

MPPT Technique for Solar System Using Multiphase Boost Converter

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Abstract—Renewable energy sources is on the rise because of the acute energy crisis in the world today. Solar energy is easily available energy compared to any other renewable energy source. Photo Voltaic system has a higher capability to provide continuous power. For energy conversion system, the Maximum Power Point Tracking (MPPT) and DC-DC Converter plays a major role. Incremental Conductance based Maximum Power Point Tracking is done to track the maximum power from solar. Multiphase Boost converter has been chosen as it reduces the stress on power semiconductor devices and hence reducing the ripple current on the load. Simulation has been carried out for the entire system and results have been discussed here.

Key words: Incremental conductance, Multiphase, ripple current, stress

I. INTRODUCTION

Sun is an abundant source of clean and free energy. India plans to produce 20 Gigawatts Solar power by the year 2020, whereas we have only realized less than half a Gigawatt of our potential as of March 2010. The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost. PV cell is basically a p-n junction which generates current when exposed to solar irradiation. PV array is a series and parallel combination of PV cells to get a specific current and voltage rating. PV array has non-linear I-V characteristic and output power depends on environmental conditions such as solar irradiation and temperature. There is a point on I-V, P-V characteristic curve of PV array called as Maximum Power Point (MPP), where the PV system produces its maximum output power. Location of MPP changes with change in environmental condition. The purpose of MPPT is to adjust the solar operating voltage close to MPP under changing environmental conditions. In order to continuously gather the maximum power from the PV array, they have to operate at their MPPT despite of the inhomogeneous change in environmental conditions. The solar panel is interfaced to the load by a dc-dc converter to attain the maximum power point.

II. BLOCK DIAGRAM OF PROPOSED SYSTEM

Power for boost converter can be obtained from any suitable DC sources such as batteries, solar panels, rectifiers and DC generators. In this paper solar panel is chosen for better performance. The components used in our proposed system is solar panel, DC-DC power converter, sensors, MPPT controller and load. The schematic diagram for the proposed system is shown in the fig 1.

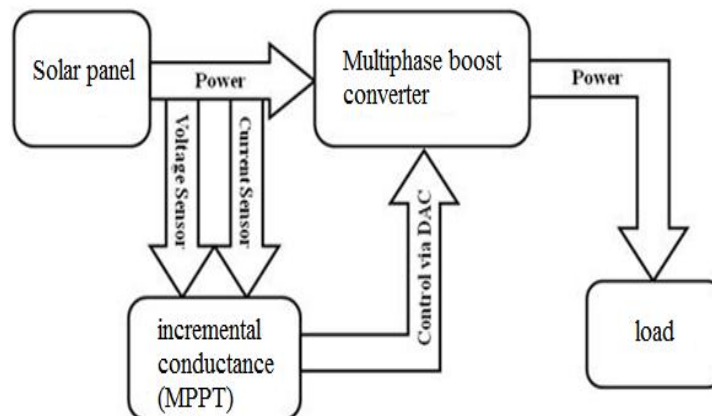


Figure 1: Block diagram of Proposed system

Here the power from solar panel is fed to the DC-DC power converter. A process that changes one DC voltage to a different DC voltage is called DC-DC conversion. DC-DC power converter is nothing it is a boost converter with an output voltage is greater than its input voltage. Boost converter is also known as step up converter since it steps up the source voltage. This converter is a class of switched mode power supply containing at least two semiconductors (a diode and a transistor) and at least one storage element such as capacitor, inductor or two in combination. Input voltage of boost converter is controlled to regulate the maximum power point of the PV array.

DC-DC converter plays a major role in solar or PV system. Voltage sensor and current sensor are fixed in between the output of solar panel and MPPT controller. Sensors are used to sense the power. MPPT controller will convert the module operating voltage to battery voltage and raise the output current in the process. MPPT process will raise the current while lowering the voltage. This can be done through the process of DC-DC conversion. Finally the power from DC-DC power converter is fed to the load.

III. SOLAR PANEL

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from a photodiode. In a photodiode light falls on n-channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased. The diagram of PV based system is shown in Fig. 2.

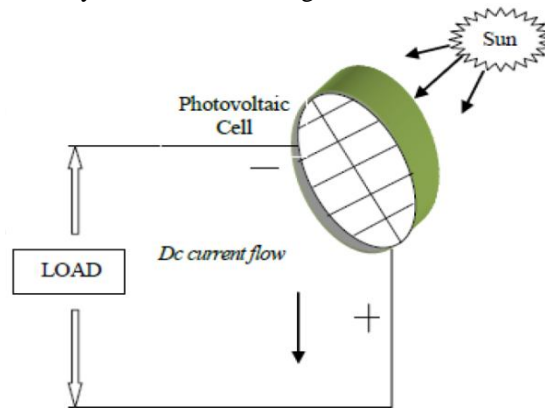


Figure 2: Photovoltaic cell

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. Fig. 3 shows the equivalent circuit model for a solar cell. Solar cell can be regarded as a non-linear current source. Its generated current depends on the characteristic of material, age of solar cell, irradiation and cell temperature.

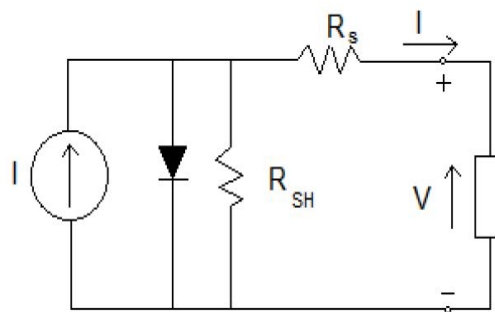


Figure 3: Equivalent circuit of solar panel

In this model we consider a current source (I) along with a diode and series resistance (R_s). The shunt resistance (R_{SH}) in parallel is very high, has a negligible effect and can be neglected. The output current from the photovoltaic array is

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

$$I_d = I_0 (e^{qV_d/KT} - 1) \quad \dots\dots\dots (2)$$

Where,

- I₀** is the reverse saturation current of the diode,
- q** is the electron charge,
- V_d** is the voltage across the diode,
- K** is Boltzmann constant (1.38 * 10⁻¹⁹ J/K),
- T** is the junction temperature in Kelvin (K)

Using suitable approximations,

$$I = I_{SC} - I_0 (e^{q(V+IR_s)/nkT} - 1) \quad \dots\dots\dots(3)$$

where,

- I** is the photovoltaic cell current,
- V** is the PV cell voltage,
- n** is the diode ideality factor

The I-V Characteristics of PV array is shown in figure 4. The maximum power point occurs at the knee of I-V curve. To the left of MPP, array operates as a current source and to the right array operates as a voltage source. It is necessary to operate the PV array at MPP, however depending on the power drawn from the array, the converter may operate in voltage or current source region.

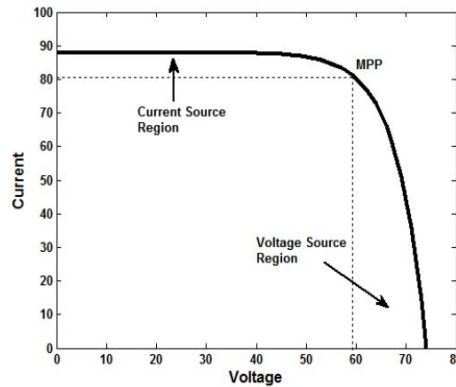


Figure 4: I-V Characteristics of PV array

IV. MULTIPHASE BOOST CONVERTER

The concept of interleaving is that of increasing the effective pulse frequency of any periodic power source by synchronizing several smaller converters and operating them with relative phase shifts. In high power applications, the voltage and current stress can easily go beyond the range that one power device can handle. Multiple power devices connected in parallel or series could be one solution. However, voltage sharing or current sharing are still the concerns. Instead of paralleling power devices, paralleling power converters is another solution which could be more beneficial. Benefits like harmonic cancellation, better efficiency, better thermal performance, and high power density can be obtained. With these multi-modular converters the current stress can be divided to a level that can be handled by semiconductor switches and reduces the ohmic component of their conduction losses. In many applications, one major concern is the input and output filters rely almost exclusively on capacitors due to the highest available energy-storage-to-volume ratio. However, the ESR of this filter capacitor causes high level thermal stress from the high switching pulsed current.

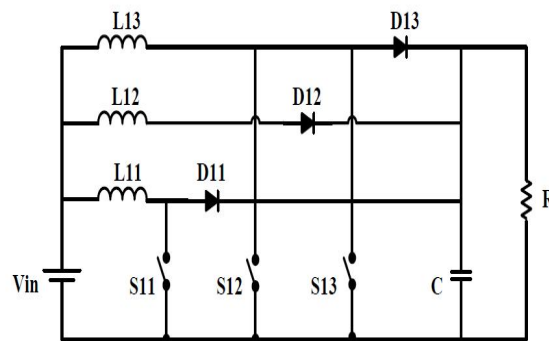


Figure 5: Three-phase boost converter

Use of multi-phase boost converter is an optimal solution for high input current dc-dc converter such as conventional boost where the current is shared among different phases. The multi-phase booster can be achieved by adding more parallel legs to the conventional boost converter. The Fig.5 shows a three-phase boost converter, where two more legs connected in parallel with the conventional one.

The multi-phase boost converter interleaves the clock signals of the paralleled power stages, reducing input and output ripple current without increasing the switching frequency. Because of the phase difference in clocking between the converters, the inductor ripple currents in the different phases tend to cancel each other, resulting in a smaller ripple current getting to the output capacitor. The frequency of the output ripple current is increased by the number of the phase. The Table no.1 figures out the status of the three-phase boost converter for different switching conditions.

Stages	S ₁₁	S ₁₂	S ₁₃	STATUS
1	ON	ON	ON	All the three phase inductors stores energy, the stored energy in the output capacitor is supplied to load.
2	ON	OFF	ON	The stored energy in the inductor L ₁₂ is transferred to load through diode D ₁₂ .
3	ON	ON	ON	Similar to stage 1, where all the three phases inductors stores energy.
4	ON	ON	OFF	The stored energy in the inductor L ₁₃ is transferred to load through diode D ₁₃ .
5	ON	ON	ON	Similar to stage 1 and 3.
6	OFF	ON	ON	The stored energy in the inductor L ₁₁ is transferred to load through diode D ₁₁ .

Table No.1: Switching status of three phase boost converter

The converter is operating in continuous conduction modes for better operational characteristics results. Thus, the different operational stages and the theoretical waveforms are represented for CCM and considering three phases only. In three-phase boost converter, the clock for the switches is phase shifted by 120 degree as shown in Fig.6. The three phase ripple current waveforms are shown with solid, dashed and dotted lines with reference to their clock signals, the ripple cancellation among different phase's results in reduced magnitude and increase in frequency by three times. The voltage transformation of three-phase boost converter is same as that of conventional boost converter. Due to interleaving of the clock pulses, all the three switches are closed for the duration $(D - 2/3) T$, three times a period with the interval of $(1 - D)T$. Where, D and T are duty ratio and switching period of the converter.

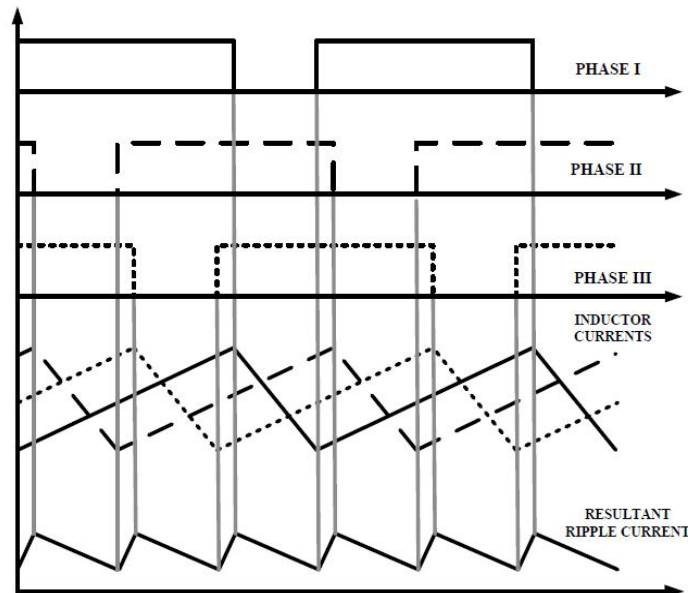


Figure 6: Theoretical three-phase inductor currents.

V. INCREMENTAL CONDUCTANCE METHOD

The incremental conductance method is based on the fact that the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by

$$\frac{dp}{dv} = 0, \text{ at MPP}$$

$$\frac{dp}{dv} > 0, \text{ left of MPP}$$

$$\frac{dp}{dv} < 0, \text{ right of MPP}$$

$$dP/dV = d(I \cdot V)/dV = I + V dI/dV \approx I + V \Delta I/\Delta V \dots\dots\dots(4)$$

The MPP can thus be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance $(\Delta I/\Delta V)$ as shown in the flowchart in Fig.7. V_{ref} is the reference voltage at which the PV array is forced to operate. At the MPP, V_{ref} equals to V_{MPP} . Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted, indicating a change in atmospheric conditions and the MPP. The algorithm decrements or increments

V_{ref} to track the new MPP. The increment size determines how fast the MPP is tracked. Fast tracking can be achieved with bigger increments but the system might not operate exactly at the MPP and oscillate about it instead; so there is a tradeoff. This paper brings the operating point of the PV array close to the MPP in a first stage and then uses Incremental Conductance to exactly track the MPP in a second stage. By proper control of the power converter, the initial operating point is set to match a load resistance proportional to the ratio of the open-circuit voltage (V_{OC}) to the short-circuit current (I_{SC}) of the PV array. This two-stage alternative also ensures that the real MPP is tracked in case of multiple local maxima. The operating point is brought into this area and then Incremental Conductance is used to reach the MPP.

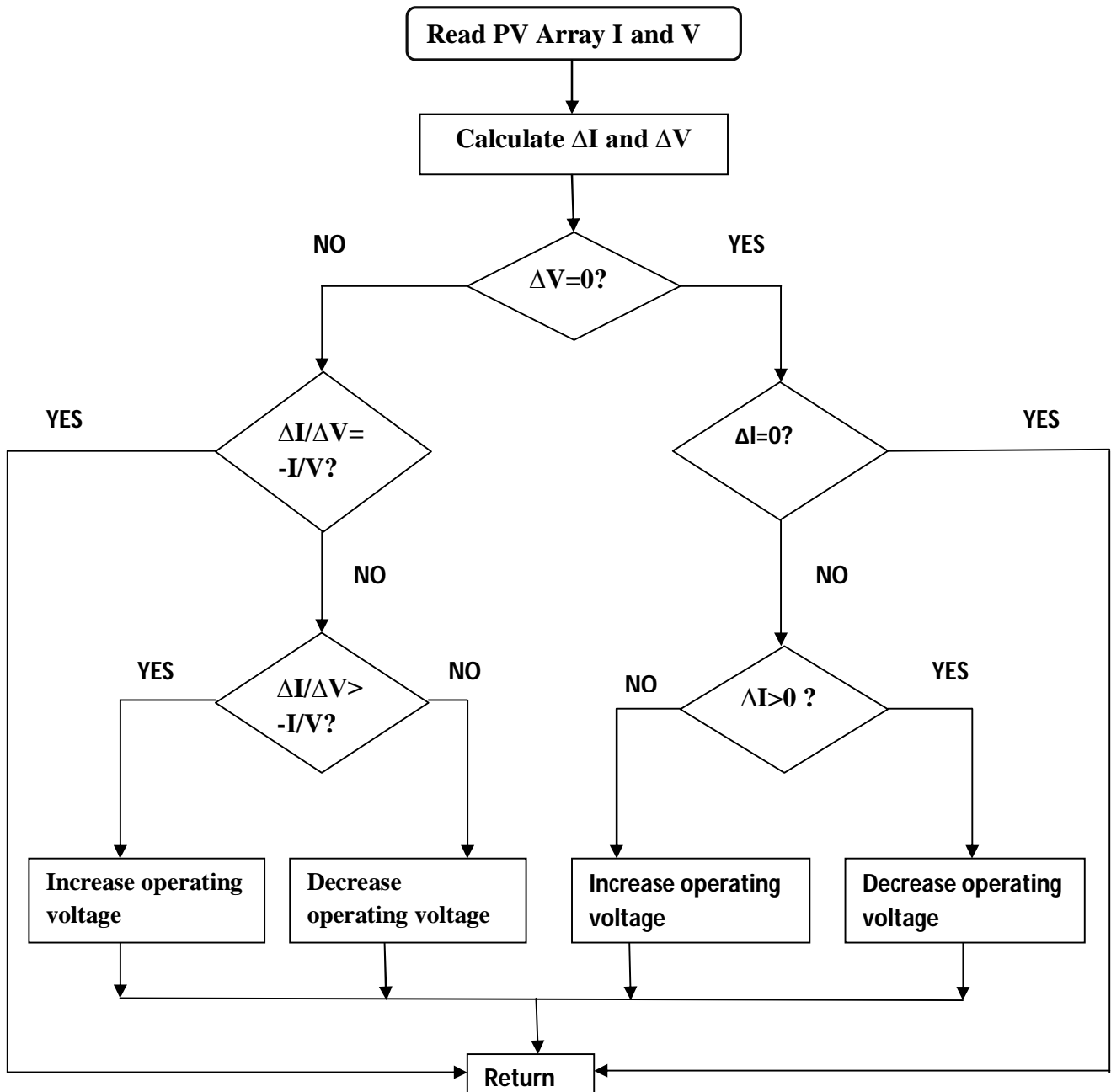


Figure 7: Flow chart for incremental conductance algorithm

VI. SIMULATION RESULTS

The model includes the PV array and three phase boost converter. The PV array is modeled with irradiation and temperature as inputs. The incremental conductance algorithm is used for maximum power point tracking which accepts instantaneous PV array voltage and current and generates the voltage corresponding to maximum power of the array. The simulation circuit is shown in Fig. 8.

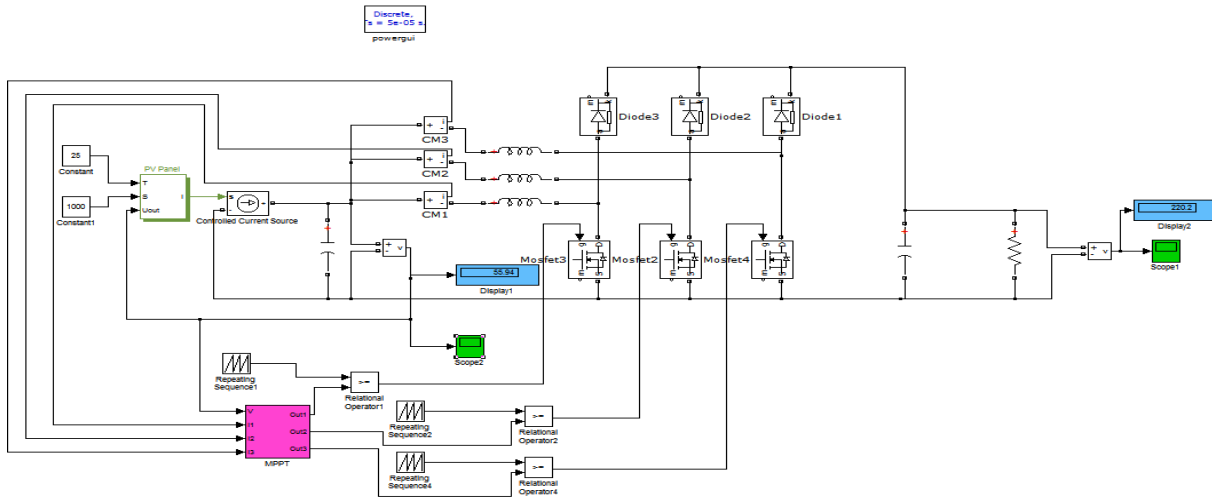


Figure 8: Simulation circuit

Let us consider photovoltaic cell with Irradiance is 1000w/mm^2 And Temperature is 25°c and Simulated the Circuit with maximum power point tracking and the results are show in figure 9 and 10

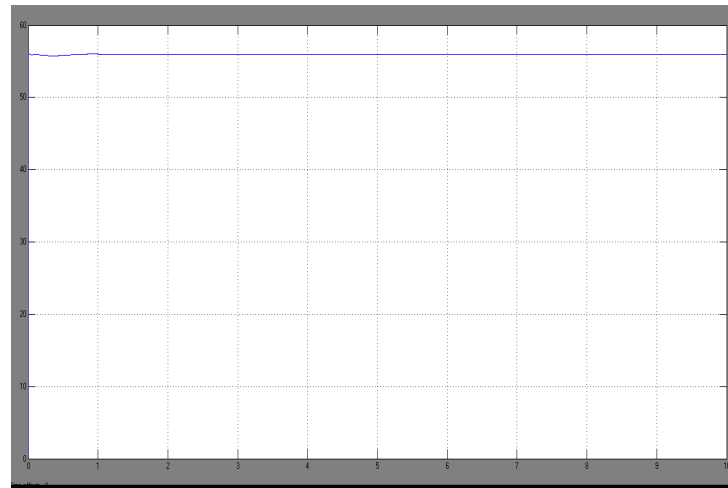


Figure 9: PV array output

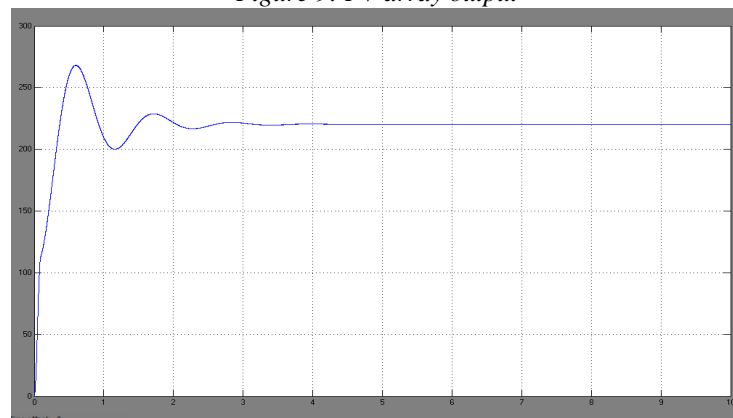


Figure 10: Output of the proposed system

VII. CONCLUSION

The shortcomings of conventional boost converter can be easily overcome by multi-phase boost converter. The high input current was divided by identical parallel modality in multi-phase boost converter. With average duty cycle very high static gain can be achieved by multi-phase boost converter. The above two advantage can be achieved by integrating multi-phase booster. The inductor current ripple cancellation leads to reduced ripple with increased frequency in multi-phase booster. This makes the way to have a smaller filter size, leading to a compact system. Thus, for the application requiring very high static gain, multi-phase multi-stage booster topology will be best suitable being an efficient system.

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