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Simulation of Photovoltaic based DC-DC Converter Topologies

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Abstract- Due to the depletion in the fossil fuel there is the major requirement of using other sources of energy.This concern has lead to the use of sources such solar energy,wind energy ,fuel cell etc.Power electronics is gaining popularity due to reduced cost and awareness in the society regarding the green environment .DC-DC Converters are required to convert the supply according to load demand .In this paper advancement in the topologies of DC-DC Converter is discussed and implemented using power sim environment. Photovoltiac system is used as the source. To extort utmost power from photovoltaic systems, utmost power point technique is used . Different topologies such as Buck ,Boost,Buck-Boost ,cuk ,zeta using solar as input are implemented and compared in this paper. as each topology has different complexities,efficiency.the work is carried using Psim

Keywords:Photovoltiacsystem,Buck,Boost,Buck-Boost,cuk,zeta converter.

I. INTRODUCTION

The era of power electronics is gaining importance due to the increase in demand for new and abundant sources of energy .Power Electronics offers many confronts due to its inimitable amalgamation of areas such as power electronic and control. Thus by bringing together the disciplines in order to achieve general understanding and consequent innovation in power processing electronic system[1]. A signal processing is concerned with active devices used is either linear or switching. But power electronics is concerned about switching mode with capacitor, Inductor & transformer but must avoid resistors in order to maintain high availability. Nowadays Renewable energy generation is gaining popularity as a source because of its various advantages such as including no fuel costs, not creating pollution ,less maintenance[2]. Though the cost of solar modules is relatively high and the efficiency is also low but the cost can be reduced by updating the production process of the solar arrays with respect to the materials.the efficiency can also be enhanced by commanding the insolation levels.The sun tracking solar collectors are used to maximize the input solar energy or it can also be increasing by rearrangement of solar cell configurations of PV arrays[2].The output from Photovoltiac module can be
enhanced with the aid of DC-DC converter. The are various topologies for this & each circuit has its own complexities, different working and efficiency. In photovoltaic applications there are various methods of maximum power tracking such as perturbation & observation (P&O),incremental conductance method etc. In P&O method maximum power point is tracked by modifying array voltage which moves operating point towards maximum. This method works satisfactorily when the isolation does not vary quickly with time. In incremental conductance method the utmost control point is tracked by comparing the augmentation and instant conductance of the solar array. by assess small changes in array voltage and current the incremental conductance is anticipated. Some control actions are applied for making small .In this paper various DC-Dc converter are studied and implemented using PSIM . Photovoltaic based buck,boost,buckboost converters are implemented with and without using crest power point tracking .all the simulation are carried in power sim (PSIM) environment.

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II. PROCEDURE FOR PAPER SUBMISSION

A photovoltiac system consists of photovoltaic module which consists of photovoltaic cell. The photovoltaic unit is a semiconductor device which is basically PN junction diode that work on photoelectric principle and convert light energy into electric energy. Electron hole pair generated and when these are pair affected by internal electric field then photoelectric current is produced. Thus PV unit is principally a current source and production of current is due to variation of photons only but not voltage.
The various numeral of P cells are connected in sequence or cascade or the amalgamation constitutes the PV module to congregate the utilization demand. The PV components of diverse substance which have high competence and of preferred degree are obtainable.
An equivalent circuit of PV is diode in antiparralel with current source. [4]

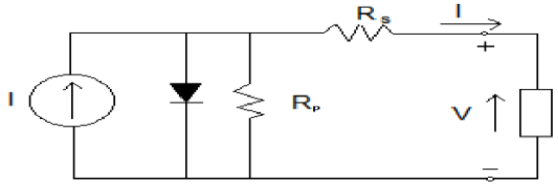

Figure 1 PV cell Model

realized by the current resource I alongwith a diode and opposition in series Rs.it also consists of a shunt resistance in parallel which is very high and so it can be neglected.

$$I = Is - Idi \quad (1)$$

$$Idi = Io(e^{\frac{qVdi}{kTjun}} - 1) \quad (2)$$

Where

Io : Diode reverse saturation current

q : charge on electron

Vdi : diode votage

k is Boltzmann constant :1.38 * 10-19 J/K

T jun: temperature of junction (K)

$$I = Is - Io\left(e^{\frac{qVdI}{kT}} - 1\right) \quad (3)$$

By required approximations,

$$I = Is - Io(e^{\frac{q(V+IRs)}{nikTi}} - 1) \quad (4)$$

Where

I : PV current

V : voltage of PV

Ti : temperature (in Kelvin)

ni : ideality factor of diode

Solar PV module have efficiency of 30%. So inorder to improve the efficiency and to extract maximum power , component has to be operated at a explicit levels of voltage . This can be achieved by following ways:

- By measuring the changing resistance by inserting a intermittent indicator current of petite level and escalating the working voltage till it is equivalent to the stagnant impedance V/I. [6]
- Succeeding technique works with escalating working voltage levels e until slant of the P vs V curve i.e DP/DV is positive [7][8]. generally a percentage linking the peak command voltage and untie network voltage is sustained to be 72 percent.
- In third technique it is infer that the purpose can be attained by corresponding the resistances by duty interval s amendment of the converter switching scheme and thus obtaining higher amount produced voltage[6].

There are various algorithm to track maximum power such :Heuristic search which include hill climbing & Perturb & Observe(P&O); farthest Value Searching ,Linear estimate Methods and Linear reoriented coordinates ; Intelligent control like Fuzzy logic and neural network; Linear control procedures .In this paper photovoltaic fed DC-DC converter using P&O technique is implemented . This Technique use simple feedback arrangement with assessed consideration In this method, the module voltage is varied periodically and the obtained power is compared with the previously state of power computed .[12]Perturbation is applied and If the power augments due to the perturbation then the agitation is sustained in the identical track. The MPP is null as the crest power is obtained and after that it lessen hence after the distribution reverses. The algorithm will swing around crest power point when the stable stipulation is achieved. The size of the small agitate is kept diminutive inured to maintain the power variation .The flow of the algorithm is such that it set the allusion p.d of the section analogous to the max out voltage of the component. The algorithm is given in figure 2

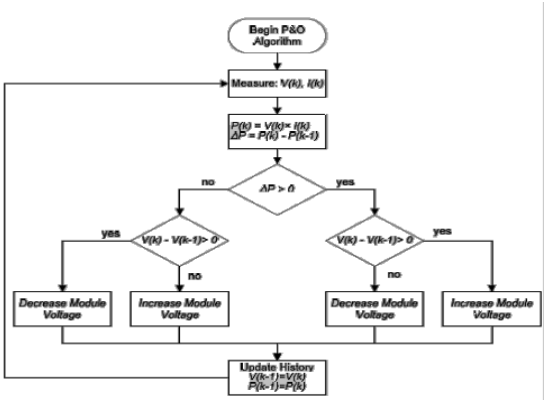

Figure 2:Flowchart of P&O Technique

III. DC-DC CONVERTERS

There are six generations of the converter topologies. Buck,Boost,Buck-Boost converter are Fundamental converters comes under First generation. The following are features of the switching converter:

- By changing the duty ratio of the converter the degree of freedom can be achieved and output voltage is controlled.
- Efficiency of these dc-dc converter is ideally unity as neglible voltage ripple and constant dc current is obtained if the appropriate filter is connected..However input current flows when the semiconductor device is ON. hence output current is the function of duty ratio only .the reason for 100% efficiency is achieved because semiconductor device used as switching device but in linear regulators it is used as linear dissipative elements or variable resistor .but practically there is some voltage drop across switch and the diode but these losses are negligible as compare to the losses in linear regulator.
- There is topological structure change for each switching period, though both switch structure is linear but due to periodic structure change converter is non linear and difficulties in modeling and analysis arises.

The DC-DC Converter works in different conduction forms (i) Continuous conduction form (ii) Discontinuous Conduction form.

Continuous conduction form: The parameters are selected in manner that load current never reaches the zero value and thus there are only two switched networks modes.

Discontinuous current form: in this mode there is a interval in which load current reduces to zero as the delay angle is more and than extinction angle and there is three switched states in each time period.

In buck boost converter the dimensionless factor K= 2L/R*Fs is used to determine the depth of discontinuity but in Buck and Boost converter k along with the duty ratio is used to determine the depth of discontinuity. Thus discontinuous mode is also referred as heavy mode with low R and heavy loading.

In buck ,buck-boost converter input current is pulsating so it requires the input filter in front of converter to lessen the current ripples ..Boost converter has dominant voltage ripple as it has pulsating output current .it is desired in the converter that the output voltage ripple should be negligible which can be met when the corner frequency of the LC filter should be very less than the switching frequency of the converter switch. Thus low output voltage can be achieved by increasing the value of capacitance or by increasing the switching frequency. Effect of electromagnetic interference and the percentage of output ripple voltage is more prominent in discontinuous mode of operation as both input and output are more pulsating. Thus by lowering the inductance transition can be done from continuous mode to discontinuous mode of operation. The responsibility of filtering out ripple voltage is equally shared among inductance and capacitance in discontinuous mode of operation but in continuous mode capacitance is prominent for filtering the ripples as inductance mainly used to energy transfer than filtering.. By following above features modeling of DC-DC converter becomes relatively simple and accurate.

Also the size and weight of the converter can be reduced by increasing the switching frequency which would allow proportional increase in the corner frequency with same voltage ripple content. Though this will reduce the size as small value of inductance and capacitor is required but will increase the cost and the switching losses thus effect the efficiency of converter.

A. Buck Converter:

The buck converter consists of semiconductor switch, capacitor, inductor as revealed in figure 1.

.In this DC-DC system average value of load voltage is less than the input voltage .Load voltage is sensed and which is used to control the turn off and turn on time of the switch. It works in two states[13].In first state when the switching device is turned on .In this input current rises and in second state switching device is turned off and freewheeling diode conducts due to the energy accumulated in the inductor and current flows all the way through L,C ,load and diode.

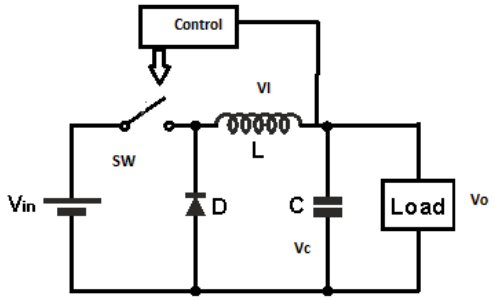

Figure3: Basic Buck Converter

In Mode I ,When Switching device is turned On ,The input current rises ,surges through the filter circuit and load.

Voltage across Inductor

$$Vl = L\frac{di}{dt} \quad (4)$$

$$Vin - Vo = L\frac{\Delta I}{t1} \quad (5)$$

Where t1 is the turn on time ,ΔI is peak to peak ripple current of the inductor.

In mode2

$$-Vo = -L\frac{\Delta I}{t2} \quad (6)$$

$$\Delta I = \frac{(Vo-Vin)\,t1}{L} = \frac{Vin\,t2}{L}$$

Substitute t1= kT,t2 = (1-k)T

$$Vo = Vin\frac{t1}{T} = kVin \quad (7)$$

Value of inductor L & C can be calculated as

$$L = \frac{Vink(1-k)}{f\Delta I} \quad (8)$$

$$C = \frac{Vink(1-k)}{8L\Delta Vcf^2} \quad (9)$$

Where ΔVc is the crest voltage of the capacitor.

B. Boost Converter

In Boost converter voltage at the load terminal is larger than the enter side voltage as shown in figure 2.This converter operates by varying the duty interval for which inductor stores the energy.Output voltage sensed by the sensor control the switching of the converter.

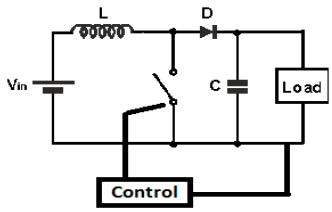

Figure4 : Basic Boost Converter

When switch is turn ON ,input current rises and will pass through inductor and it will store energy.

When switch is turned off, current will flow through L,C,load and diode .Inductor current will fall and release its energy to load.

So when switch is turned ON

$$Vin = L\frac{\Delta I}{t1} \quad (10)$$

When switch is off current falls

$$Vin - V0 = -L\frac{\Delta I}{t2} \quad (11)$$

Using equation 7&8 we get,

$$Vo = Vin\frac{T}{t2} = \frac{Vin}{1-k} \quad (12)$$

Value of L& C can be calculated as

$$L = \frac{Vsk}{f\Delta I} \quad (13)$$

$$C = \frac{Iok}{f} \quad (14)$$

C. Buck-Boost Converter

In Buck Boost converter , voltage at the load side is less than or greater than a input voltage as shown in figure 3

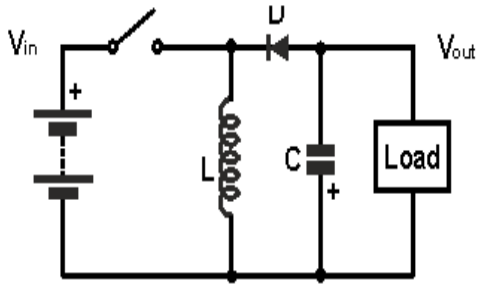

Figure 5 : Basic Buck-Boost Converter

In this arrangement of buck- boost converter ,the number of component are same as buck or boost converter but the output is of opposite polarity of input.

The input current increases in turn on time of switch and inductor store energy and its current heighten .when switch is turned OFF ,path of the current will be through L,C,D and load and inductance energy will transmit to the load.

So when switch is turned ON

$$Vin = L\frac{\Delta I}{t1} \quad (15)$$

When switch is off current falls

$$Vo = -L\frac{\Delta I}{t2} \quad (16)$$

From 12 &13 we get,

$$Vo = -\frac{Vink}{1-k} \quad (17)$$

Value of L& C can be calculated as

$$L = \frac{VinVo}{f(Vin-Vo)\Delta I} \quad (18)$$

$$C = \frac{IoVo}{(Vo-Vin)f\Delta Vc} \quad (19)$$

D. Cuk Converter

This is a converter which combines the advantages of the basic DC-DC structure shown in figure 4 .Cuk converter provides the advantages such as continuous input current ,continuous output current and output voltage can either be greater or smaller than the input voltage.

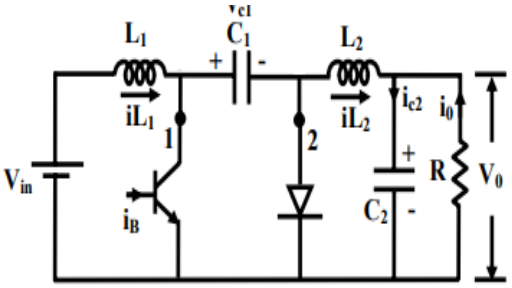

Figure 6:Basic Cuk Converter

In cuk converter capacitor is charged to the polarity as revealed in figure 4 .Now when switching device is turned ON

$$Vin = L1\frac{\Delta I1}{t1} \quad (20)$$

Then when switch is turned off then diode will be turned ON

$$Vin - Vc1 = -L1\frac{\Delta I1}{t2} \quad (21)$$

Average output voltage of capacitor C1

$$Vc1 = \frac{Vs}{1-k} \quad (22)$$

When switch is turned off then

$$Vo = -L2\frac{\Delta I2}{t2} \quad (23)$$

$$\Delta I2 = \frac{(Vc1+Vo)t1}{L2} = -\frac{Vat2}{L2} \quad (24)$$

The average output voltage is

$$Vc1 = -\frac{Va}{k} \quad (25)$$

Equating equation 19 & equation 22

$$Vo = -\frac{kVs}{1-k} \quad (26)$$

IV. SIMULATION & RESULTS

The various DC-DC converter are implemented in PSIM environment .these converter are fed by PV module and P&O technique is being implemented. The following are the model of different converters.

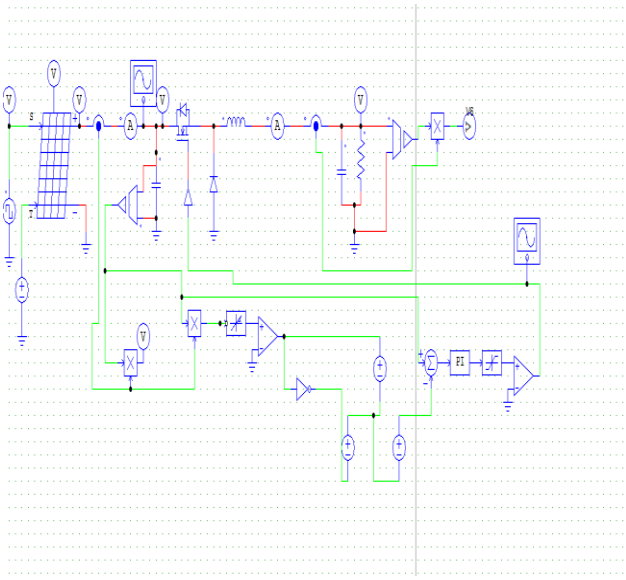

Figure 7: Buck Converter with MPPT

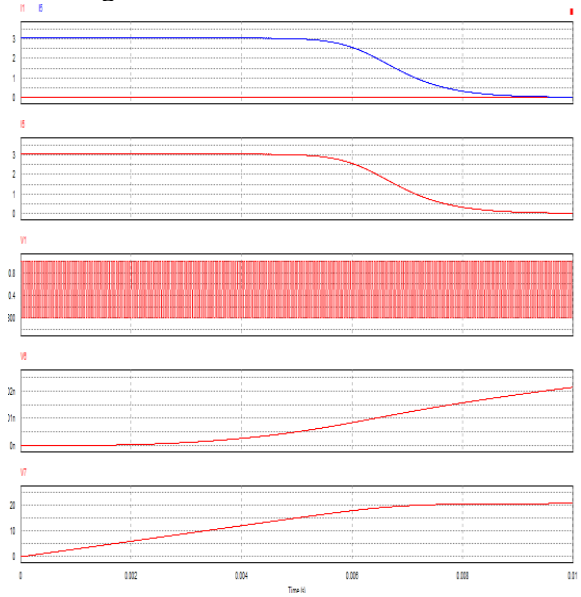

Figure 8 Simulation result of Buck Converter

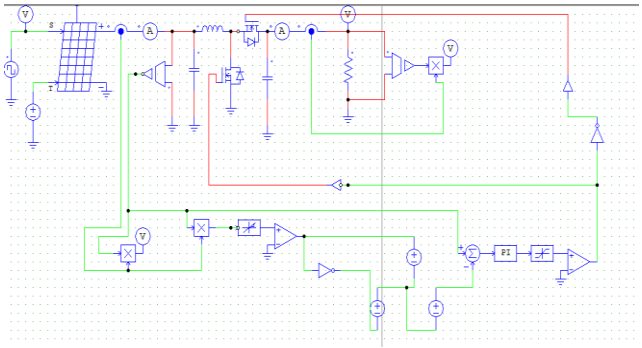

Figure 9: Buck-Boost Converter with MPPT

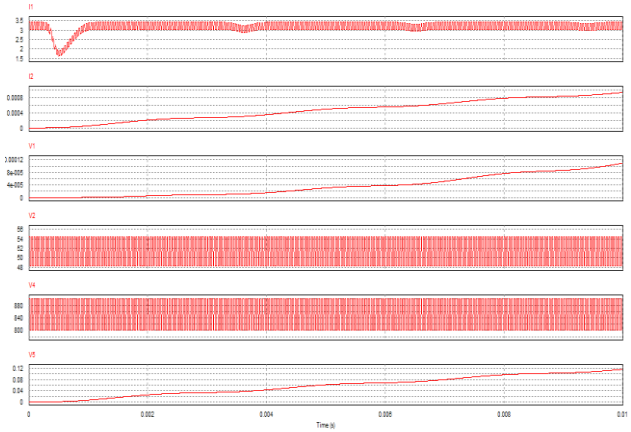

Figure 10. Simulation result of Buck Converter

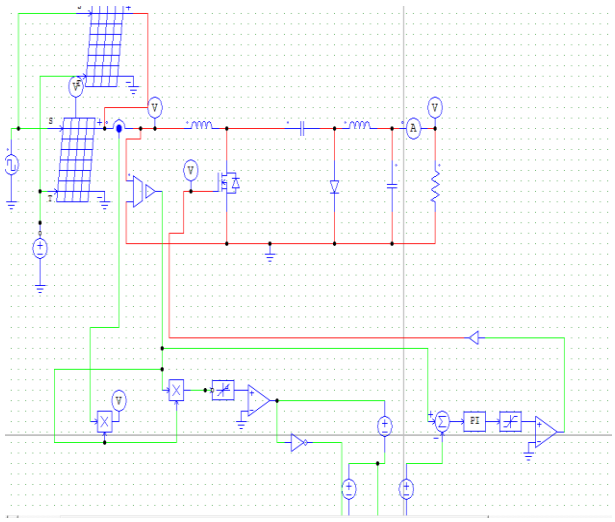

Figure 11 Cuk Converter with MPPT

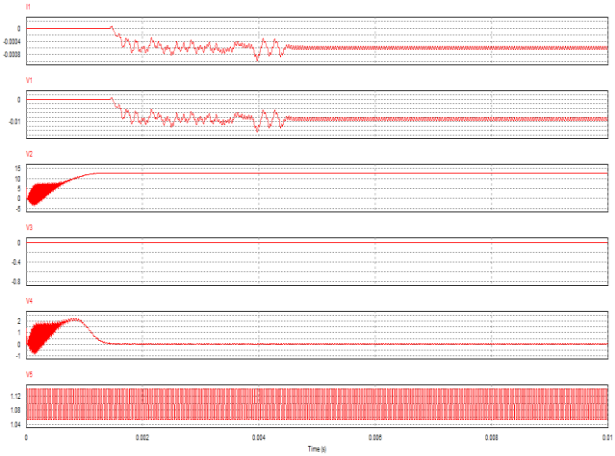

Figure 12 Simulation of Cuk Converter with MPP

V. CONCLUSION AND FUTURE SCOPE

This paper provide the need of photovoltaic systems for the beneficial of the society. The features & design consideration of the DC-DC converter are being conferred in this paper. Various DC –DC converter topologies are analyzed using photovoltaic system. To extract maximum power from the PV Module there are different maximum power point tracking algorithm and need of MPPT is discussed in this paper. By using MPPT algorithm and DC/DC bi-direction converter, solar array is operated at maximum power point irrespective of variations of solar irradiance. These DC-DC converter can be implemented using intelligent techniques and can be extended to various level. There are various application such as water pumping system, hybrid vehicle ,grid tie inverters in which DC-DC converter can be implemented.

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