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Voltage Regulation of Standalone Solar Home System

Akshay Patel[1], Sumit K. Rathor[2]

[1]Electrical Engineering Department (GCET)
[2]Electrical Engineering Department (GCET)

Abstract — *Microgrid is easiest way to meet increasing demand of rural areas. Currently growth in DC home appliances load like LED bulb, Mobile/Laptop charger, oven, hair-dryer etc. are increasing and therefore DC-DC converter is solution to meet electricity need from local distributed energy resources to increase system efficiency. This paper represent results of simulation of DC-DC converter, maximum power point tracking algorithm for solar photovoltaic module and closed loop PI control system to obtain 12v and 24v dc constant output voltage. The proposed system is used to track maximum power from solar module and is directly given to DC load or DC microgrid.*

Keywords — *Microgrid, Maximum Power Point Tracking, Voltage regulation, Photovoltaic, DC-DC converter*

I. Introduction:

With increase in demand of low cost energy and growing concern about environmental issues, solar photovoltaic based systems are being increasingly used. The application of PV system can be classified into two categories: Standalone system and Electric Utility grid connected system. The standalone system is widely used in rural areas where electric utility grid is out of reach.

But due to the problem of nonlinear I-V (Current vs Voltage) characteristic limit application of solar PV. Due to this Nonlinearity it is difficult to extract maximum power from solar panel. Therefore to extract available maximum power from solar photovoltaic system maximum power point tracking (MPPT) methods have been used.

Many MPPT algorithms have been proposed in the literature to extract maximum available power like perturb & observe algorithm, incremental conductance algorithm and fuzzy logic method.

Maximum power produced by solar cell depends on the solar temperature and irradiation. As the solar irradiation falling on Photovoltaic module varies throughout the day, operating points of PV module also change. P&O algorithm is most widely used algorithm to track maximum power. This algorithm perturbs the duty cycle which controls the power converter and find the maximum power point of P-V characteristics.

II. Equivalent circuit of Solar PV cell:

Figure show a single solar cell. As shown in fig. (1) A resistance Rs that is connected in series with a parallel combination of the following elements (1) Current source (2) Two exponential diodes (3) Parallel resistor (Rsh)

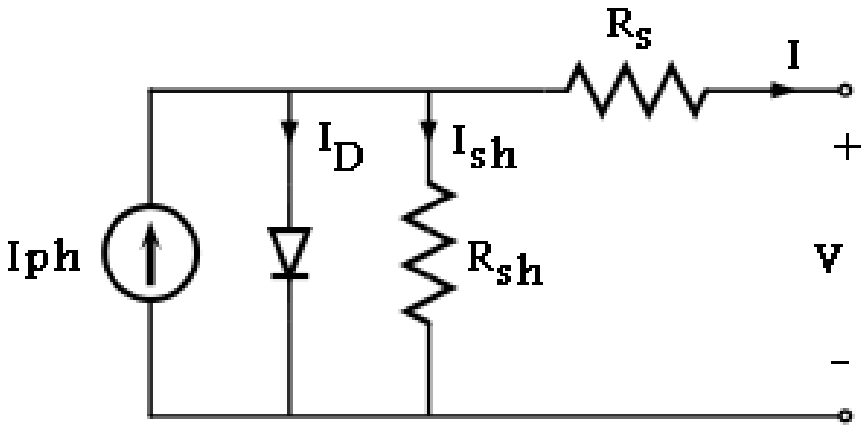


Fig. (1) Equivalent circuit of solar cell

III. Solar cell Characteristics:

The V-I characteristics of the solar cell differs from each other. The V-I characteristics of solar PV cell is as shown in figure. Due to the nonlinearity of characteristics extraction of maximum power from solar panel is not possible. The power voltage curve is as shown in the figure. There is a peak power point in P-V curve that represent a particular voltage and current. But solar panel will not be able to maintain the maximum power point constantly due to the some deviation and change in irradiation and changes in temperature.

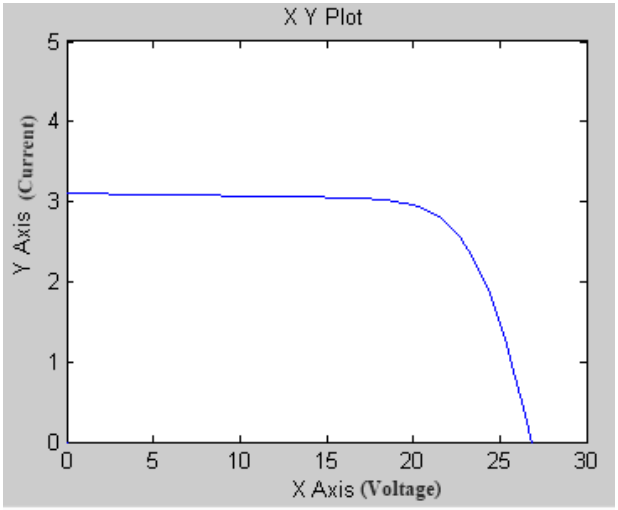


Fig. (2-a)I-V Characteristic

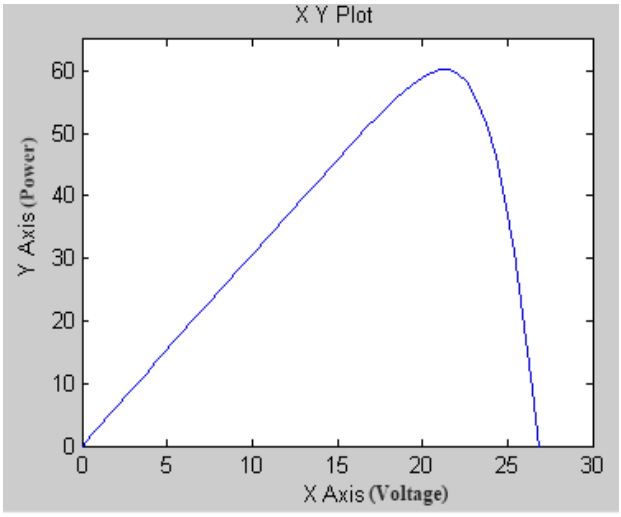


Fig. (2-b)P-V Characteristic

IV. Solar DC microgrid with MPPT and PI controller:

Microgrid is group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundary which can connect or disconnect from electric utility grid to operate it in both grid connected or islanded mode. The main advantage of a DC microgrid is that it provides a better compliance with DC type loads and DERs. For example Solar PV and battery storage would give output in form of DC so there is readily available DC power for DC loads. So there will be fewer conversion loss. This DC microgrid integrated with solar PV generation is shown in fig. This DC microgrid is combination of solar PV module, MPPT algorithm, DC-DC converter, DC loads.

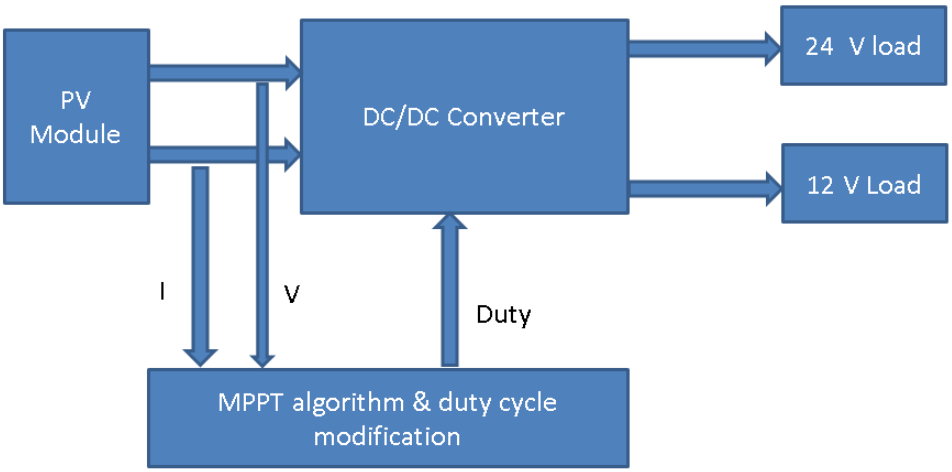


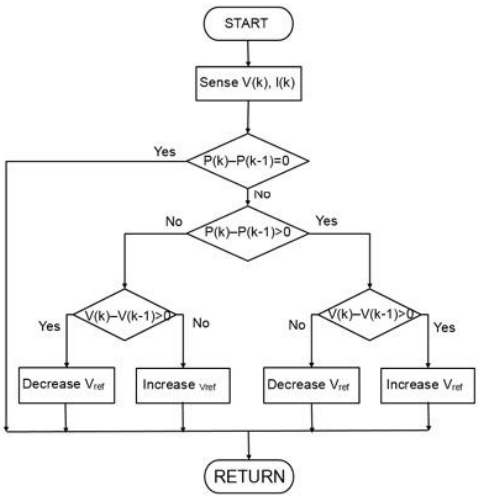
Fig. (3) DC microgrid with MPPT and PI

V. Solar PV module and MPPT:

Power supplied by a PV module depends on the load connected to the PV module. MPPT is algorithm which used with solar charge controller to extract maximum available power from PV module under specific conditions. The voltage at which Solar PV module can produce maximum power is called 'Peak Power Point' or 'Maximum Power Point'. MPPT is most effective under Cloudy or hazy atmosphere, cold weather.

(1)Perturb and Observe algorithm:

Perturb and Observe algorithm is one of the most used algorithm from all the MPPT algorithms. This algorithm uses a fixed step size value, which is determined by requirement of tracking accuracy and speed of the solar module considered. However, the accuracy will be decreased with the increase in step size. Because of fast varying atmospheric conditions, Perturb and Observe algorithm will not be able to track MPP (Maximum Power Point) so it will result in lower efficiency.



VI. DC-DC converter

Solar PV module gives DC power therefore it can be directly fed to DC load through DC-DC converter to reduce conversion loss. In this paper Buck-Boost converter is used due to its ability to increase/decrease output voltage.
Buck-Boost converter is designed in MATLAB using MOSFET (switch) diode &RLC circuit element which are there in power system library. Buck-Boost converter gives output voltages that may be higher or lower than the input voltage depends on duty cycle. If duty cycle is less than 0.5 than operate in buck mode and if duty cycle is greater than 0.5 than operate in boost mode. At the value of 0.5 converter will operate in ideal mode.

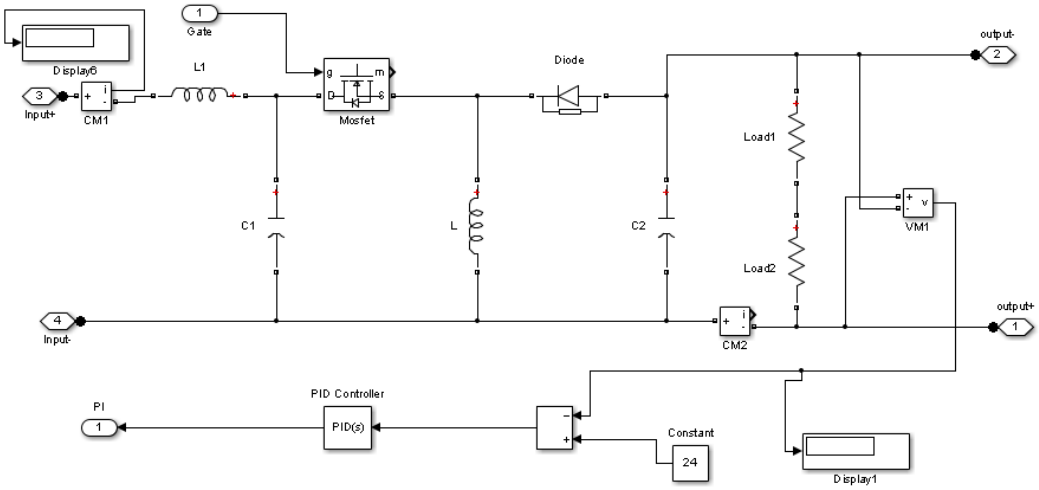


Fig. (4)Closed loop buck-boost converter with PI controller

VII. Simulation result:

The Simulink model of closed loop DC-DC converter for DC microgrid with Solar PV module is as shown in fig. Solar PV module is modelled using electrical characteristics to provide output voltage and current. Perturb & Observe algorithm is design in MATLAB function block using C language. PWM signal are generated using combination of output of PI controller and MPPT duty cycle.

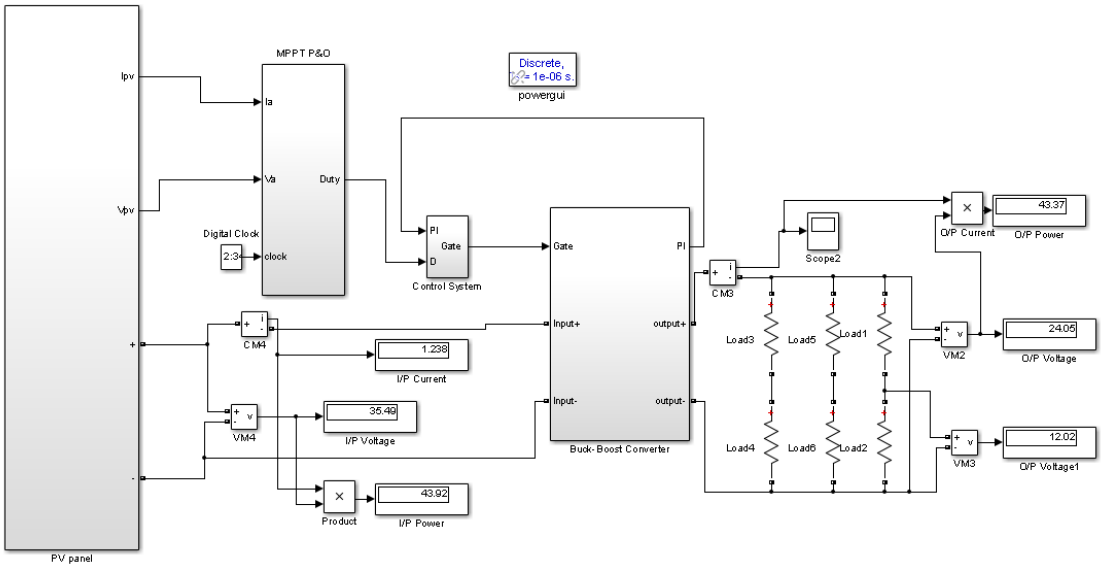


Fig. (5)Closed loop buck-boost converter integrated with solar module

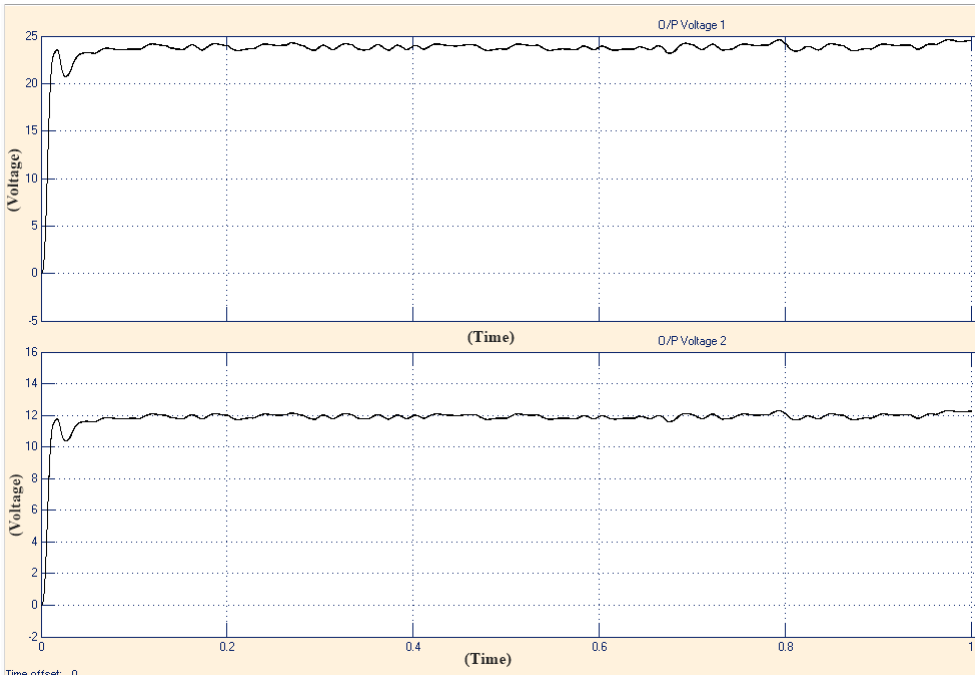


Fig. (6) DC 12V & 24V output voltage of Buck-Boost converter

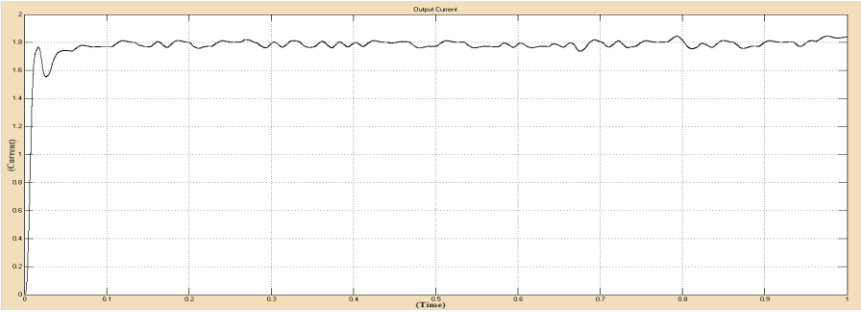


Fig. (7) DC 1.8A output current of buck-boost converter

VIII. Conclusion:

This paper presents photovoltaic system with MPPT algorithm and DC-DC converter. Equivalent circuit of solar cell with I-V and P-V characteristics of PV cell is presented. To extract maximum available power from PV module, Perturb & observe algorithm is used. This paper also include simulation of DC-DC converter for application of DC microgrid at two different voltage levels: 12V and 24V DC. This low voltage DC output voltage is used for small home appliances load. The constant output voltage is obtained through PI controller and MPPT algorithm to track maximum power from solar PV module. The simulation result shows the buck-boost converter application for maintaining constant voltage at DC bus irrespective of variation of solar PV generation.

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