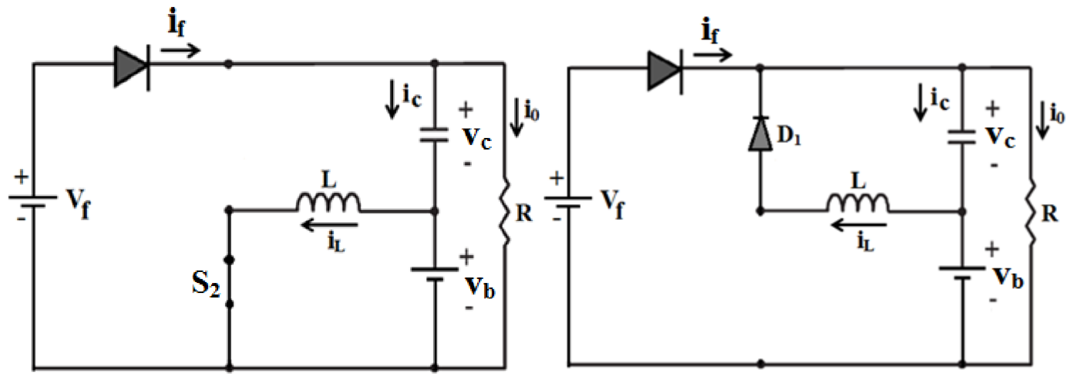
2. Bi-directional DC-DC converter topology:

Bi-directional converter shown in Fig: 2 can be considered as a multifunctional converter [10] which is having capability of working as MPPT controller, battery bank charger, step-up/down converter, battery regulator. The bi-directional converter operates as a buck converter in the battery charging mode and as a boost converter when the battery must supply the load or when the load requirement is higher than the energy generated. The power circuit operation are as given below in Fig: 4 (a) , (b) and Fig: 5 (c), (d).



(a) **(b)**

Fig: 4 (a), (b) Buck mode of Operation (S_1=ON, S_2=OFF)



(c) **(d)**

Fig: 5 (c), (d) Boost mode of Operation (S_1=OFF,S_2=ON)

State-Space representation of Bi-directional DC-DC converter topology:

There are two modes of operation namely: Buck mode and Boost mode. So, we obtain '4' state equations as follows:

Buck operation mode:

ON state:

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{L} \\ \frac{-1}{C} & \frac{-1}{R_L C} \end{bmatrix} \begin{bmatrix} i_L \\ v_c \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{C} \end{bmatrix} i_f + \begin{bmatrix} 0 \\ \frac{-1}{R_L C} \end{bmatrix} v_b$$

OFF state:

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{R_L C} \end{bmatrix} \begin{bmatrix} i_L \\ v_c \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{C} \end{bmatrix} i_f + \begin{bmatrix} \frac{1}{L} \\ \frac{-1}{R_L C} \end{bmatrix} v_b$$

Boost operation mode:

ON state:

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{R_L C} \end{bmatrix} \begin{bmatrix} i_L \\ v_c \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{C} \end{bmatrix} i_f + \begin{bmatrix} \frac{-1}{L} \\ \frac{-1}{R_L C} \end{bmatrix} v_b$$

OFF state:

$$\begin{bmatrix} \dfrac{di_L}{dt} \\ \dfrac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \dfrac{-1}{L} \\ \dfrac{1}{C} & \dfrac{-1}{R_L C} \end{bmatrix} \begin{bmatrix} i_L \\ v_c \end{bmatrix} + \begin{bmatrix} 0 \\ \dfrac{1}{C} \end{bmatrix} i_f + \begin{bmatrix} 0 \\ \dfrac{-1}{R_L C} \end{bmatrix} v_b$$

IV. Power Management Strategies

The power flow model which is shown in Fig: 6 describes about the different modes of transition (or) power flow from PV source to the load and converter. The converter includes the MPPT algorithm and battery. Incremental Conductance (InC) MPPT algorithm which is described in [18] is used to operate the PV array at maximum power point (MPP) respectively.

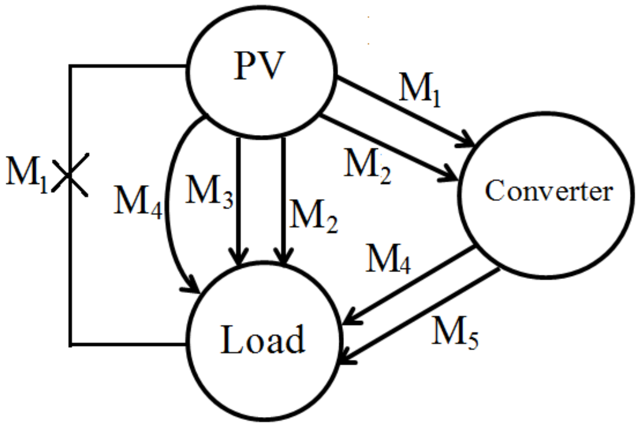


Fig: 6 State diagram (or) power flow diagram.

Modes of transition: From Fig: 6, the power flow conditions are explained as described below:

- Mode 1 (M_1): operation without load (I_L=0; I_f=I_c)
  When load is not connected, the battery is charged with the PV module current (I_f=I_c).
- Mode 2 (M_2): operation with load current less than MPP current (I_L<I_{mpp})
  If the load current value (I_c) is lower than the PV module MPP current (I_{mpp}), part of the energy generated by the PV module is used to supply the load, and another part is used to charge the battery.
- Mode 3 (M_3): operation with load current equal to MPP current (I_L=I_{mpp})
  In this condition, the power processed by the dc-dc converter is zero. The efficiency of the power system can be considered close to 100% because the maximum power of the PV module is transferred to the load without any power processing by dc-dc converter.
- Mode 4 (M_4): operation with load current higher than MPP current (I_L>I_{mpp})
  All the energy generated by the PV module is supplied to the load. The additional power that is necessary to complement the load power must be supplied by dc-dc converter. The battery is discharged in this condition.
- Mode 5 (M_5): operation without solar irradiation (I_f=0)

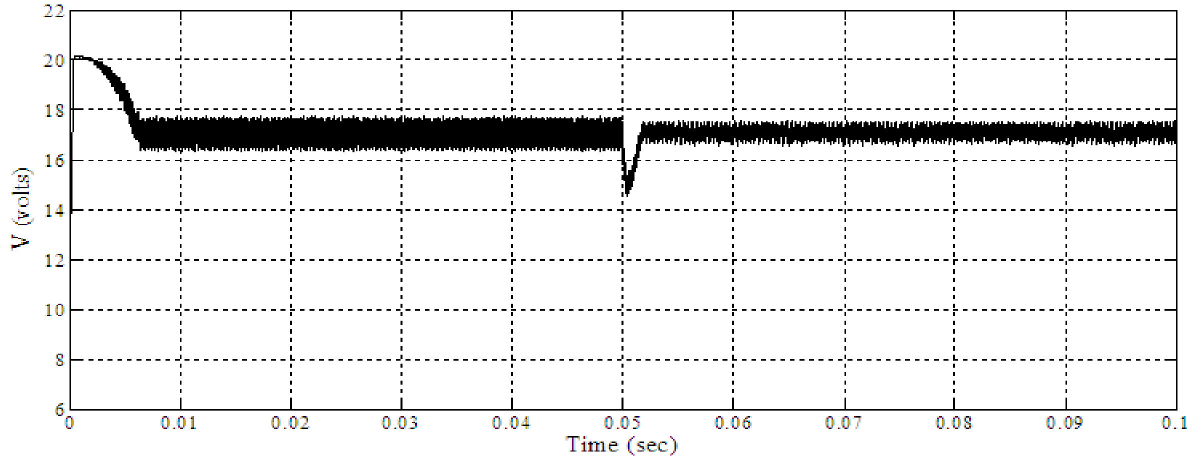
The dc-dc converter supplies the load during operation when there is no solar irradiation or under shading condition. The battery will be in discharging condition and the dc-dc converter operates as boost converter.
where
I_f= photovoltaic current; I_L=load current; I_c=converter current; Impp = Current at maximum power point.

V. Simulation Results

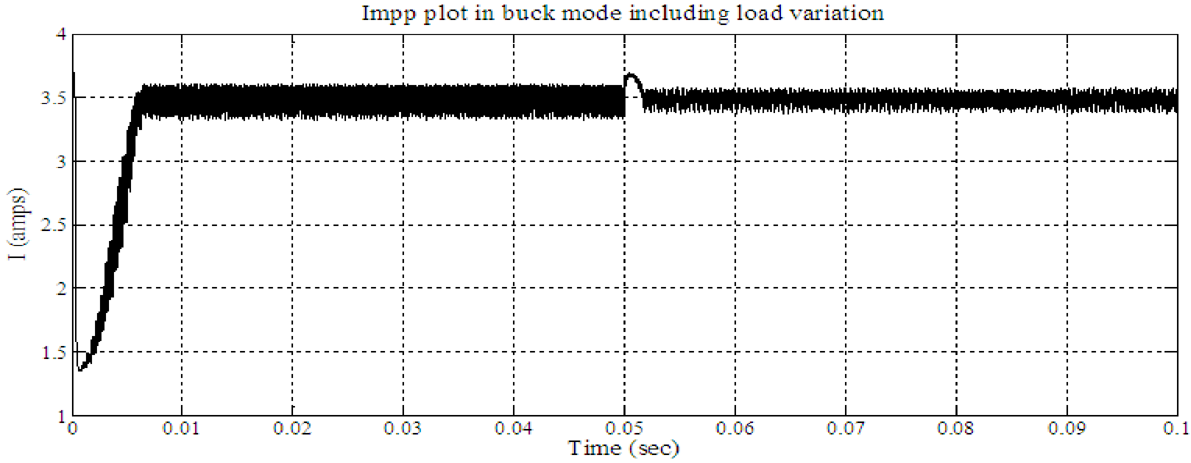
Simulation results of PV array with Bi-directional converter is as shown below:

(a) Only Buck mode of operation with load variation:

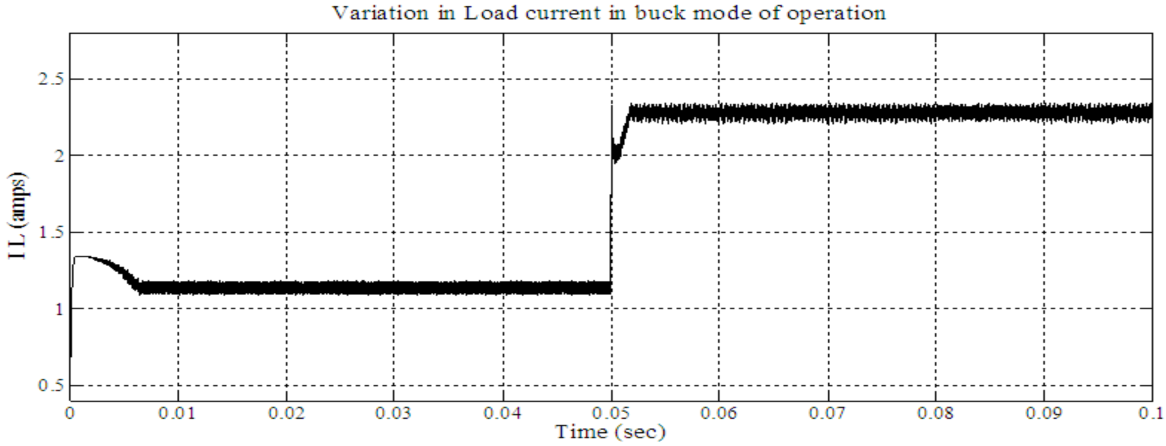
In buck mode of operation, I_{mpp}=I_c+I_L
where I_{mpp}=Current at MPP, I_c = Converter current, I_L = Load current.



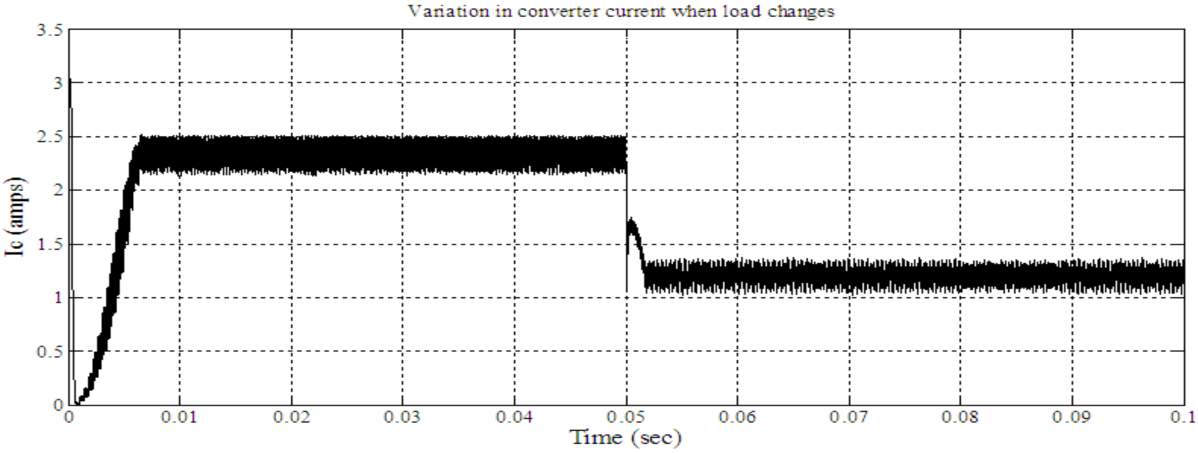
Impp plot in buck mode including load variation



Variation in Load current in buck mode of operation

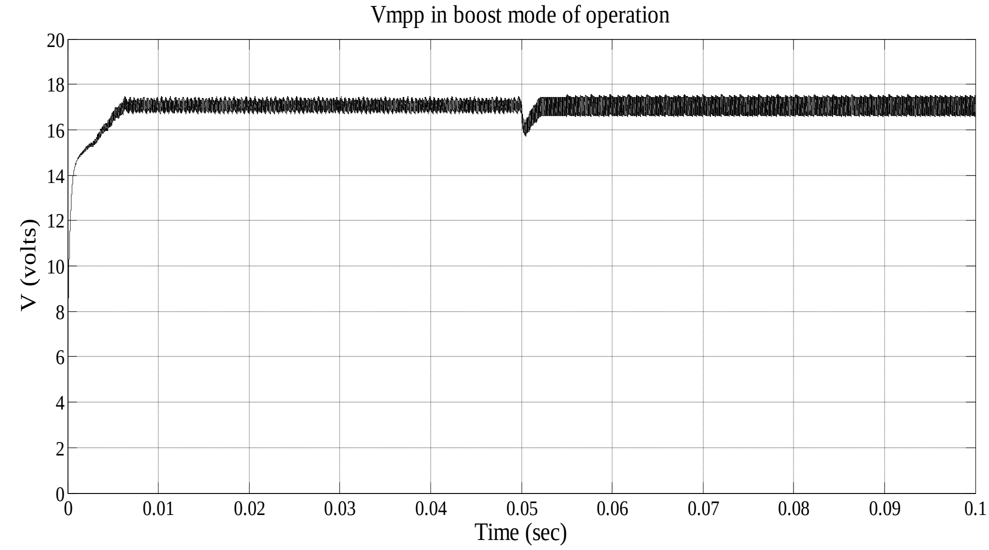


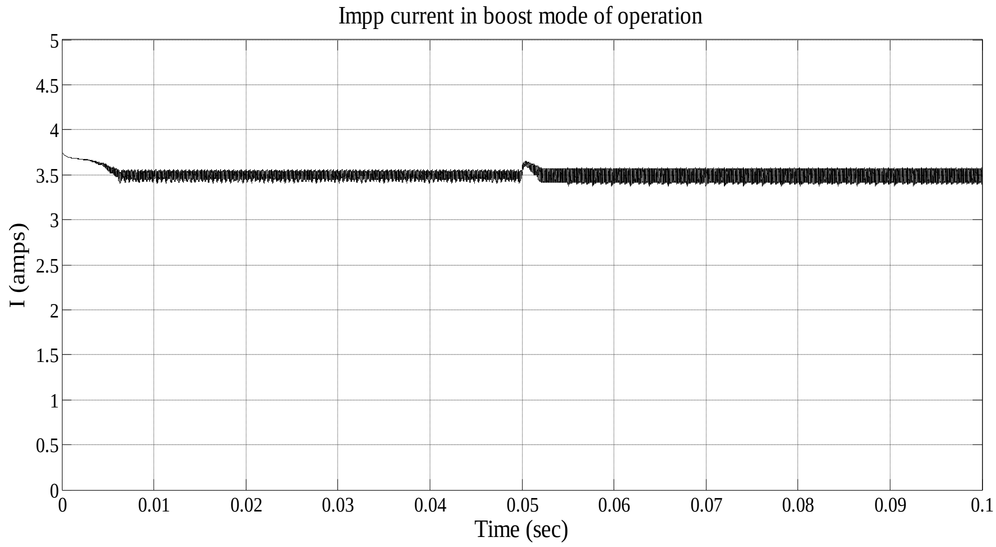
Variation in converter current when load changes

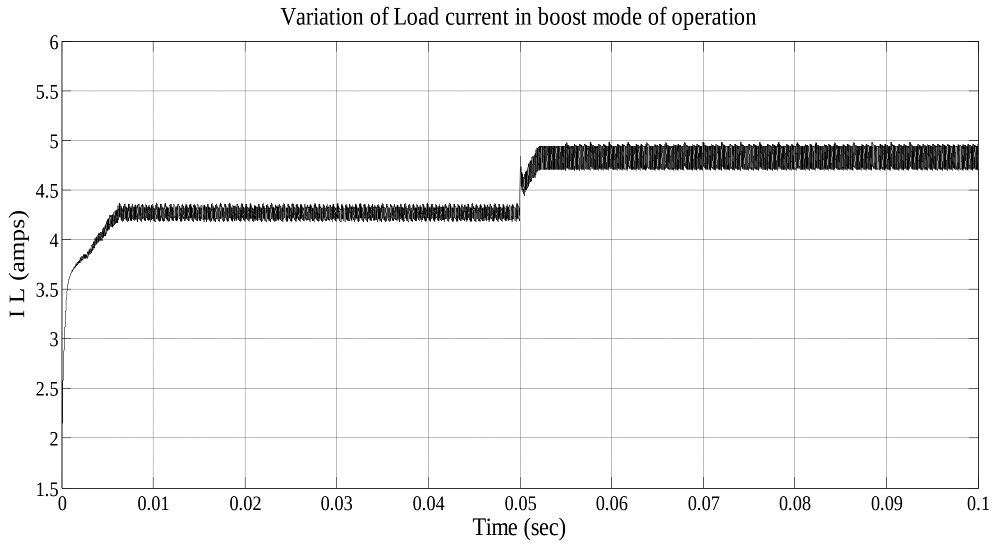


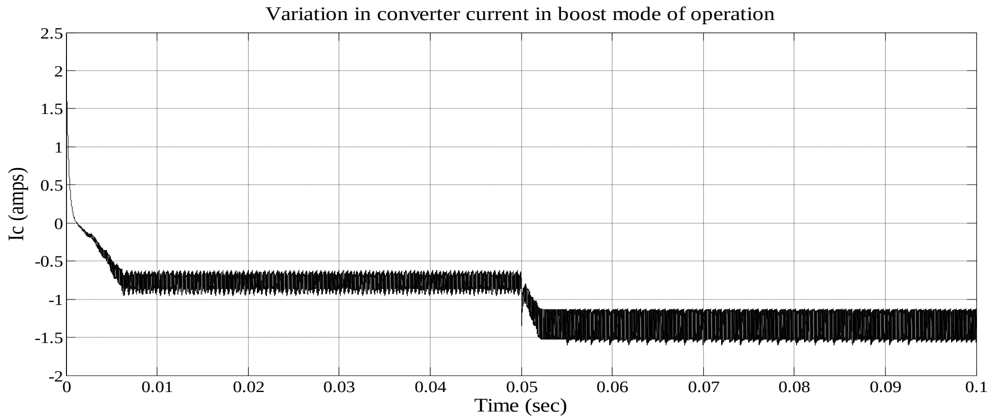
(b) Only Boost mode of operation with load variation:

In boost mode, $I_{mpp}+I_c=I_L$

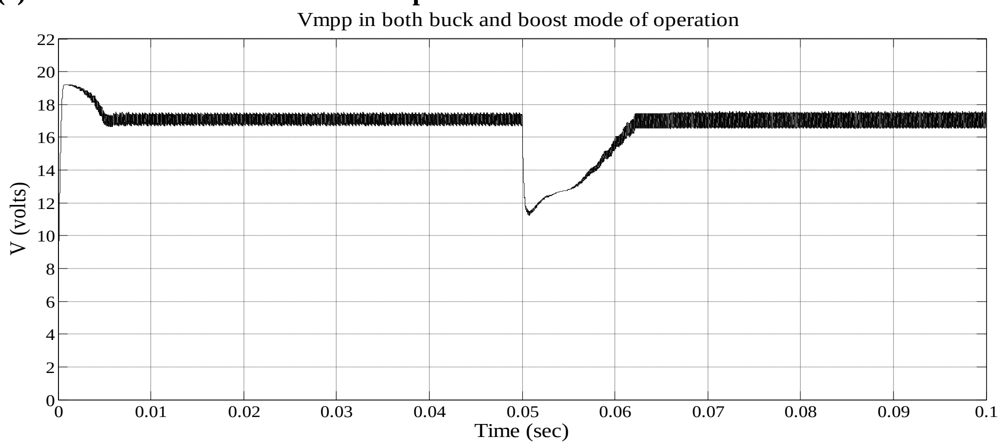


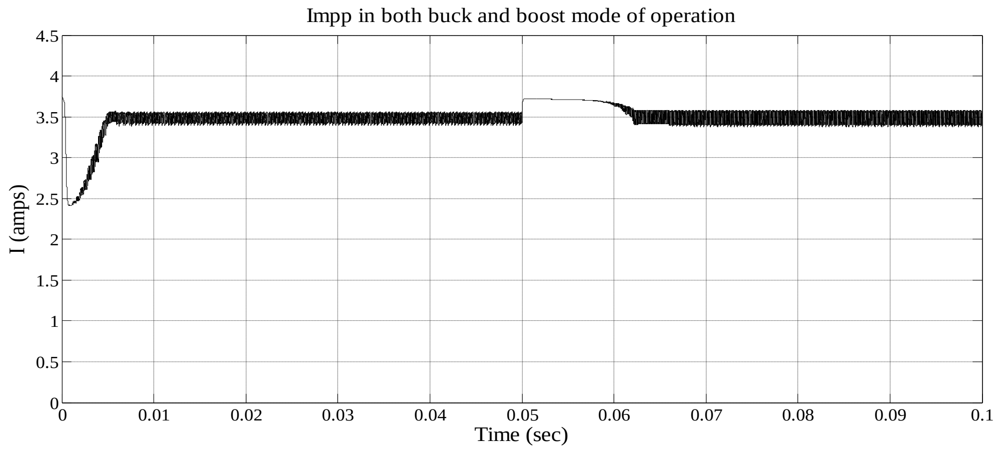


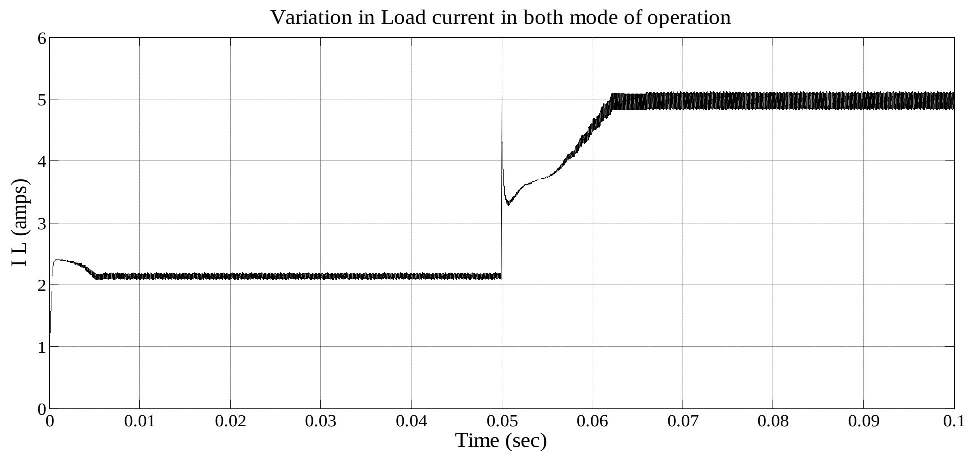


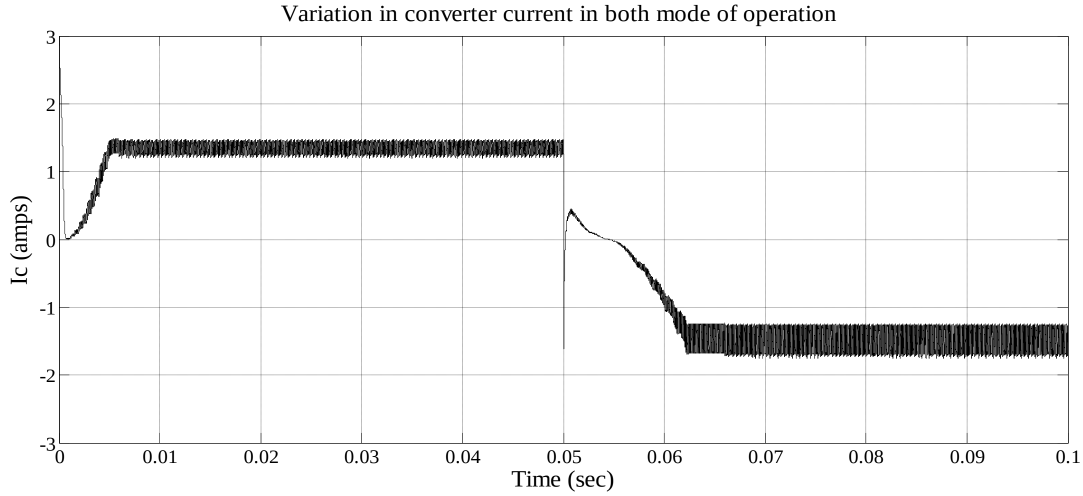


(c) Both Buck and Boost modes of operation with load variation:









VI. Conclusion

This paper mainly explained about the importance of coordination control and power flow diagram of parallel connected PV array system. The simulation results show the variation of V_{mpp} and I_{mpp} at different modes of operation of the bi-directional DC-DC converter topology. There is a considerable reduction in the cost of circuit and model is simple to analyze. The state equations are also presented in this paper to understand the system behavior.

References

[1]. A. Nasiri, S. A. Zabalawi, And G. Mandic, "Indoor Power Harvesting Using Photovoltaic Cells For Low-Power Applications," Ieee Transactions On Industrial Electronics, Vol. 56, No. 11, Pp. 4502–4509, November 2009.

[2]. N. Fermia, G. Petrone, G. Spagnuolo, And M. Vitelli, "Optimization Of Perturb And Observe Maximum Power Point Tracking Method," Ieee Transactions On Power Electronics, Vol. 20, No. 4, Pp. 963–973, July 2005.

[3]. L. Zhang, W. G. Hurley, And W. H. Wolfle, "A New Approach To Achieve Maximum Power Point Tracking For Pv System With A Variable Inductor," Ieee Transactions On Power Electronics, Vol. 26, No. 4, Pp. 1031–1037, April 2011.

[4]. W. Xiao, N. Ozog, And W. G. Dunford, "Topology Study Of Photovoltaic Interface For Maximum Power Point Tracking," Ieee Transactions On Industrial Electronics, Vol. 54, No. 3, Pp. 1696–1704, June 2007.

[5]. S. J. Chiang, H. J. Shieh, And M. C. Chen, "Modeling And Control Of Pv Charger System With Sepic Converter," Ieee Transactions On Industrial Electronics, Vol. 56, No. 11, Pp. 4344–4353, November 2009.

[6]. F. Ongaro, S. Saggini, And P. Mattavelli, "Li-Ion Battery-Supercapacitor Hybrid Storage System For A Long Lifetime, Photovoltaic-Based Wireless Sensor Network," Ieee Transactions On Power Electronics, Vol. 27, No. 9, Pp. 3944–3952, September 2012.

[7]. H. Wang And B. Li, "The Cooperated Mppt Control Of Stand-Alone Pv Power Generation System," Conf. Proceedings Of Intelligent Control And Automation (Wcica), 2010.

[8]. Z. Liao And X. Ruan, "A Novel Power Management Control Strategy For Stand-Alone Photovoltaic Power System," Conf. Procedings Of Power Electronics And Motion Control Conference 2009.

[9]. H. Mahmood, D. Michaelson, And J. Jiang, "Control Strategy For A Standalone Pv/Battery Hybrid System," Conf. Proceedings Of Iecon 2012 - 38th Annual Conference On Ieee Industrial Electronics Society 2012.

[10]. R. Gules, J. D. P. Pacheco, H. L. Hey, And J. Imhoff, "A Maximum Power Point Tracking System With Parallel Connection For Pv Stand-Alone Applications," Ieee Transactions On Industrial Electronics, Vol. 55, No. 7, Pp. 2674–2683, July 2008.

[11]. D. J. Lee And L.Wang, "Small-Signal Stability Analysis Of An Autonomous Hybrid Renewable Energy Power Generation/Energy Storage System Part I:Time-Domain Simulations," Ieee Transactions On Energy Conversion, Vol. 23, No. 1, Pp. 311–320, March 2008.

[12]. A. M. O. Haruni, M. Negnevitsky, Md. E. Haque, And A. Gargoom, "A Novel Operation And Control Strategy For A Standalone Hybrid Renewable Power System," Ieee Transactions On Sustainable Energy, Vol. 4, No. 2, Pp. 402–413, April 2013.

[13]. F. Valenciaga And P. F. Puleston, "Supervisor Control For A Stand-Alone Hybrid Generation System Using Wind And Photovoltaic Energy," Ieee Transactions On Energy Conversion, Vol. 20, No. 2, Pp. 398–405, June 2005.

[14]. M. G. Villalva, J. R. Gazoli, And E. R. Filho, "Comprehensive Approach To Modeling And Simulation Of Photovoltaic Arrays," Ieee Transactions On Power Electronics, Vol. 24, No.5, Pp. 1198-1208, May 2009.

[15]. S.K. Patil, D.K. Mahadik, "Design Of Maximum Power Point Tracking (Mppt) Based Pv Charger," Iosr Journal Of Electronics And Communication Engineering (Iosr-Jece),2011..

[16]. Govind Anil, Nirmal Murugan, Mufeed Ubaid, "Pi Controller Based Mppt For A Pv System", Iosr Journal Of Electrical And Electronics Engineering (Iosr-Jeee)Vol-6,Issue 5, 2013.

[17]. Shridhar Sholapur, K.R. Mohan, T.R. Narasimhegowda, "Boost Converter Topology For Pv System With Perturb And Observe Mppt Algorithm", Iosr Journal Of Electrical And Electronics Engineering (Iosr-Jeee) Vol-9, Issue 4, 2014.

[18]. A. Safari, Mekhilef. S, "Simulation And Hardware Implementation Of Incremental Conductance Mppt With Direct Control Method Using Cuk Converter", Ieee Transactions Of Industrial Electronics, Vol No:58, Issue: 4, P No:1154-1161, April, 2010.