ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 1, Issue 4, July 2013

DESIGN OF CUK CONVERTER WITH MPPT TECHNIQUE

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ABSTRACT: Today solar energy became an important resource of energy generation. But the efficiency of solar system is very low. To increase its efficiency MPPT techniques are used. The main disadvantage of solar system is its variable voltage. And to obtained a stable voltage from solar panels DC-DC converters are used . DC-DC converters are of mainly three types buck, boost and cuk. This paper presents use of cuk converter with MPPT technique. Generally buck and boost converters used. But by using cuk converter we can step up or step down the voltage level according to the load requirement. The circuit has been simulated by MATLAB and Simulink softwares.

Keywords: Cuk converter, MPPT, PV system, simulation

I. INTRODUCTION

A main attraction of PV systems is that they produce electric power without harming the environment, by directly transforming a free inexhaustible source of energy, solar radiation, into electricity. This fact, together with the continuing decrease in PV arrays cost and the increase in their efficiency (threefold over the same period), imply a promising role for PV generation systems in the near future. The dependence of power generated by a PV array and its MPOP on atmospheric conditions can readily be seen in the current-voltage (I-*V)* and the power-voltage *(P-V)* characteristics of PV arrays as shown in Fig. 1.

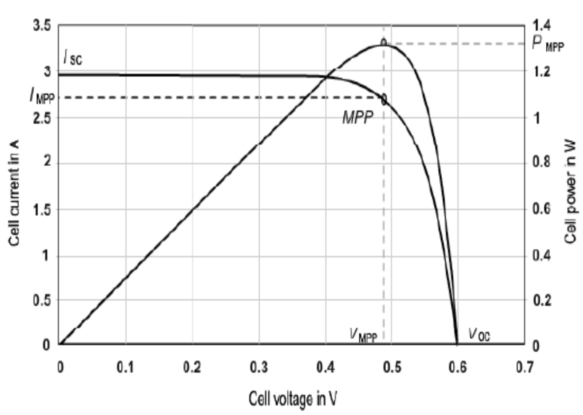

Figure 1: P-V I-V curve of a solar cell at given temperature and solar irradiation

The efficiency of solar cells depends on many factors such as temperature, insolation, spectral characteristics of sunlight, dirt, shadow, and so on. Changes in insolation on panels due to fast climatic changes such as cloudy weather and increase in ambient temperature can reduce the photovoltaic (PV) array output power. In other words, each PV cell produces energy pertaining to its operational and environmental conditions. In addressing the poor efficiency of PV systems, some methods are proposed, among which is a new concept called ―maximum power point tracking‖ (MPPT).All MPPT methods follow the same Goal which is maximizing the PV array output power by tracking the maximum power on every operating condition.[3]

A switch-mode DC-DC converter is heart of MPPT hardware. A DC-DC converter therefore implemented to produce a constant voltage and deliver maximum power from solar panel to load [6]. The output voltages of dc-dc converters are generally controlled by using a switching concept. Earlier choppers with silicon controlled rectifier device were known as dc-dc converters. But now a days for many industrial application SPMS based dc-dc converters are used, based on IGBTs and MOSFETs. For output voltage regulation Pulse width modulation (PWM) is widely used as discussed in [1].

Photovoltaic Cell

Solar cell convert sunlight directly to dc power. Photovoltaic cell generates electricity from the sun. PV panel works under the phenomenon of photoelectric effect. When solar cell are

ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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exposed to sunlight , it converts solar energy into electrical energy

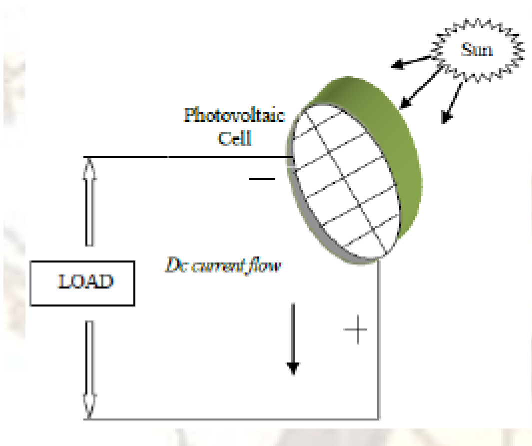

Fig 2. Photovoltaic cel l[5]

The system configuration for the topic is as shown figure 2. Here the PV array is a combination of series and parallel solar cells. This array develops the power from the solar energy directly and it will be changes by depending up on the temperature and solar irradiances.

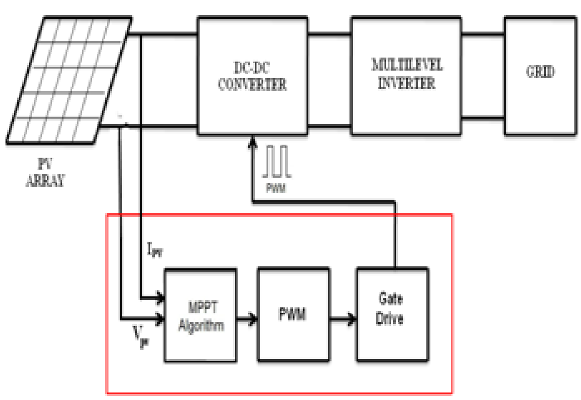

Fig. 3. System Configuration of PV System

So we are controlling this to maintain maximum power at output side we are boosting the voltage by controlling the current of array with the use of PI controller. By depending upon the boost converter output voltage this AC voltage may be changes and finally it connects to the utility grid that is nothing but of a load for various applications. Here we are using Five-level H-Bridge Cascade multilevel inverter to obtain AC output voltage from the DC boost output voltage.

$$I = I_L - I_o\left(e^{\frac{q(V+IR_s)}{kT}} - 1\right) - \frac{V + IR_s}{R_{sh}}$$

II. ROLE OF MPPT IN SPV SYSTEM

Photovoltaic systems normally use a maximum power point tracking (MPPT) technique to continuously deliver the highest possible power to the load when variations in the isolation and temperature occur, Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. PV modules still have relatively low conversion efficiency; therefore, controlling maximum power point tracking (MPPT) for the solar array is essential in a PV system. The Maximum Power Point Tracking (MPPT) is a technique used in power electronic circuits to extract maximum energy from the Photovoltaic (PV) Systems. In the recent days, PV power generation has gained more importance due its numerous advantages such as fuel free, requires very little maintenance and environmental benefits. To improve the energy efficiency, it is important to operate PV system always at its maximum power point. Many maximum power point Tracking (MPPT) techniques are available and proposed various methods for obtaining maximum power point. But, among the available techniques sufficient comparative study particularly with variable environmental conditions is not done. This paper is an attempt to study and evaluate s60e main types of MPPT techniques namely, Open-circuit voltage and Short-circuit current, P&O, IC etc. [6]

A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated. The generated current varies linearly with the solar irradiance. The basic equation that describes the I-V Characteristics of the PV model is given by the following equation:

Where:

I	Cell Current (A).
I_L	Light Generated Current (A).
I_o	Diode Saturation Current.
Q	Charge of Electron = 1.6x10-19 (Coul).
K	Boltzmann Constant (J/K)
V	Cell Output Voltage (V)
R_s , R_{sh}	Cell Series and Shunt Resistance (Ohms).

This equation shows the dependence of PV current on temperature and hence the dependence of power drawn from the PV array.

III. MPPT TECHNIQUES

There are many methods used for maximum power point tracking a few are listed below:

- Perturb and Observe method
- Incremental Conductance method
- Parasitic Capacitance method
- Constant Voltage method
- Constant Current method

ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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1. Perturb and Observe method

This method is the most common. In this method very less number of sensors are utilized [7] and [8]. The operating voltage is sampled and the algorithm changes the operating voltage in the required direction and samples $\frac{dp}{dv}$. If $\frac{dp}{dv}$ is positive, then the algorithm increases the voltage value towards the MPP until $dPdV$is negative. This iteration is continued until the algorithm finally reaches the MPP. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power point (MPP).

2. Incremental Conductance method

This method uses the PV array's incremental conductance $dIdV$to compute the sign of$dP\ dV$. When $dIdV$is equal and opposite to the value of I/V (where $dPdV$=0) the algorithm knows that the maximum power point is reached and thus it terminates and returns the corresponding value of operating voltage for MPP. This method tracks rapidly changing irradiation conditions more accurately than P&O method. One complexity in this method is that it requires many sensors to operate and hence is economically less effective [7] and [8].

P=V*I

Differentiating w.r.t voltage yields;

$$\frac{dP}{dV} = \frac{d(V*I)}{dV}$$

$$\frac{dP}{dV} = I * \left(\frac{dV}{dV}\right) + V * \left(\frac{dI}{dV}\right)$$

$$\frac{dP}{dV} = I + V * \left(\frac{dI}{dV}\right)$$

When the maximum power point is reached the slope $\frac{dp}{dv}$=0 .

Thus the condition would be;

$\frac{dp}{dv}$=0

$$I + V * \left(\frac{dI}{dV}\right) = 0$$

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

3. Parasitic Capacitance method

This method is an improved version of the incremental conductance method, with the improvement being that the effect of the PV cell's parasitic union capacitance is included into the voltage calculation [7] and [8].

4. Constant Voltage method

This method which is a not so widely used method because of the losses during operation is dependent on the relation between the open circuit voltage and the maximum power point voltage. The ratio of these two voltages is generally constant for a solar cell, roughly around 0.76. Thus the open circuit voltage is obtained experimentally and the operating voltage is adjusted to 76% of this value [9].

5. Constant Current method

Similar to the constant voltage method, this method is dependent on the relation between the open circuit current and the maximum power point current. The ratio of these two currents is generally constant for a solar cell, roughly around 0.95. Thus the short circuit current is obtained experimentally and the operating current is adjusted to 95% of this value [9].

The methods have certain advantages and certain disadvantages. Choice is to be made regarding which algorithm to be utilized looking at the need of the algorithm and the operating conditions. For example, if the required algorithm is to be simple and not much effort is given on the reduction of the voltage ripple then P&O is suitable. But if the algorithm is to give a definite operating point and the voltage fluctuation near the MPP is to be reduced then the IC method is suitable, but this would make the operation complex and more costly.

IV. FLOW CHART OF MPPT ALGORITHMS

Two of the most widely used methods for maximum power point racking are studied here. The methods are

1. Perturb & Observe Method.
2. Incremental Conductance Method.

The flow charts for the two methods are shown below.

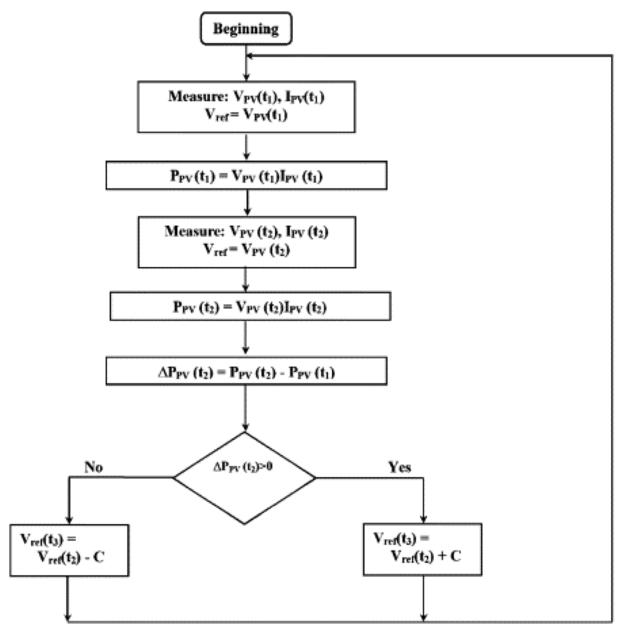

Figure 3: Flow chart of perturb & observe

ISSN 2321 – 2004
ISSN 2321 – 5526

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INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 1, Issue 3, June 2013

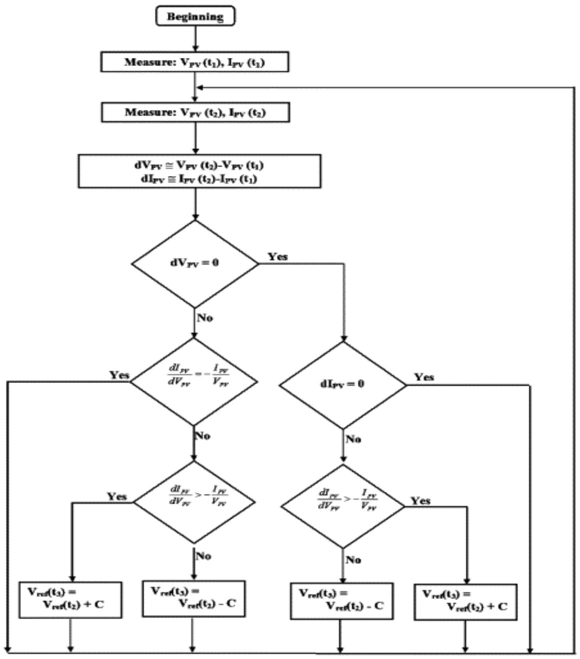

Figure 4: Flow chart of incremental conductance method

V. CUK CONVERTER OPERATION

Many years ago, Dr. Cuk invented the integrated magnetic concept called Dc-transformer, where the sum of Dc fluxes created by currents in the winding of the input inductor L1 and transformer T is equal to Dc flux created by the current in the output inductor L2 winding. Hence the Dc fluxes are opposing each other and thus result in a mutual cancellation of the Dc fluxes. Cuk converter has several advantages over the buck con-verter. One of them cuk converter provide capacitive isola-tion which protects against switch failure (unlike the buck topology) [8]. Other advantage is, the input current of the Cúk is continuous, and they can draw a ripple free current from a PV array that is important for efficient Maximum power point tracking (MPPT)[1].

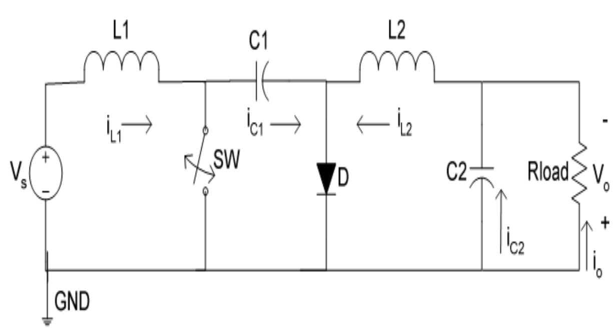

Figure 5: Circuit Diagram of basic cuk converter

The circuit arrangement of the Cuk converter using MOSFET switch is shown in Figure.2 in case of Cuk con-verter the output voltage is opposite to input voltage. When the input voltage turned on and MOSFET (SW) is switched off, diode D is forward biased and capacitor C1 is charged through L1–D. here the operation of converter divided into two modes.[1]

Mode-1:- When MOSFET switch is turned on at t=0. The current through L1 rises. And at the same time the voltage of C1 reverse biases diode D and turn it off. The capacitor C1 discharges its energy to the circuit C1-C2-load-L2.

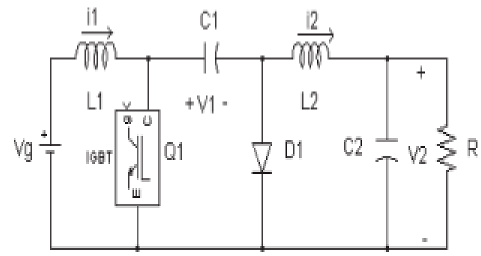

Figure 6:- Cuk converter with switch ON

Mode-2:- When MOSFET switch is turned off at t = t1. The capacitor will start to charge from input supply Vs and the energy stored in the inductor transferred to the load. The capacitor C1 is the medium for transferring energy from source to load[1].

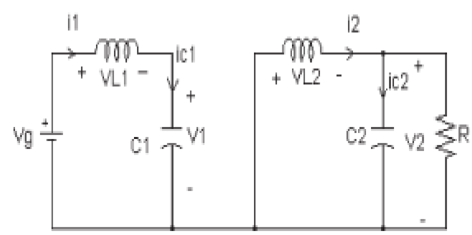

Figure7:- Cuk converter with switch OFF

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VI. SIMULATION of Cuk converter

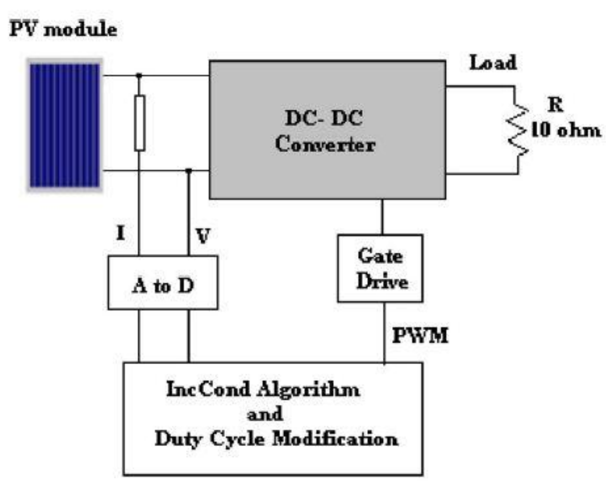

Fig 8. Block diagram of MPPT with cuk converter

ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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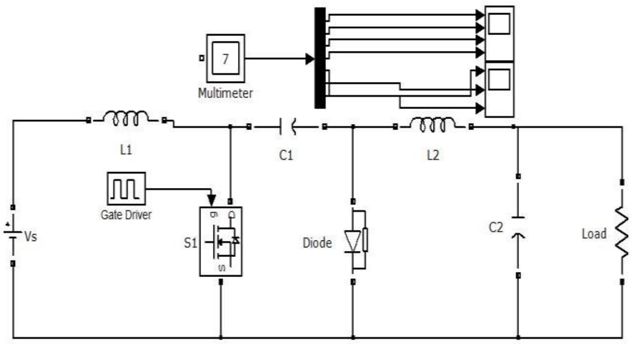

Fig 9:- Simulation model of cuk converter

VII. SIMULATION Result

The simulations were carried out in Simulink and the various voltages, currents and power plots were obtained.

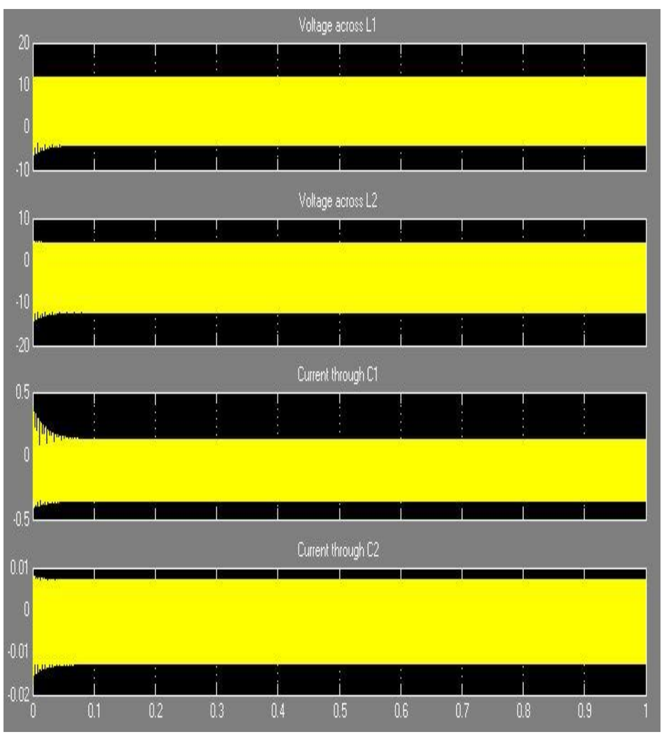

Fig.10:Output of cuk converter when duty cycle 25%

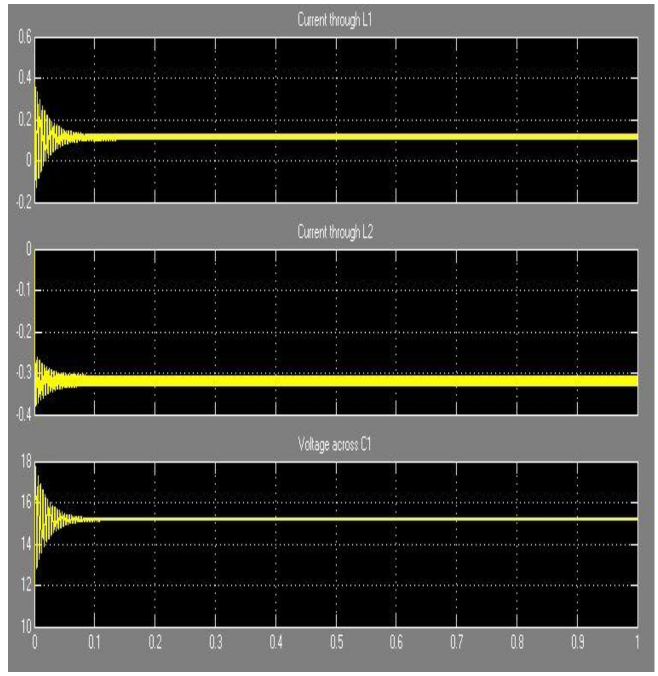

Fig.11. Output of cuk converter when duty cycle is 25%

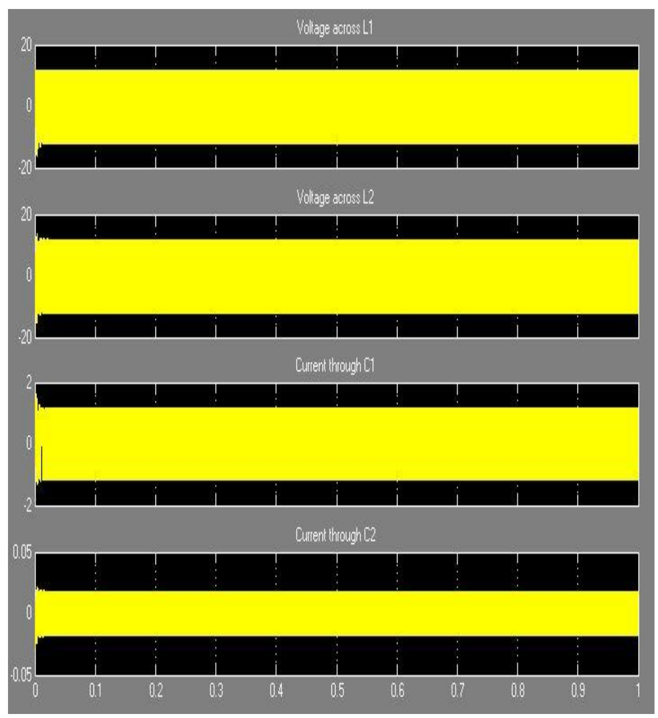

Fig. 12. Output of cuk converter when duty cycle is 50%

ISSN 2321 – 2004
ISSN 2321 – 5526

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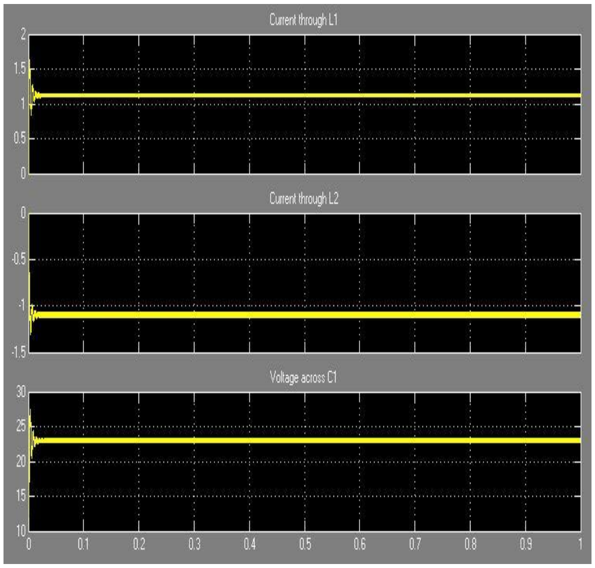

Fig. 13. Output of cuk converter when duty cycle is 50%

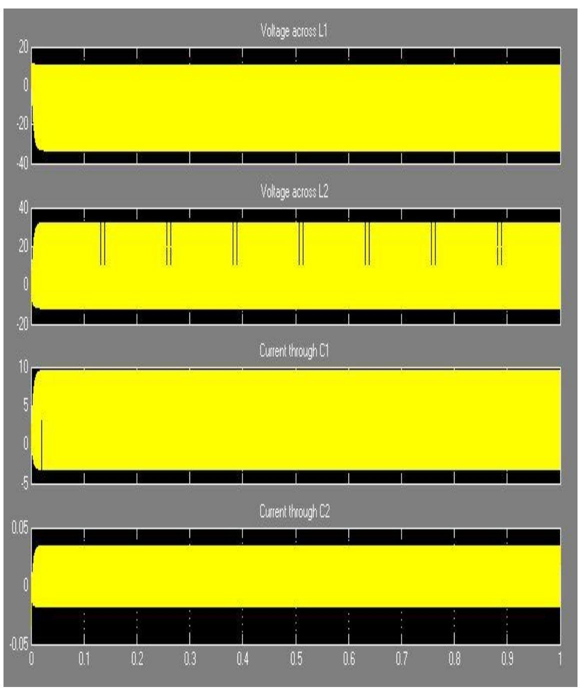

Fig. 14 Output of cuk converter when duty cycle is 75%

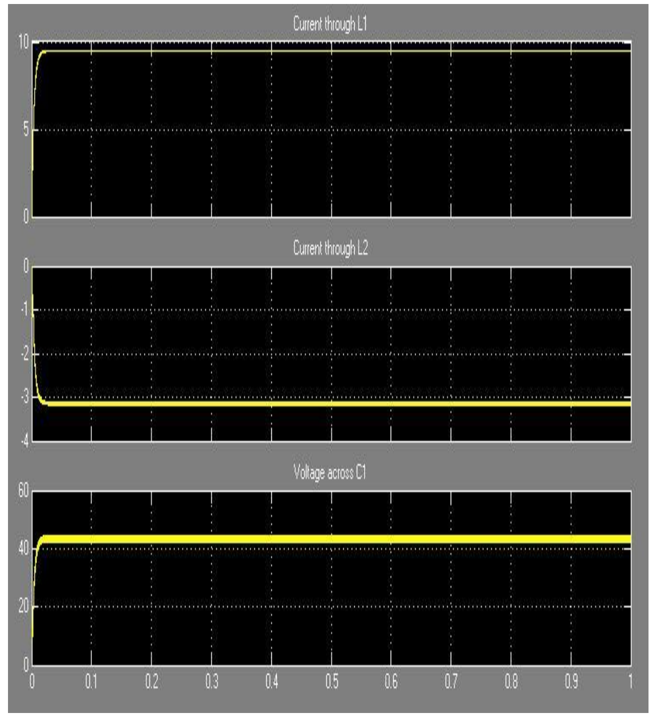

Fig. 15 Output of cuk converter when duty cycle is 75%

VIII. RESULT

In this paper, Cuk converter is simulated using MATLAB. In Cuk converter, the duty cycle is varied and corresponding voltage and current is observed. It is found that at 50% duty cycle, the performance of convertor is better than other values of duty cycle. At this duty cycle, the output power of Cuk converter is maximum.

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ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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