International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 7, Number 3 (2014), pp. 475-483

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MPPT with Z Impedance Booster

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ABSTRACT

The output of PV module depends on solar irradiance and temperature which are dynamic in nature. Hence an algorithm which dynamically computes the operating point of the solar panel is required. In this manuscript Maximum Power Point Tracking algorithm (MPPT) is used for efficient conversion of solar energy. MPPT is used to tune the circuit continuously so that maximum power from solar array can be drawn irrespective of weather or load variations. Presently Buck, Buck-Boost converters are used to implement MPPT algorithms. This paper presents Z impedance network based booster and inverter to realize Perturb and Observe algorithm of MPPT. The Z booster circuit presented employs a unique LC network which provides the novel power conversion concept. By controlling the duty cycle, Z impedance booster with inverter can provide buck or boost operation.

Keywords - Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O), Photo Voltaic(PV), Space Vector Pulse Width Modulation (SVPWM), Z impedance booster

I. INTRODUCTION

Power delivered by a PV system depends on the irradiance, temperature and the current drawn from the cells[1]. It means power from PV module is a function of atmospheric conditions. In order to maximize the output of a PV system, continuously tracking the maximum power point (MPP) is necessary irrespective of atmospheric conditions. Tracking of MPP is realized with the help of MPPT algorithms. This manuscript steps through P&O algorithm of MPPT. According to the theory of maximum power transfer, power delivered to the load is maximum when the source internal impedance is equal to load impedance. Thus the impedance seen from the converter side needs to match the internal impedance of solar array. This matching is done with the help of MPPT algorithms by adjusting the voltage and current such that the maximum power point is achieved. Block diagram of PV system with MPPT control is shown in Fig.1. Block diagram shown consists of PV array, power conditioner, MPPT controller and 3 phase resistive-inductive load. Power conditioner in this manuscript is realized by *Z impedance booster* and inverter. Inverter used employs SVPWM scheme. The major advantage of SVPWM is improvement in harmonic performance and reduction in current waveform distortion[2-4].

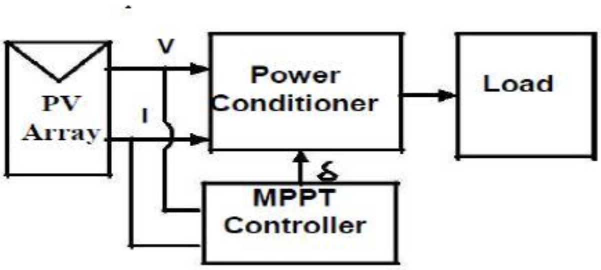

Fig.1. PV system with MPPT control

II. PROBLEM OVERVIEW

Fig.2 shows the characteristic power curve of a PV array. The problem considered by MPPT technique is to automatically find the voltage VMPP or current IMPP at which a PV array should operate to obtain the maximum power output PMPP under a given temperature and irradiance.

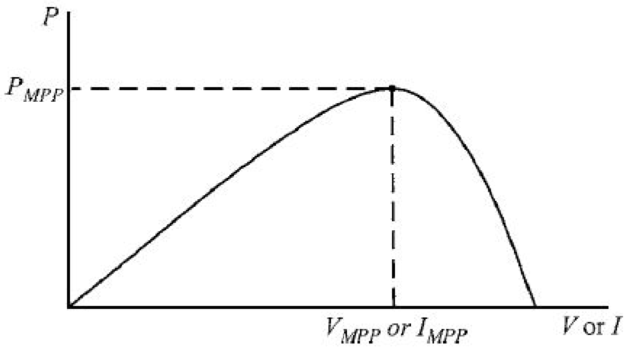

Fig.2. Characteristic PV array power curve

III. P&O ALGORITHM

P&O algorithm is the most popular MPPT method due to its ease of implementation and good performance when the irradiation is constant. In this method, the sign of the last perturbation and the sign of the last increment in the power are used to decide what the next perturbation should be .On the left of the maximum power point, incrementing the voltage increases the power whereas on the right, decrementing the voltage increases the power. If there is an increment in the power, the perturbation should be kept in the same direction and if the power decreases, then the next perturbation should be in the opposite direction. Based on these facts, the algorithm is implemented[5-6]. The process is repeated until the maximum power point (MPP) is reached. Then the operating point oscillates around the MPP. The shortcomings of this method are oscillations around the MPP and tracking in the wrong direction during rapidly changing atmospheric conditions. A flowchart of the algorithm is shown in Fig.3.

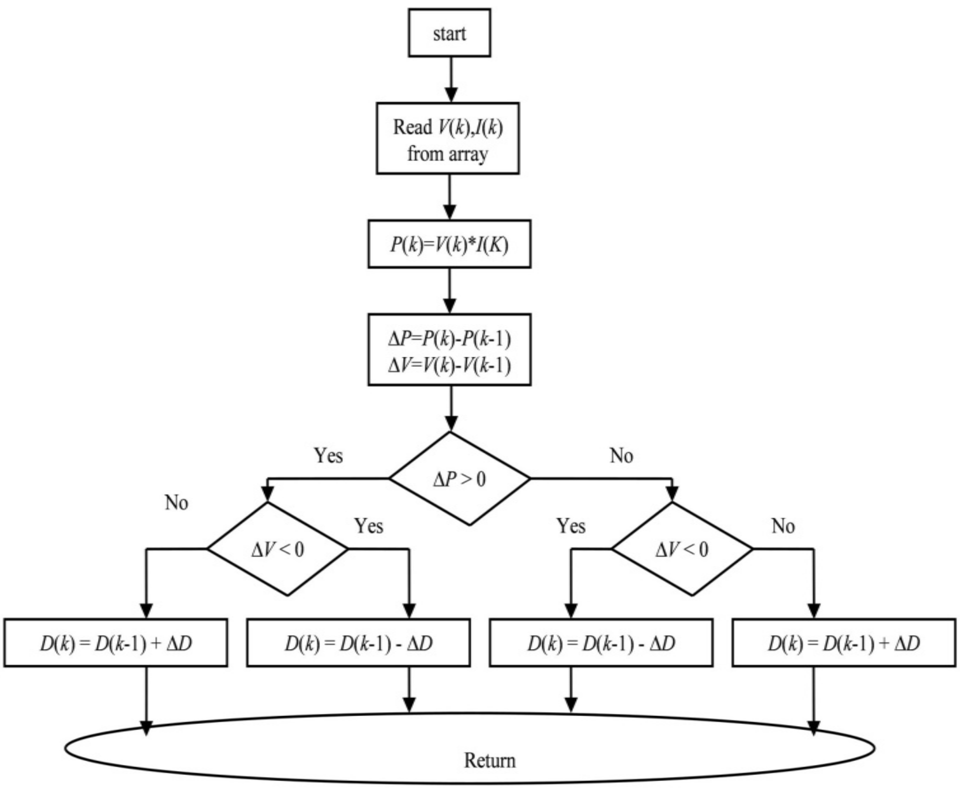

Fig.3. Flowchart of P&O algorithm

IV. Z IMPEDANCE BOOSTER

In Fig. 4, a two-port network that consists of a split inductor L1 and L2 and capacitors C1 and C2 connected in X shape is employed to provide an impedance source (Z-source) coupling the inverter to the PV array. The inductance L1 and L2 can be provided through a split inductor or two separate inductors[7]. By varying the duty cycle and modulation index of inverter the voltage gain of overall circuit can be set more or less than unity. It means buck and boost operation can be implemented with the help of this network. P&O algorithm of MPPT gives the pulses corresponding to maximum power to switch connected in parallel with Z impedance network as shown in Fig.4.

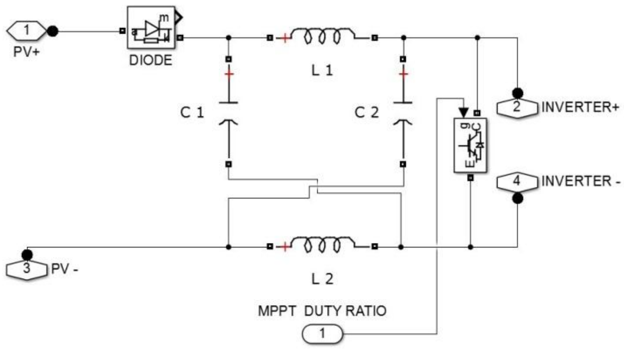

Fig.4. Z impedance booster

V. MODES OF OPERATION OF Z BOOSTER

1)Mode I

Switch connected in parallel with Z impedance network (as shown in Fig.4) gets pulses according to MPPT algorithm. During Toff, pulses are not given to above mentioned switch, Z impedance booster operates in mode I. Equivalent circuit during mode I is shown in Fig.5. Inverter acts as a current source, when viewed from Z impedance network, supplying the load. Assume that the inductors (L1 and L2) and capacitors (C1 and C2) have the same inductance and capacitance respectively to make the network symmetrical[7-8]. Capacitors are charged with the polarities shown in Fig.5.

Here,
VO= Net PV cell voltage,
Vi= DC link voltage of inverter,
VC1=VC2=VC= Voltage across capacitors C1 and C2
VL1 =VL2 =VL = Voltage across inductors L1and L2

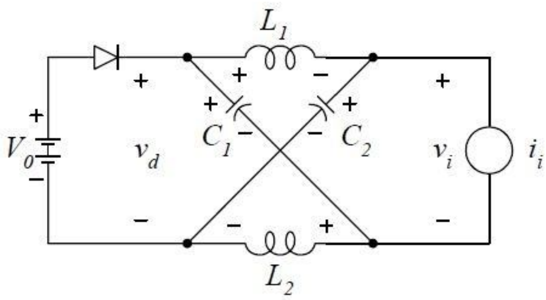

Fig.5. Equivalent circuit during mode I

2)Mode II

During Ton, pulses are given to switch connected in parallel with Z impedance network, mode II takes place. In this mode diode becomes reverse biased. Hence PV cell gets disconnected from rest of circuit. This provides short circuit protection to PV cell during Ton. Equivalent circuit of mode II is shown in Fig.6. During this mode C1 discharges through L1 and C2 through L2. Output voltage becomes zero for the duration equal to Ton [7-8].

Here,

VL1=VC1=VC

VL2=VC2=VC

Vd=2VC

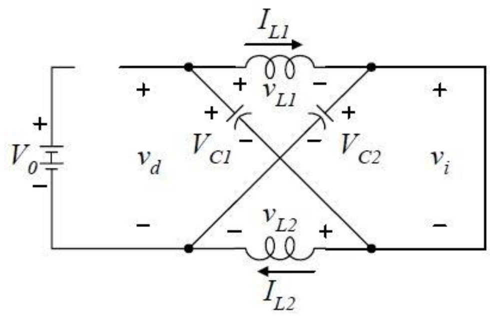

Fig.6. Equivalent circuit during mode II

3) Mode III

During Toff of pulses mode III takes place. Equivalent circuit of mode III is shown in Fig.7. Inductors were charged in mode II and therefore following calculations are done[7-8],

VL=VO - VC, (1)

Vd=VO, (2)

Vi=VC - VL=2VC - VO, (3)

f=1/T=Switching frequency,

T=Ton +Toff,

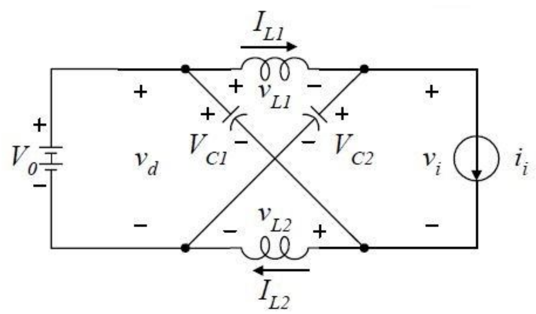

Fig.7. Equivalent circuit during mode III

VI. CALCULATION [7-8]

By Volt-Second balance theory for inductor,
Average voltage across inductor over one switching cycle is zero. Therefore,

$$VL*T = (Ton* VC) + (Toff *(VO - VC)) \quad (4)$$

Similarly, the average dc link voltage across the inverter is given by,

$$Viavg = (Ton* 0)+(Toff *(2VC-VO)$$
$$=(Toff/ (Toff -Ton))* VO$$
$$=VC \quad (5)$$

Peak DC link voltage across the inverter is given by Vipeak,

$$Vipeak=VC - VL=2VC - VO$$
$$=(T/(Toff- Ton))* VO \quad (6)$$

$$\text{Where,} B=(T/(Toff- Ton)) \quad (7)$$
=Boost factor of Z impedance network
$>= 1$

Output peak voltage per phase of inverter is given by Vacph,

$$Vacph=M* Vipeak \quad (8)$$

Where,
M=Modulation index of SVPWM
$<= 1$
Therefore,

$$Vacph=(M*B*VO)/2 \quad (9)$$

M*B = Buck boost factor
=BB
= (0 to infinity)

Hence, output AC voltage can be stepped up and down by choosing an appropriate buck-boost factor BB.

VII. SALIENT FEATURES OF Z BOOSTER

1)Advantages

- If conventional inverter[2] is connected to Z impedance network then advantages of both Voltage source and Current source inverter are obtained[7].
- Unique feature of Z impedance booster is its ability to provide ride through during voltage sag to sensitive AC load fed by PV cell through inverter. Voltage sag in PV cell may occur due to momentary but sudden weather changes.
- Inductors in Z impedance network smoothen ripples in current and capacitors smoothen ripples in voltage. One of the disadvantages of P&O algorithm is, operating point oscillates continuously around MPP even if atmospheric conditions are unchanged and situation becomes worse when there are changes in atmospheric conditions[5-6]. In such situations while tracking MPP, current and voltage ripples are produced which can be smoothened by Z impedance network.

- By replacing conventional buck- boost converter by Z booster, we can get all the advantages of Z source inverter. In a nutshell we can say that Z impedance booster along with conventional inverter is a pseudo Z source inverter.

2) Disadvantages

- Z impedance booster alone cannot provide buck operation, but when coupled with conventional inverter, it can act as a buck-boost converter by adjusting values of B and M.
- As compare to conventional buck-boost converter[9], Z impedance booster requires more number of inductors and capacitors.

VIII. SIMULATION and RESULTS

Fig.8, shows the circuit simulated in MATLAB/SIMULINK. PV cells used, have open circuit voltage of 44.2 V and short circuit current of 5.2 A. Two such PV cells are connected in series to get VO=88.4V. Temperature and Irradiance at which circuit is simulated are 35Celsius and 1000Watt/m^2. For Z impedance booster, L1=L2=L=5mH and C1=C2=C=1uF so that output is 440 V at switching frequency of 650Hz. Switching frequency is given by MPPT algorithm. Output of Z impedance booster is given to inverter. Controlling method used in inverter is SVPWM to get sinusoidal current. Inverter gives 3 phase, 440 V line to line voltage. This AC voltage is used to feed 3phase resistive-inductive load. Fig.9, shows switching pulses given by MPPT algorithm and Fig.10, shows the line to line voltage of inverter.

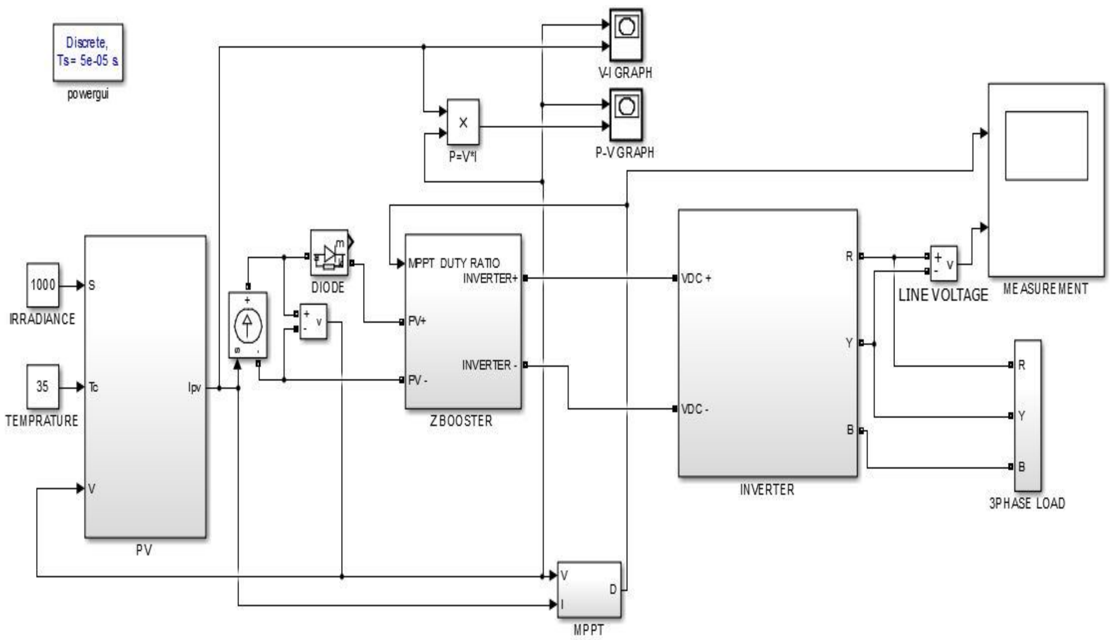

Fig.8.Simulation in MATLAB

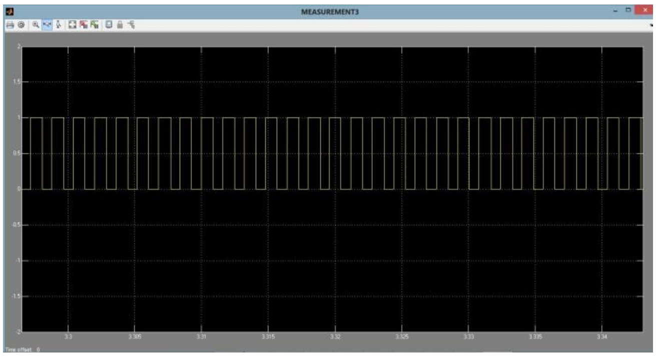

Fig.9.Switching pulses given by MPPT

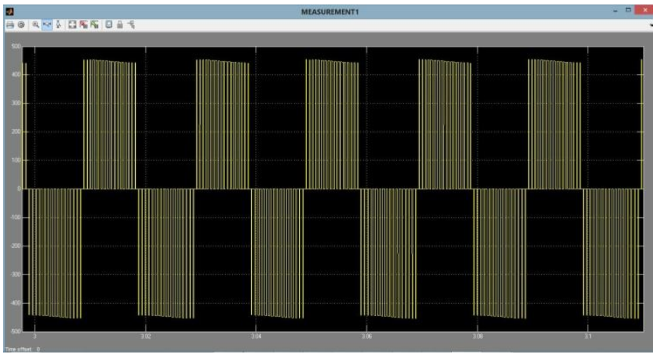

Fig.10.Line to Line voltage

IX.CONCLUSION

This paper has presented the concept of Z impedance booster which can be used as an alternative to conventional buck-boost converters. The Z impedance booster has a unique LC network which provides novel boosting concept of DC voltage. The paper has mainly focused on P&O algorithm of MPPT. The model is simulated in MATLAB.

Acknowledgment

The authors would like to thank faculties and colleagues for their support in this work.

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