DC-DC Converters in Solar PV System

V. Arun, I. Kumaraswamy

Abstract*: Even though solar energy is a fuel free energy generation, but the difficulty involved with the novel generation is needed to consider all the accepts, such as isolation, irradiance and all other atmospheric conditions, including the angle placement of solar cells, causes a low performance with all these conditions not possible to get maximum power at better efficiency. To get the maximum electrical power from the available solar isolation needs to incorporate the novel techniques to increasing the efficiency of the solar system. Out of all maximum power point tracking (MPPT) techniques, the simplest method is perturb and observation method because it is a easiest method out of all other MPPT techniques and it is easier to implementation for DC to DC converters are used to convert the power delivered by the solar system as per the requirement, some of the DC-DC converters are used in the theoretical analysis are boost, buck-boost and CUK converters with the MPPT techniques have been resolved with the help of MATLAB/Simulink and computed the diversity among each and every converter in this paper.

Keywords*: Boost, Buck-Boost, Cuk, Perturb and Observe method, Incremental Conductance, Maximum power point tracking, Solar PV Array.

I. INTRODUCTION

Now a days the world has enhanced the technology and growth development, electricity also competes with the trending world. But the problem with the generation of an electricity is consumption of fuel. Major power generation in India and some other countries are mainly depends up on coal. Because the fuel used in thermal power generating station is coal, in order to produce the electricity, consumption of a coal is increased with the increasing generation of electrical power. So, it's mandatory to explore the other sources to generate electricity, because the coal is a fossil fuel. One of the promising alternative sources for generation of an electricity is solar insolation. In order to produce electrical energy by using solar cells from the radiation of the sun. The power delivered from solar cells is in the form of direct current in nature. To utilize the energy delivered by the solar system need to make it conditioned.

Revised Manuscript Received on January 30, 2020.
* Correspondence Author
V. Arun*, Associate Professor, Department of EEE, Sree Vidhyanikethan Engineering College (Autonomous), Tirupathi, India. Email: varunpse@yahoo.com
I. Kumaraswamy, Department of Electrical and Electronics Engineering from Narayana Engineering College, Nellore, India

To utilize the electricity as per the requirement, need to convert as per the requirement so converters place a prominent role as the time of conversion. This paper gives an analysis of various converters in a PV system. Some of the converters discussed in this paper are boost, buck-boost and CUK converter to grab the maximum power from the available source, the converters need an advanced techniques to grab the maximum power when it is available. Here the introduction of MPPT techniques is incorporated in the system (i.e.) Perturb and observe method and incremental conductance methods are used in this paper. PV array fed with DC-DC converter and MPPT block diagram is depicted in Fig.1. The analysis of each converter using MPPT and comparison among the converter using MPPT techniques is described in this paper and converters and MPPT techniques are modelled in the MATLAB- Simulink, the results are given in the comparative form.

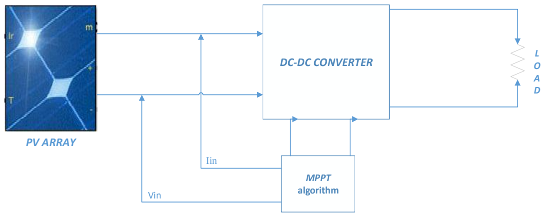
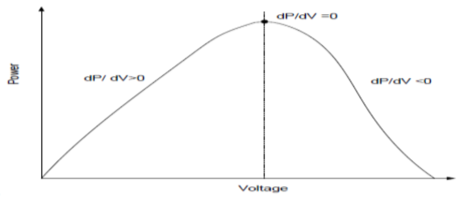


Fig. 1 PV with DC-DC converter and MPPT

II. P&O AND INCREMENTAL CONDUTANCE MPPT TECHNIQUES FOR PV SYSTEM

The Perturb and Observe technique are performed by intermittently perturbing (either increasing or decreasing) the array voltage or current in addition, comparing the strength of the PV output from the preceding cycle of disruption. If the employed voltage of the PV array swings as well as increases in energy, the scheme will move the operational point of the PV array in that way and the basic PV-characteristics have been depicted in the Fig.2. When the operating point is stimulated in the reverse way. In the following perturbation cycle the procedure continues in the same way. When the steady state is touched the procedure equivocates around the topmost point. In a direction to retain the power variation minor, the perturbation proportions are held in reserve very small. The operating point of the module in that specific voltage level is detected as well as there is some power loss due to this perturbation, leads to flops to tracking the power under fast fluctuating atmospheric circumstances. But still, in the technique is very popular in addition simple [1]. The procedure equivocates at the steady state around the extreme point. To keep the dissimilarity in power small, the scope of the perturbation is kept made minor. From the incline, it is probable to gain the equivalent position of this electrical load point.



The variation in power with respect to the variation in voltage is demarcated as the rise.
Where,

$$\frac{dP}{dV} > 0 \text{ Left of the curve}$$
$$\frac{dP}{dV} < 0 \text{ Right of the curve}$$
$$\frac{dP}{dV} = 0 \text{ Curve Peak}$$

III. BOOST CONVERTER

However, the power delivered by the PV array one directly fed to converter before going to utilize it. But the challenge here is after the technology has been improved everywhere for that the converter fed to the PV system [5]. Is to grab the maximum electrical power instead of placing a greater number of the solar cell system. In order to grab maximum electrical power from the solar isolation in the non-isolating condition the Boost converter is associate with the MPPT are used.

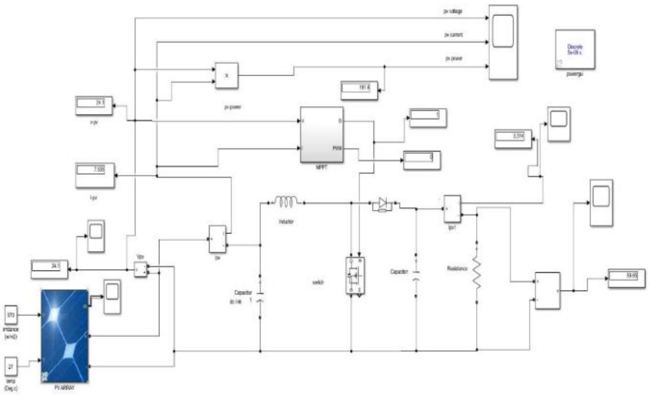


Fig. 3 Boost converter with P&O based MPPT

The Boost converter fed with the solar systems in associated with the (MPPT) technology depicted in the Fig.3. The system has been implemented in MATLAB/Simulink, and the associated results are depicted in Fig.10. The Fig. 4 shows the Boost Converter with I.C Algorithm. The Boost Converter increases the output voltage by the duty cycle of the Boost conversion gate pulses, which allows you to adjust the converter variable duty cycle to achieve maximum power on the cargo side if the irradiance or temperature changes.

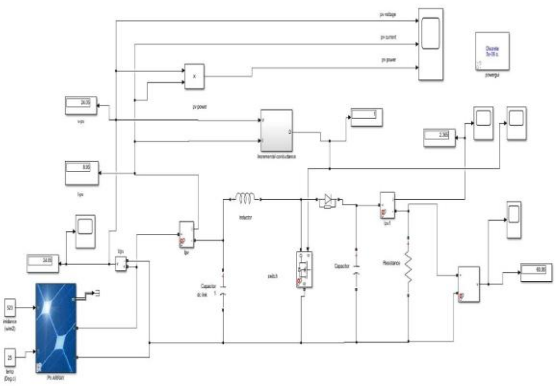


Fig. 4 Boost converter with Incremental Conductance based MPPT

The simulation has been performed for a progressive change of solar irradiance from 600 to 1200 W/m^2 for different values of temperature such that varies from 25° c to 40° c, the response of boost converter was depicted in Fig. 11.

IV. BUCK-BOOST CONVERTER

Here, the P&O technology is used to take the maximum available power with Buck-Boost converter, because the converter can function Buck-Boost as required. When needed, it can increase the voltage. The Buck-Boost converter system is depicted in the Fig. 5. The associated results of Buck-Boost converter with MPPT has been depicted in the Fig. 12.

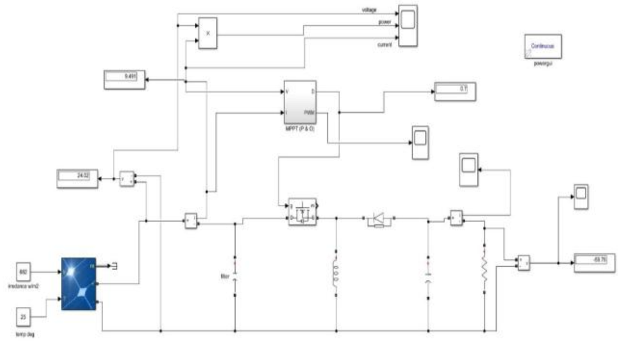


Fig. 5 Buck-Boost converter with P&O based MPPT

The non-isolating Buck-Boost converter are used to decrease or increase the voltage [6]. The Fig. 6. shows the Buck-Boost DC-DC Converter.

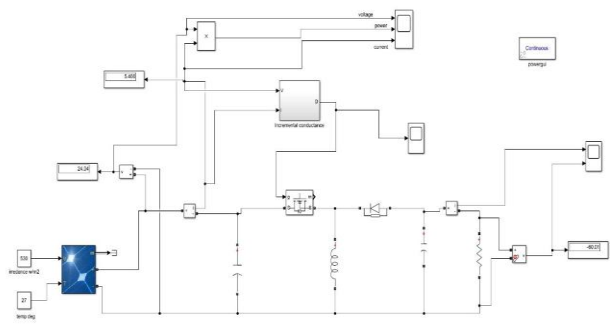


Fig. 6 Buck-Boost converter with Incremental Conductance based MPPT

Retrieval Number: B7037129219/2020©BEIESP
DOI: 10.35940/ijitee.B7037.019320
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Solar PV system's output and input voltages are depends on the irradiance and temperature so whenever the change in the irradiance or temperature the Buck-Boost converter can used to get maximum power at the load side. The simulation has been performed for a progressive change of solar irradiance from 500 to 1000 W/m^2 for dissimilar values of temperature such that varies as of 25° to 40° and the response was depicted in Fig. 13.

V. CUK CONVERTER

The Fig. 7 shows PV system with CUK Converter and P&O technique. The CUK Converter boost or buck the input voltage to a greater value or lesser value of output voltage based on the load according to the duty cycle applied to its gate input of the MOSFET in the CUK converter so that whenever there is a change in the irradiance or temperature, the duty cycle of the converter need to be adjusted in order to get maximum power at the load side.

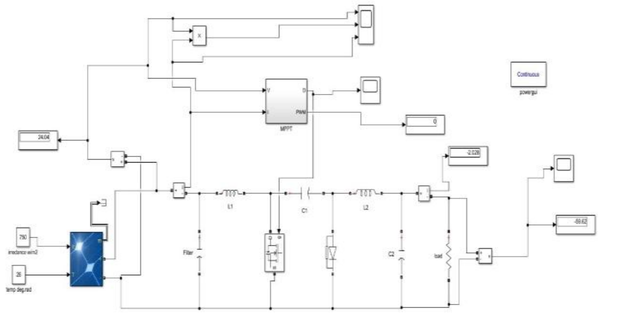


Fig. 7 CUK converter with P&O based MPPT

The simulation has been performed for a progressive change of PV solar irradiance from 500 to 1000W/m^2 for different values of temperature such that changes from 25° c to 40°c. PV array with P&O technique with CUK converter and response are depicted in Fig. 14.

The Fig. 8 shows CUK Converter with I.C algorithm. The CUK Converter increases or decreases the input voltage to either greater or lower the value of output voltage and the response was depicted in Fig. 15. The duty cycle of the converter can be varied in order to get extreme power at the load side. The simulation has been performed for a progressive change of solar irradiance from 500 to 1000W/m^2 for different values of temperature such that varies from the 25°c to 40°c.

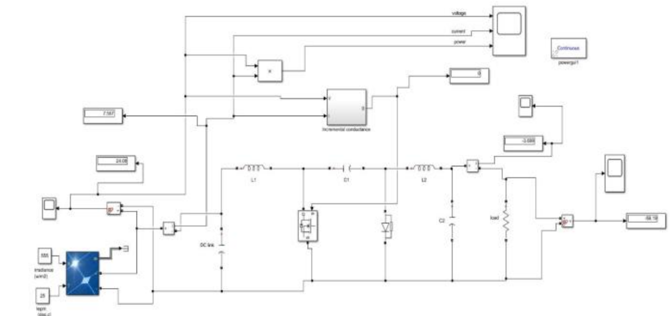


Fig. 8 CUK converter with Incremental Conductance based MPPT

The drawback of the P&O technique to trace maximum energy under rapidly mutable atmospheric circumstances is overwhelmed by the technique of IC. The IC can stop the operational point, and increment the trace point of MPP. If this point is not met, the operational point should be corrected by means of relationship among dI/dV and –I/V characteristics and relation are obtained from the derivative of. When dp/dv is negative, it stated that, at the right side of MPPT is positive and left side of MPPT is negative. Comparing to P & O, this method is fast, efficient and the tracking speed is high and it decreases the irradiance value and best accuracy. The drawback of this method is the complexity over P&O method. The condition at which, the PV module is operated at maximum power point is, when the ratio of incremental change in output conductance is equivalent to negative output conductance [2].

At maximum power point $\frac{dP}{dV} = 0$

Since P=VI

$$\frac{d(vi)}{dV} = 0 \quad \text{(At MPP condition)}$$

So,

$$\frac{dI}{dV} = -\frac{1}{V}$$

Here $Gd = \frac{dI}{dV}$ =dynamic (incremental) conductance

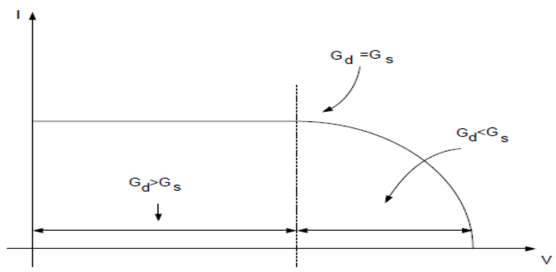


Fig. 9 I-V characteristics (basic idea of INC algorithm)

$Gs = -\frac{1}{V}$ =Static conductance

So,

$$\frac{dI}{dV} > -\frac{1}{V} \quad \text{Left of the curve}$$

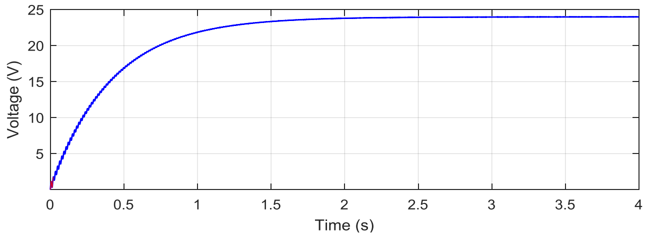
$$\frac{dI}{dV} < -\frac{1}{V} \quad \text{Right of the curve}$$

$$\frac{dI}{dV} = -\frac{1}{V} \quad \text{Curve Peak}$$

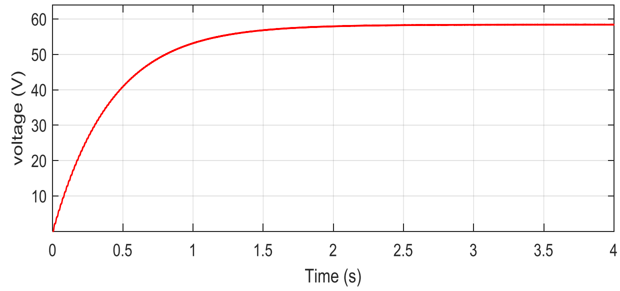
According to the above expression algorithm is implemented for MPPT, instead of the P-V curve, IV curve is used for Incremental & Conductance method.

VI. RESULTS AND DISCUSSIONS

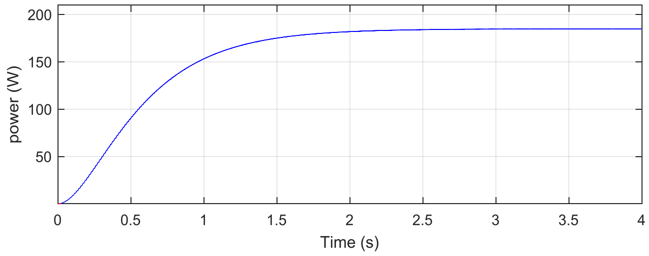
The Fig. 10 shows the output voltage with irradiance varying from 500 W/m^2 to 1000W/m^{2}and temperature varies with the 25°C to 40°C for the photovoltaic System with the Boost Converter and Perturb and Observe technique. The duty cycle of 0.6. Hence, the input voltage of 24V has been increased to 59.55V under standard conditions i.e. 570w/m2 irradiance and 25°C temperature. It can be noticed that the current; voltage and power are at their maximum at 1000W/m^2 and 25°C. As they decrease with the value of irradiance decreases from 1000W/m2 to 500W/m^2 and temperature increases from 25°C to 40°C.



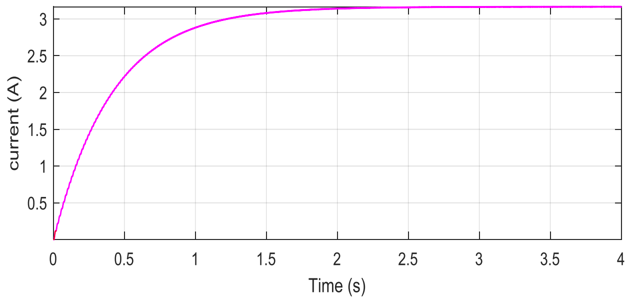
(a) PV voltage



(b) Output voltage



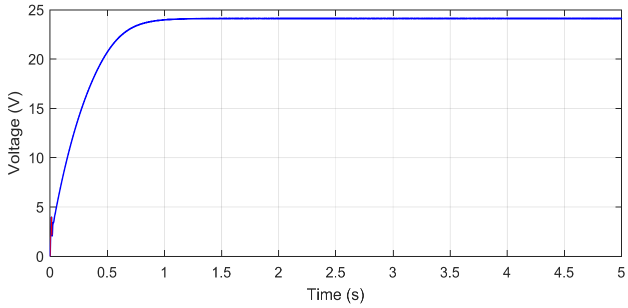
(c) output power



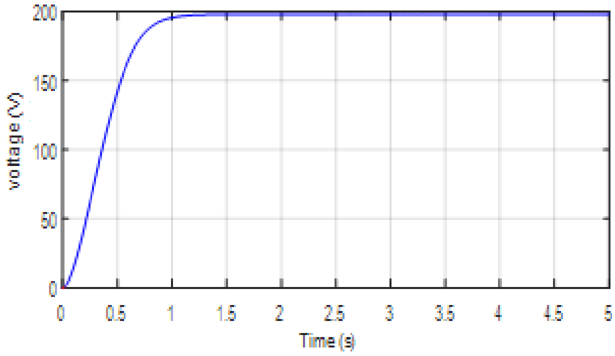
(d) output current

Fig. 10 Response of Boost Converter using MPPT P&O Technique

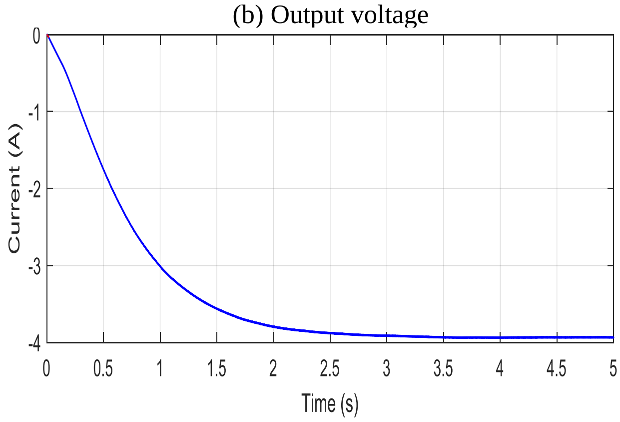
The Fig. 11 shows the output voltage for PV system with a Boost converter and the Incremental conductance technique for irradiance variations from 500W/m^2 to 1000W/m^2 and temperature variable from 25°C to 40°C. The converter designed for a duty cycle of 0.7. Hence, the input voltage of 24 V has been increased to 60.6 V under standard conditions i.e. 682w/m^{2}irradiance and 25°C temperature. It can be noticed that the voltage at the maximum at 1000W/m^2 and 25°C.



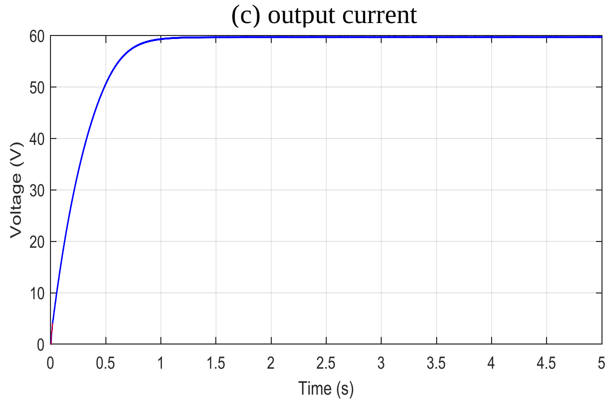
(a) PV voltage



(b) Output voltage



(c) output current



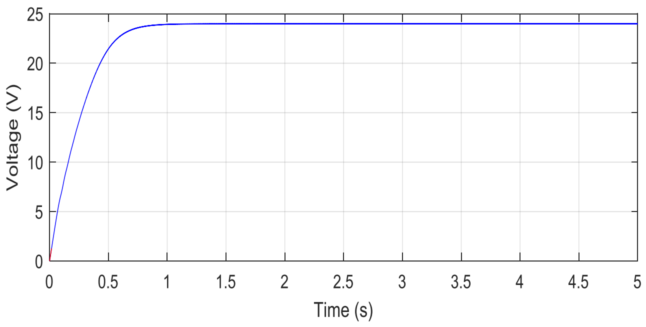
(d) output voltage

Fig. 11 Response of Boost Converter using MPPT I.C Technique

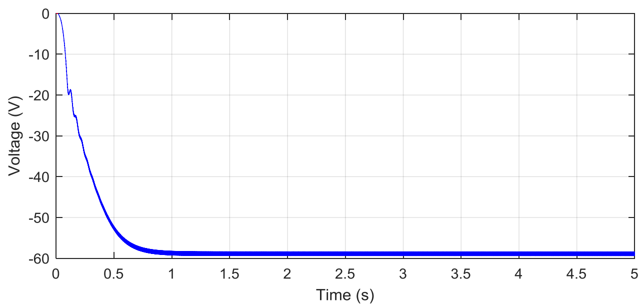
Current, voltage and power are the maximum at 1000W/m^2 and 25°C. They are decreasing as the value of irradiance decreases from 1000W/m2 to 500W/m^2 and temperature increasing the 25°C to 40°C.

Retrieval Number: B7037129219/2020©BEIESP
DOI: 10.35940/ijitee.B7037.019320
Journal Website: www.ijitee.org

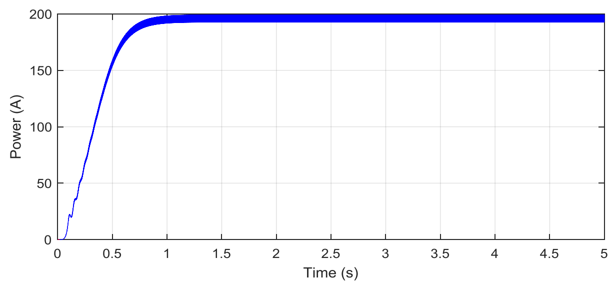
Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)



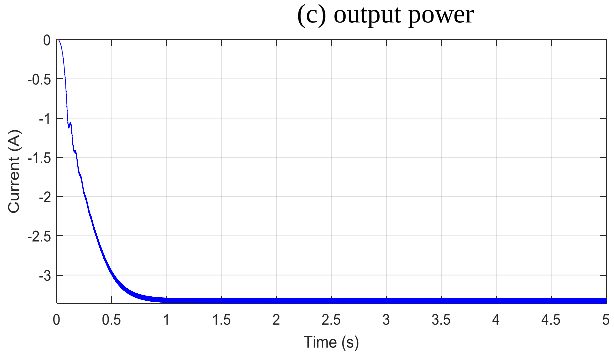
(a) PV voltage



(b) Output voltage



(c) output power

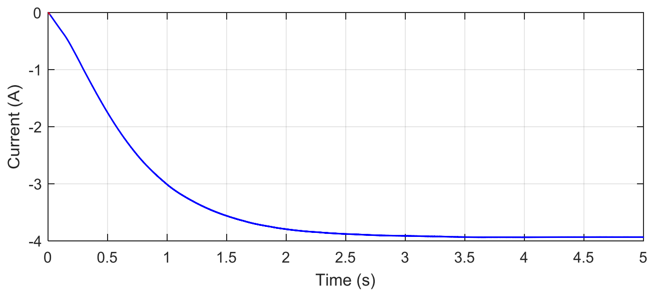


(d) output current

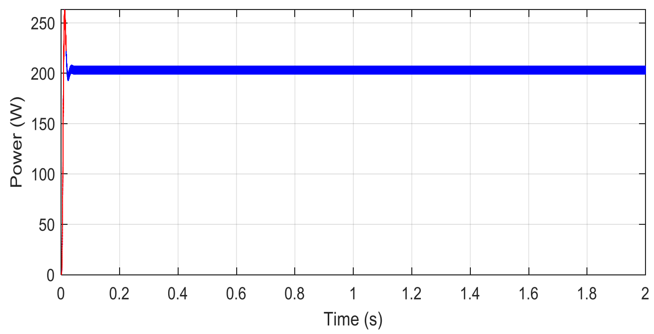
Fig. 12 Response of Buck-Boost converter with P&O

Fig. 12 and 13 shows the output voltage for irradiance varies with 500W/m^2 to 1000W/m^2 and temperature changing from 25°C to 40°C for a PV System working with a Buck-Boost Converter with P&O and IC technique. The circuit has been designed for a duty cycle of 0.7. The input voltage of 24V has been bucked to -60.1V at 1Sec with P&O and 0.1sec with IC. PV systems under standard conditions i.e. 1000w/m^{2}irradiance and 30°C temperature

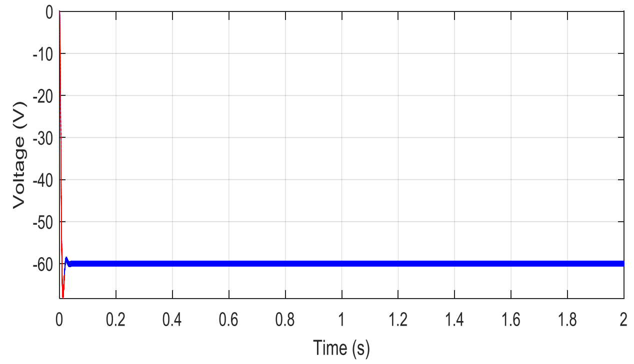
It can be noticed that the current, voltage and power are at their maximum at 1000W/m^{2}and 25°C. If irradiance and temperature changes the input voltages and output voltages also changes. The value of irradiance decreases from 1000W/m^2 to 600W/m^2 and temperature increases from 25°C to 40°C.



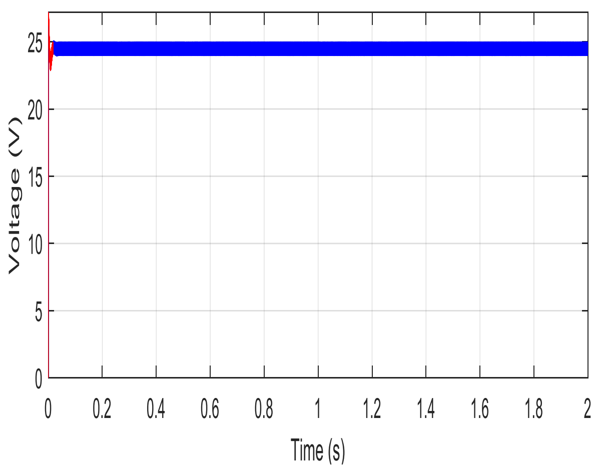
(a) output current



(b) output power



(c) Output voltage



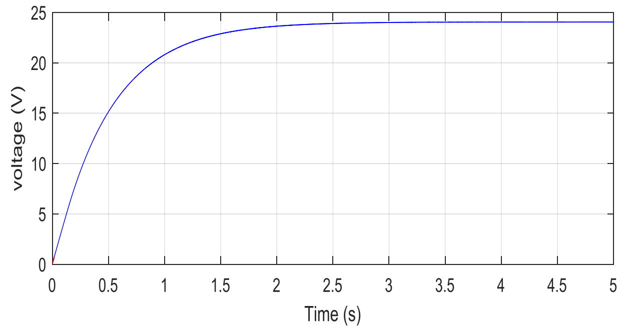
(d) PV voltage

Fig. 13 Response of Buck-Boost converter with I.C

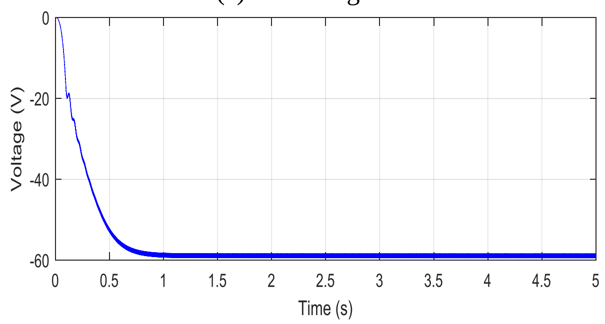
The Cuk converter results are shown in the Fig. 14. For the irradiance changing with the 500W/m^2 to 100W/m^2 and temperature also changing from 25°C to 40°C with the CUK Converter using P&O technique. As the duty cycle of 0.5, the circuit has been designed. Hence, the input voltage is 24V and decreased up to -60V.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

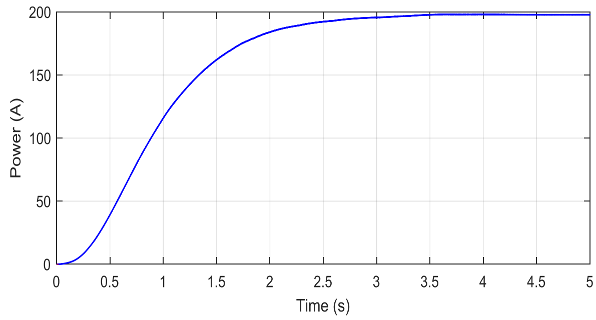
The CUK converter and Buck-Boost are similar but the only difference is separated with the capacitor [3]. The PV system under standard conditions i.e. 1000w/m^2 irradiance and 25°C temperature. It can be experiential that the current, voltage and power are at their maximum at 1000W/m^2 and 25°C. As they decrease the value of irradiance declines from 1000W/m^2 to 500W/m^2 and temperature rises from 25°C to 40°C.



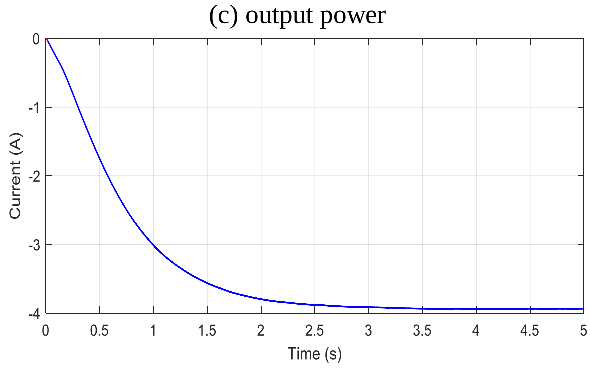
(a) PV voltage



(b) Output voltage



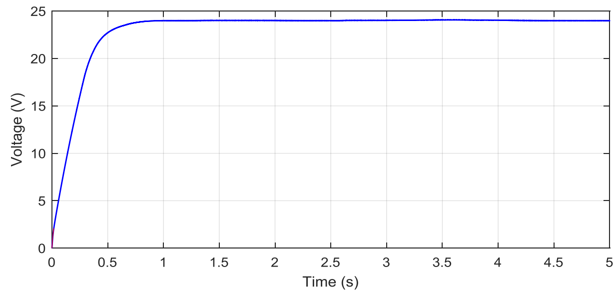
(c) output power



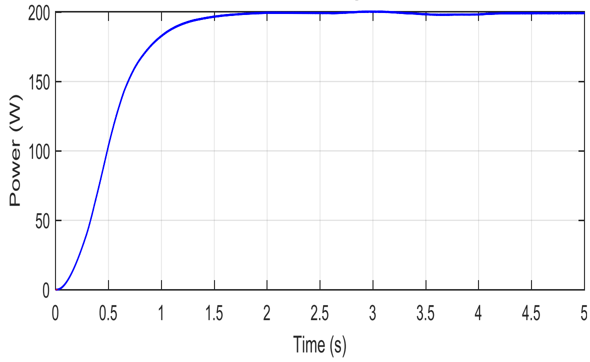
(d) output current

Fig. 14 Response of CUK converter with P&O

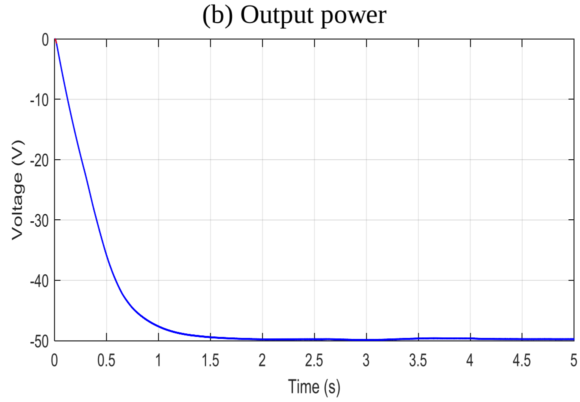
In response of CUK converter are displayed in Fig. 15 Solar PV systems irradiance changing from 500 W/m^2 to 1000W/m^2 and temperature also varying from 25°C to 40°C. The system has been designed for duty cycle of 0.5. Later, the input voltage of 24V has been decreased to -59.55V under standard atmospheric conditions i.e. 1000w/m^2 irradiance and 25°C temperature.



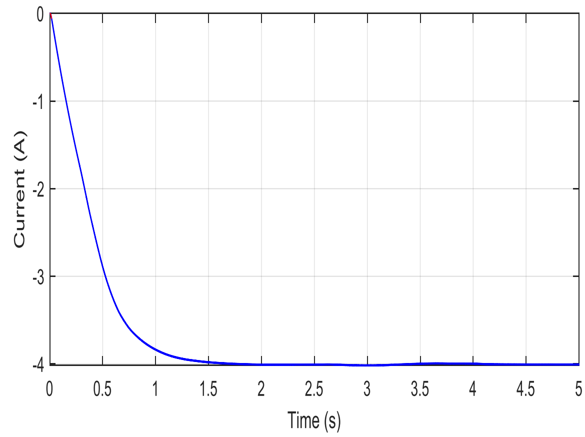
(a) PV voltage



(b) Output power



(c) Output voltage



(d) output current

Fig. 15 Response of CUK converter with I.C

It can be observed that the current; voltage and power are at their maximum at 1000W/m^2 and 25°C. They reduction as the value of irradiance drops from 1000W/m^2 to 500W/m2 and temperature rises from 25°C to 40°C.

Retrieval Number: B7037129219/2020©BEIESP
DOI: 10.35940/ijitee.B7037.019320
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Table. 1 Comparative Study of MPPT Technique Various Converters

Parameters	Boost		Buck-Boost		CUK	
	P&O	I.C	P&O	I.C	P&O	I.C
V_{in}	24	24	24	24	24	24
V_{out}	59.55	60.6	-59.76	-60.01	-59.62	-49.19
I_{in}	7.55	8.95	9.4	5.46	5.24	7.56
I_{out}	3.32	3.9	-3.39	-3.56	-3.02	-3.69
p_{out}	196.1	199.2	-199.2	-199.8	198	198.2
η %	98.01	99.01	99.24	99.9%	98.9%	99.1

VII. CONCLUSION

When the peripheral atmosphere deviations suddenly occurred, the system cannot track the maximum power point quickly. With the use of various types of dc-dc converters it is probable to track the maximum power point (MPP) with a rise in the efficiency of the system, but the other hand, with the excess use of dc-dc converter here can be decreased in overall efficiency of the system. Furthermore, from the results changing irradiance and temperature, it can be decided that as the irradiance reductions or increases a lesser amount of the solar energy is received by the photovoltaic system and hence the output current, voltage and power decrease or increases. The Incremental Conductance technique is well-organized than Perturb and Observe technique. P&O technique fails under rapidly varying environmental conditions. I.C technique eliminates the challenges Perturb and Observe technique.

REFERENCES

1. Barnam Jyoti Saharia, Subhadeep Bhattacharjee, “A comparative study on converter topologies for Maximum Power Point Tracking application in photovoltaic generation,” Journal of Renewable and Sustainable Energy. vol. 6, no. 05, pp. 31-40, 2014.
2. Tekeshwar Prasad Sahu, T.V. Dixit, Ramesh Kumar, “Simulation and Analysis of Perturb and Observe Maximum power point tracking techniques for photovoltaic Array Using ĊUK Converter,” Advance in Electronic and Electric Engineering, vol. 4, no 2, pp. 213-224, 2014.
3. R.B. Wankhede, U.B. Vaidya, “Energy Comparison of MPPT Techniques Using Cuk Converter,” International Journal of Innovative Research in Advanced Engineering (IJIRAE), vol. 1, no. 6, pp. 277-283, 2014.
4. A. M. Atallah, A. Y. Abdelaziz, R. S. Jumaah, “Implementation of perturb and observe MPPT of PV system with direct control method using buck and buck-boost converters.” Emerging Trends in Electrical, Electronics & Instrumentation Engineering: An international Journal (EEIEJ), vol. 1, no. 1, pp. 31-44, 2014.
5. D. Saravana Selvan, “Modeling and Simulation of Incremental Conductance MPPT Algorithm for Photovoltaic Applications,” International Journal of Scientific Engineering and Technology, vol. 2, no.7, pp. 681-685, 2013.C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.
6. Saad Mekhilef, S.Zahra Mirbagheri, S. Mohsen Mirhassani, “Maximum Power Point Tracking with Incremental Conductance method using conventional interleaved boost converter,” Science Direct, vol. 42, no. 04, pp. 24-32, 2013.

AUTHORS PROFILE

V. Arun, received the B. Tech degree in Electrical and Electronics Engineering with distinction from SRM University, Chennai, India in 2007, the M.E. degree in Power Systems Engineering with Distinction from affiliated College of Anna University, Coimbatore, India in 2009 and the Ph.D. Degree from Annamalai University, Chidambaram, India in 2016. He is currently an Associate Professor with the faculty of Electrical and Electronics Engineering, Sree Vidhyanikethan Engineering College (Autonomous), Tirupathi, India. His research interests include power electronics systems, including the design and control of multilevel inverters, and advanced power and energy systems.

I. Kumaraswamy, received the B. Tech degree in Electrical and Electronics Engineering from Narayana Engineering College, Nellore, India in 2006, and the M.Tech. degree in Electrical Power Systems with Distinction from SreeVidyanikethan Engineering College, Tirupati, India in 2008 and the Ph.D. Degree from JNTU Hyderabad, India in 2018. He is currently an Associate Professor with the faculty of Electrical and Electronics Engineering, Sree Vidhyanikethan Engineering College (Autonomous), Tirupathi, India. His research interests include Renewable energy systems, and power systems.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)