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RESEARCH ARTICLE

DUAL MAXIMIZATION OF POWER IN A SOLAR PHOTOVOLTAIC SYSTEM

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ABSTRACT

This paper proposes an efficient solar tracker system using a dual MPPT controller. It consists of three step DC to DC converter, which has been controlled by a microcontroller based unit. MPPT (Maximum Power Point Tracking) is used in photovoltaic system to maximize the PV array output power, irrespective of temperature, irradiation conditions and electrical characteristics of the load. The first MPPT controller is a dual axis solar tracker, which ensures optimization of the conversion of solar energy into electricity by properly orienting the PV panel in accordance with the real position of the sun to track azimuth and elevation angles. The second MPPT controller controls the duty cycle of the converter using modified Incremental Conductance algorithm to enable the PV array operate at maximum operating power at all conditions. The proposed control scheme eliminates oscillations and tracks the global maximum power point (GMPP) accurately. The simulation has been accomplished in MATLAB software.

INTRODUCTION

The need of the hour is the renewable energy resources which takes the mankind in the path of non – polluting, green and healthy ecosystem. Solar power is the cheaper and best solution for electricity generation as it is available everywhere and is free to harness. Mechanical solar tracking system maximizes the solar energy by positioning PV panels such that solar radiations are normal to the panel surface. Position of sun can be tracked by sensors and control algorithms and the solar panel maintained always normal to direction of sun. Dual – axis tracking is used which is implemented using PIC microcontroller. There is a Maximum Power Point (MPP) in the power - voltage characteristic of PV panel where power is maximum. MPPT utilize algorithm for operating PV panel at its MPP irrespective of atmospheric conditions so that maximum power is extracted from panel. The algorithm used in this paper is Modified Incremental Conductance (Inc Cond) algorithm. A DC-DC converter interface is required in between PV cell and battery for implementing MPPT, which is a Three Step Boost converter. MPPT algorithm is implemented using same PIC microcontroller.

Modeling of pv cell

The simplest model of a PV cell consists of an ideal current source in parallel with an ideal diode.

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The current generated by photons is represented by the current source (often denoted as I_{PH} or I_L). The output current (I) from the PV cell is found by applying the Kirchoff's current law (KCL) on the equivalent circuit shown in Fig. 1

$$I = I_{sc} - I_d \quad (1)$$

where: I_{SC} is the short-circuit current and I_d is the current shunted through the intrinsic diode.

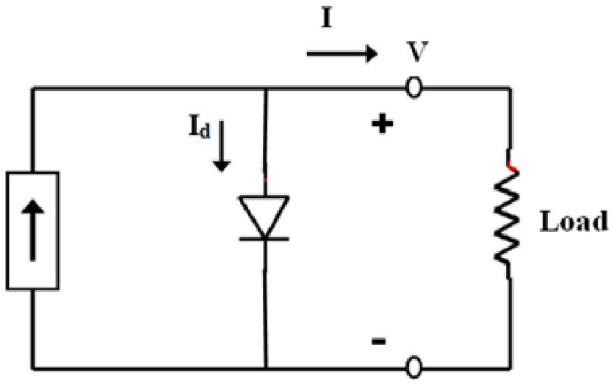

Fig. 1. Equivalent Circuit of PV Cell

The diode current I_d is given by Shockley's diode equation:

$$I_d = I_o\left(e^{\frac{qV_d}{kT}} - 1\right) \quad (2)$$

Where,

I_o is the diode's reverse saturation current (A),
q is the electron charge (1.602×10-19 C),
V_d is the voltage across the diode (V),
k is the Boltzmann's constant (1.381×10-23 J/K),
T is the junction temperature (K).

A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline silicon (Si) cells, thus a number of PV cells are connected in series to achieve a desired output voltage. The series-connected cells are placed in a frame to form a module.

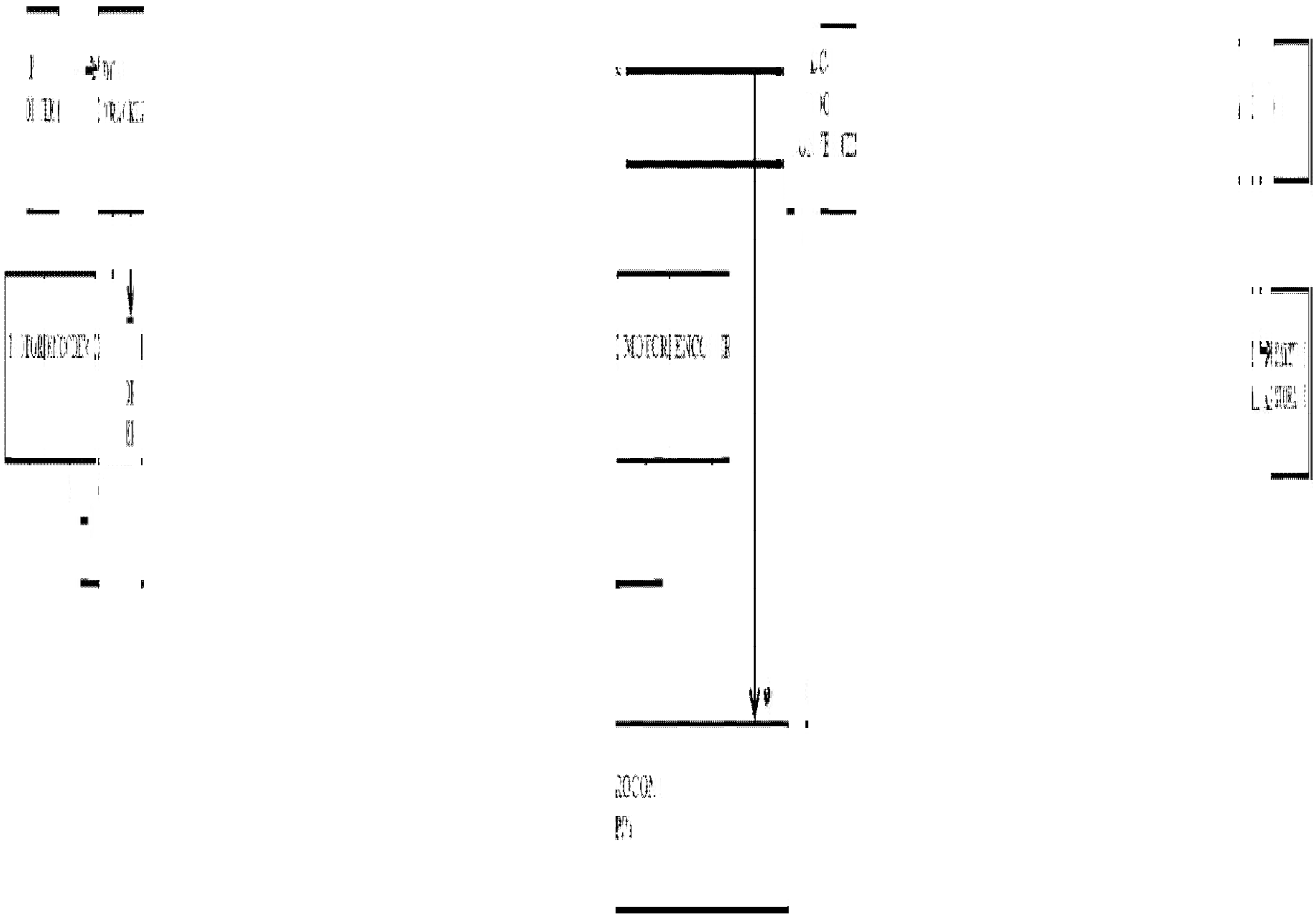

Fig. 2. Block Diagram of the Proposed System

Replacing I_d of the equation (1) by the equation (2) gives the current-voltage relationship of the PV cell

$$I = I_{sc} - I_o\left(e^{\frac{qV}{kT}} - 1\right) \quad (3)$$

The reverse saturation current of diode (I_o) is found by setting the open-circuit condition. Using the equation (3), let I = 0 (no output current) and solve for I_o.

$$0 = I_{sc} - I_o\left(e^{\frac{qV_{oc}}{kT}} - 1\right) \quad (4)$$

$$I_{sc} = I_o\left(e^{\frac{qV_{oc}}{kT}} - 1\right) \quad (5)$$

$$I_o = \frac{I_{sc}}{\left(e^{\frac{qV_{oc}}{kT}} - 1\right)} \quad (6)$$

SOLAR TRACKER

In order to track the sun trajectory, a two-axis tracker is used. The tracker is controlled using an astronomical angular trajectory generation. Given the date, time, latitude, and longitude of the current location of the system, the microcontroller calculates the sun reference azimuth and elevation angles using pre implemented equations. The panel azimuth and elevation angles are next controlled to follow their reference values using digital closed loop position control. Incremental optical encoders are connected to the motor shafts to provide the angular position and speed information to the microcontroller to implement the control algorithm.

Dual –Axis Solar Tracker

Dual axis trackers have two degrees of freedom that act as axes of rotation. They can rotate simultaneously in horizontal and vertical directions. So they are able to point exactly at the sun at all times in any location. These tracking systems realize movement both along the elevation and azimuthal axes. Dual axis tracking systems naturally provide the best performance, given that components have high enough accuracy. In the proposed system dual axis tracker is used. The tracking mechanisms can be classified into three types, namely, passive method, optical method, and the astronomical method. Astronomical tracking employs the longitude and latitude data of a given location to determine the sun current position. It involves simpler programming, reduced implementation cost, and lower power consumption as the need for additional sensors is eliminated. This method also provides high degree of accuracy and is not sensitive to atmospheric conditions. In the proposed system, astronomical method is used.

Maximum power point TRACKER (MPPT)

Maximum power point tracker (MPPT) is basically an electronic system that controls the duty circuit of the converter to enable the photovoltaic module operate at maximum operating power at all condition. It is not some sort of mechanical tracking system that physically rotates the photovoltaic modules to face sunlight directly. The advantages of MPPT are greatest during cloudy or hazy days, cold weather and when the battery is deeply discharged. There are different types of maximum power point tracker methods developed over the years and they are listed below as follows:

- Perturb and observe method
- Incremental conductance method

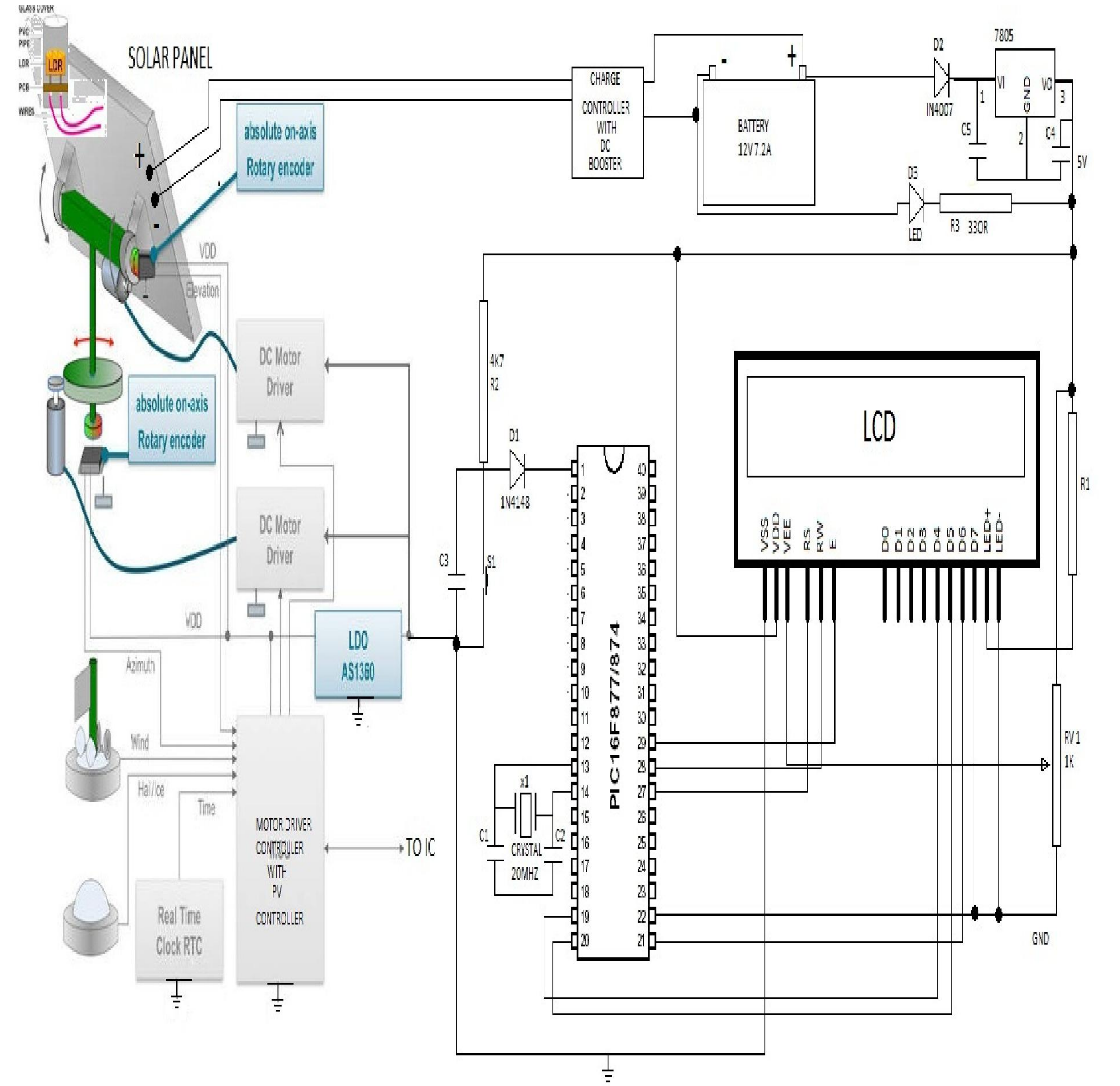

Fig. 3. Proposed System Architecture

- Fuzzy logic method
- Artificial neutral network method
- Peak power point method
- Open circuit voltage method
- Temperature method

MPPT plays a very significant role because without MPPT the desire output electrical power will not be achieved with changing weather conditions.

Modified Incremental Conductance Algorithm

The Inc Cond method makes use of instantaneous and Incremental Conductance to generate an error signal, which is zero at MPP. But, it is not zero at most of the operating points. The PI controller is used to make the error from MPPs near to zero. In the proposed system, PI controller is eliminated and duty cycle is adjusted directly from the algorithm. The step size for the Inc Cond MPPT method is generally fixed. The power drawn from PV array with a larger step size contributes to faster dynamics but excessive steady state oscillations, resulting in low efficiency.

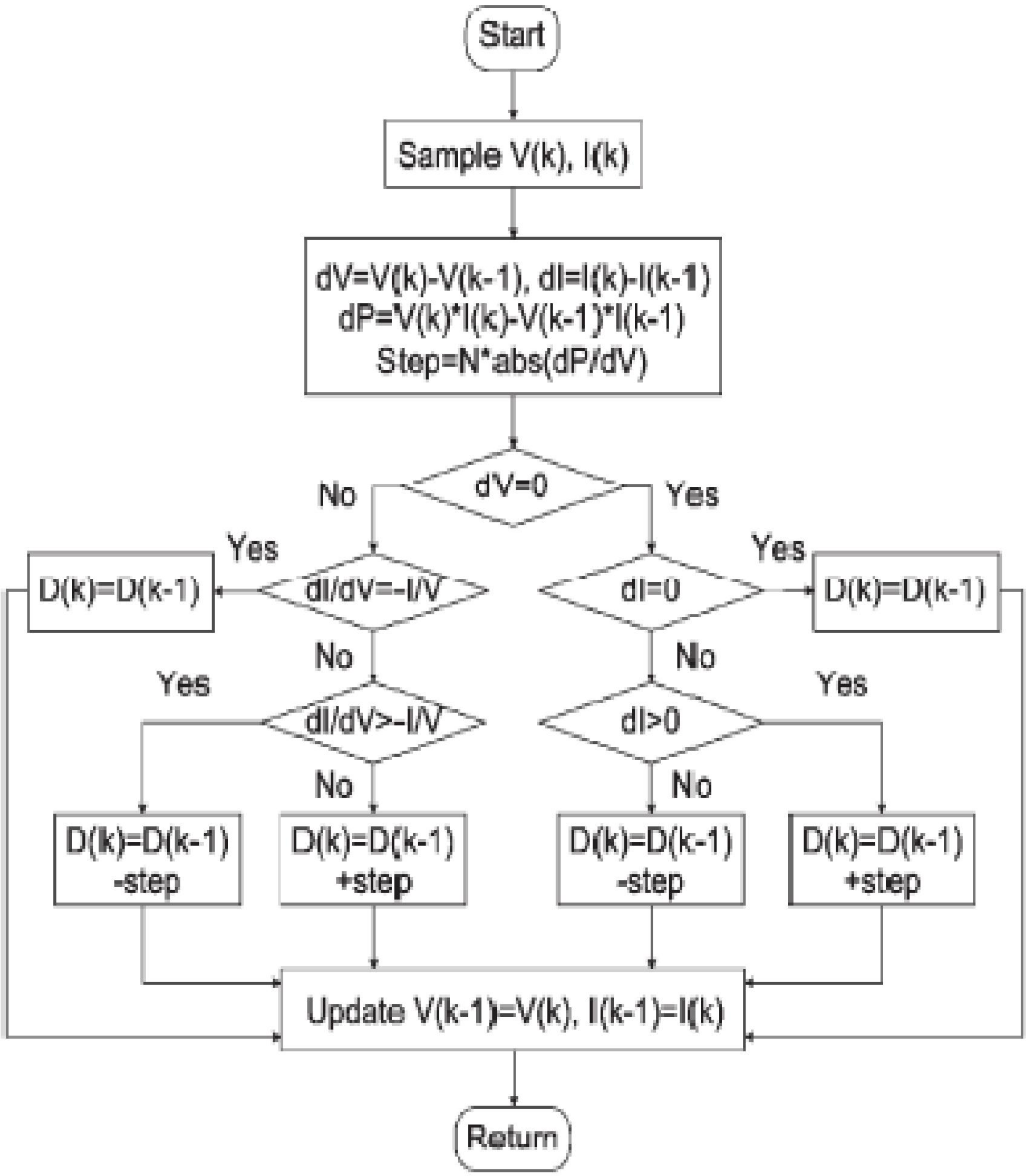

Fig. 4. Flow Chart for Modified Incremental Conductance MPPT algorithm

This is reversed while the MPPT is running with a smaller step size. Such design dilemma can be solved with variable step size iteration. Fig. 4 shows the flowchart of the modified variable step size Inc Cond MPPT algorithm, where the step size of converter duty cycle iteration is automatically tuned.

Three step boost converter

Voltage Lift Technique has been employed in design of DC/DC converters, for e.g. four series Luo-Converters.

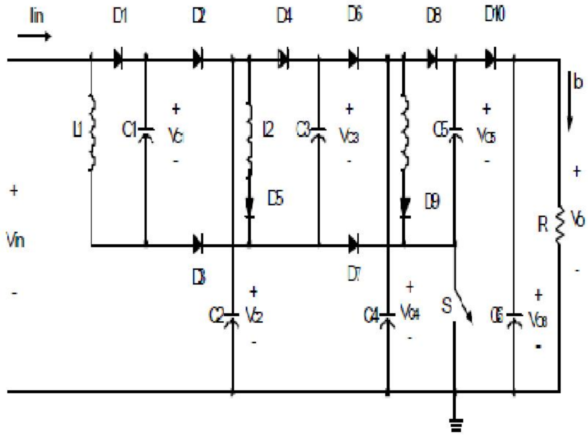

Fig. 5. Three Step Boost Converter Circuit

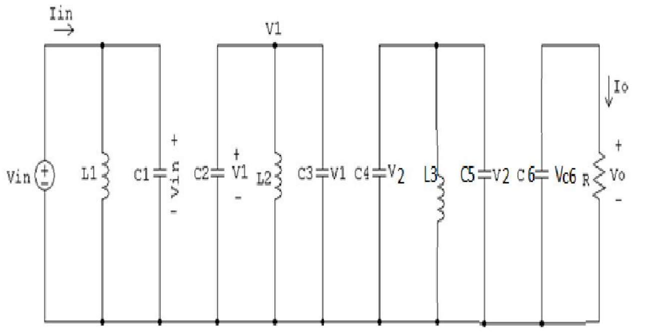

Fig.6. ON mode of Three Step Boost Converter

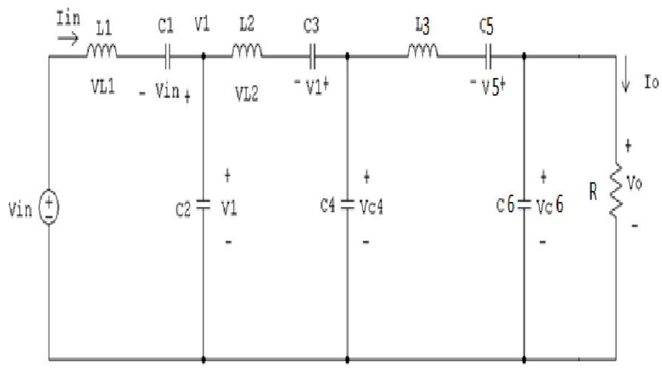

Fig.7. OFF mode of Three Step Boost Converter

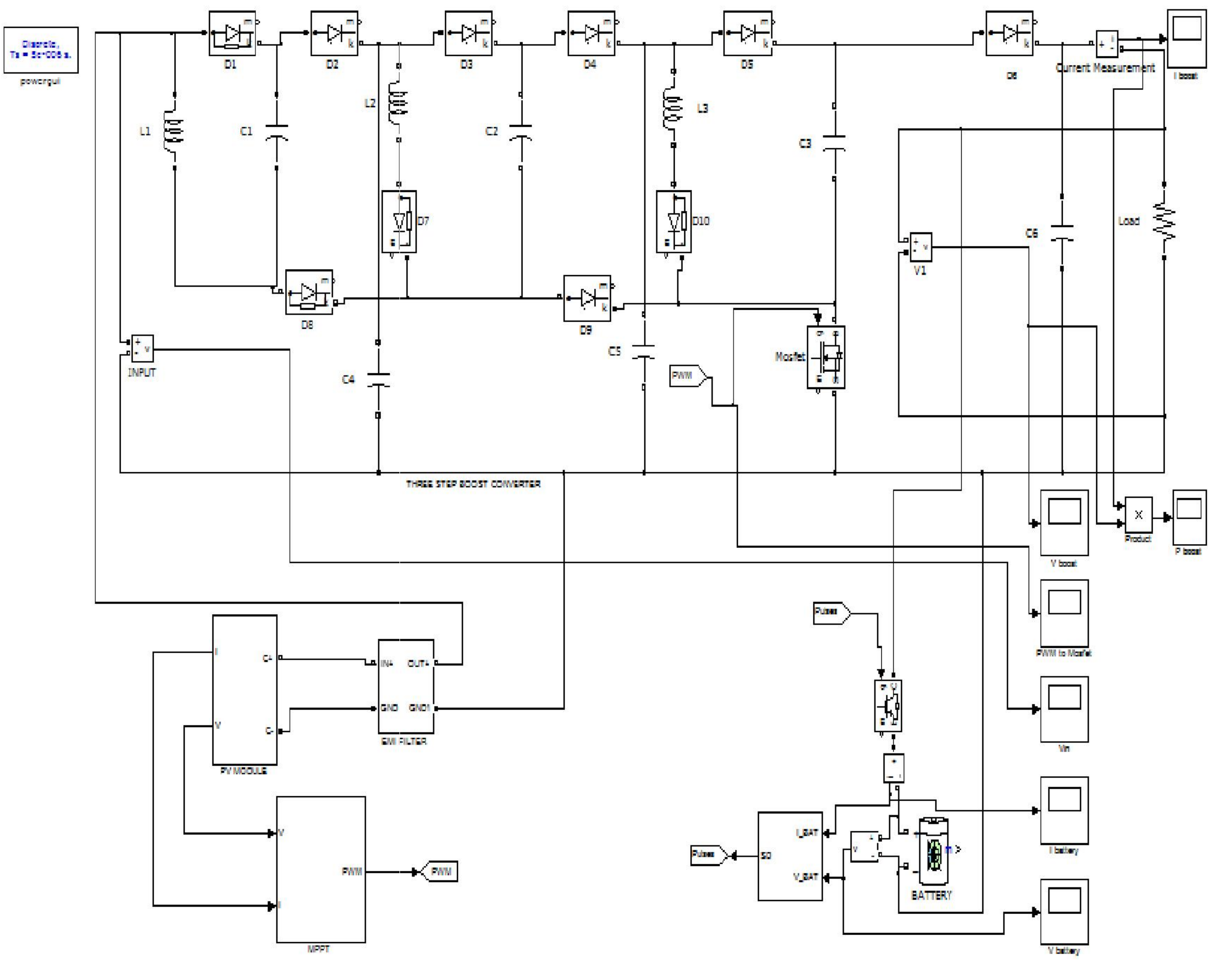

Fig. 8. Simulation Circuit of Proposed System

However output voltage increases in arithmetic progression. Super-lift converters enhance the voltage transfer gain (VTG), which increases stage-by-stage in geometric progression. A three step DC/DC boost converter is used in the proposed system, which is a triple-lift circuit. The voltage across capacitor C1 is charged to V_{in}. As described before, the voltage across capacitor

$$V_1 = \frac{2-k}{1-k} V_{in} \quad (7)$$

$$V_2 = \left(\frac{2-k}{1-k}\right)^2 V_{in} \quad (8)$$

The voltage across capacitor C5 is charged to V_2. The current flowing through inductor L3 increases with voltage V_2 during switching-on period and decreases with voltage – (V_o-2V_2) during switching-off (1-k) T. Fig. 6 and Fig. 7 shows the ON mode and OFF modes of three step boost converter. The output voltage V_o across capacitor C6 is

$$kTV_2 = (1-k)T\,(V_o - 2V_2) \quad (9)$$

$$V_o = \frac{2-k}{1-k} V_2 = \left(\frac{2-k}{1-k}\right)^2 V_1 = \left(\frac{2-k}{1-k}\right)^3 V_{in} \quad (10)$$

Simulation results

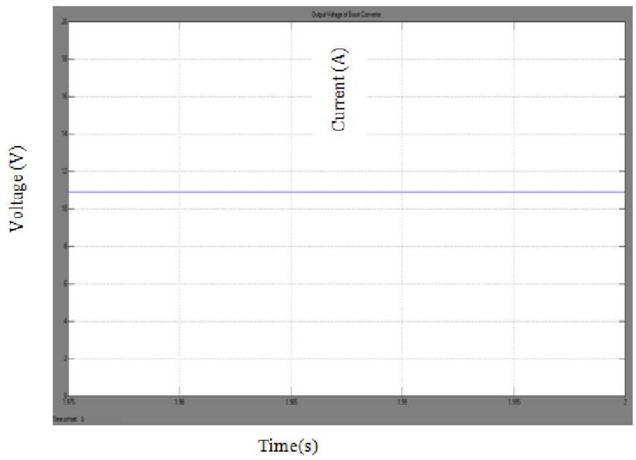

Fig. 9. Output Voltage of Boost Converter

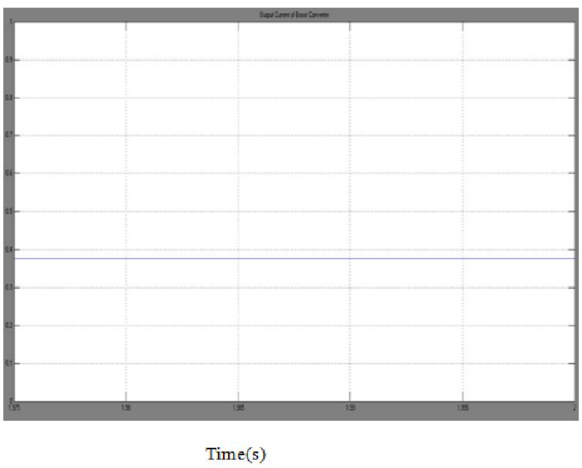

Fig.10. Output Current of Boost Converter

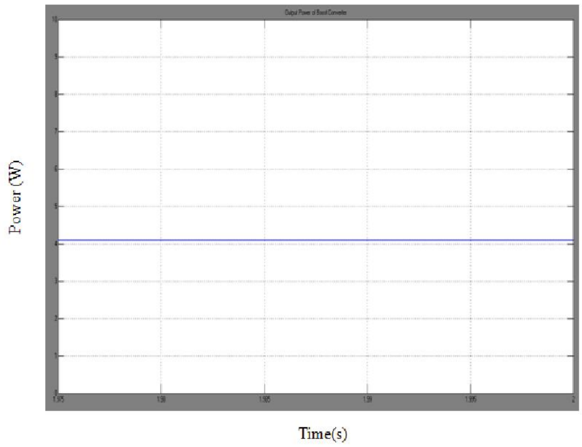

Fig. 11. Output Power of Boost Converter

Specifications of Three Step Boost Converter

1. Inductance (L1,L2,L3) : $10e^{-3}$ = 10mH
2. Capacitance (C1 – C6) : $2.2e^{-6}$ = 2.2µF
3. MOSFET – IRF540

The simulation results show that for a temperature of 25°C and insolation of 400 W/m^2, the output of PV is 4V. Output voltage of three step boost converter is 12V.

Conclusion

This paper presents an efficient solar tracker system using dual – MPPT controller. The MPPT controller is combined with dual – axis panel tracking controller to improve the efficiency of overall photovoltaic system. Simulation results show the advantages of the proposed technique. The proposed technique eliminates oscillations and tracks the GMPP accurately. The dual axis solar photovoltaic panel tracker is capable to track the sun throughout the year.

REFERENCES

Ahmad, Al., Nabulsi. and Rached Dhaouadi. 2012.Senior Member, IEEE "Efficiency Optimization of a DSP-Based Standalone PV System Using Fuzzy Logic and Dual-MPPT Control", *IEEE Transactions on Industrial Informatics*, VOL. 8, NO. 3, August 2012.

Ahmed Bin-Halabi, Adel Abdennour. and Hussein Mashaly. 2013. "Experimental Implementation of Micro-controller Based MPPT for Solar PV system", *International Conference on Microelectronics, Communication and Renewable Energy.*

Eftichios Koutroulis and Kostas Kalaitzakis. 2001. Member, IEEE, and Nicholas C.Voulgaris "Development of a Microcontroller-Based, Photovoltaic Maximum Power Point Tracking Control System", *IEEE Transactions on Power Electronics*, VOL. 16, NO.1, January 2001.

Fang Lin Luo and Hong Ye. 2013. "Super-lift boost converters", *IET Power Electronics*.

Fangrui Liu, Shanxu Duan, Fei Liu, Bangyin Liu, and Yong Kang. 2008. "A Variable Step Size INC MPPT Method for PV Systems", IEEE Transactions on Industrial Electronics, VOL. 55, NO. 7, July 2008.

Hoonki Kim. 2013. Student Member, IEEE, Sangjin Kim, Chan-Keun Kwon, Student Member, IEEE, Young-Jae Min, Member, IEEE, Chulwoo Kim, Senior Member, IEEE, and Soo-Won Kim, Member, IEEE "An Energy-Efficient Fast Maximum Power Point Tracking Circuit in an 800-μW Photovoltaic Energy Harvester", *IEEE Transactions on Power Electronics*, VOL. 28, NO. 6, June 2013.

Kok Soon Tey. 2014. Dept. of Electr. Eng., Univ of Malaya, Kuala Lumpur, Malaysia; Mekhilef.S "Modified Incremental Conductance Algorithm for Photovoltaic System Under Partial Shading Conditions and Load Variation", *IEEE Transactions on Industrial Electronics*, VOL. 61, NO. 10, October 2014.

Moacyr Aureliano Gomes de Brito, Luigi Galotto, Jr., Leonardo Poltronieri Sampaio, Guilherme de Azevedo e Melo, and Carlos Alberto Canesin. 2013.

Moein Jazayeri, Sener Uysal. 2014. Member, IEEE, Kian Jazayeri "Evaluation of Maximum Power Point Tracking Techniques in PV Systems using MATLAB/Simulink", Sixth Annual *IEEE Green Technologies Conference*, 978-1-4799-3934-3/14 $31.00 ©2014.

Sebastijan Seme. 2011. Student Member, IEEE, Gorazd Stumberger, Member, IEEE, and Joze Vorsic, Member, IEEE "Maximum Efficiency Trajectories of a Two-Axis Sun Tracking System Determined Considering Tracking System Consumption", *IEEE Transactions on Power Electronics*, VOL. 26, NO. 4, April 2011.

Senior Member, IEEE "Evaluation of the Main MPPT Techniques for Photovoltaic Applications", *IEEE Transactions on Industrial Electronics*, VOL. 60, NO.3, March 2013.

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