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Zeta Converter Fed Integrated Inverter For Grid Connected PV System with Optimal Power Point Tracking

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ABSTRACT*:* For high power efficiency in the grid connected PV system zeta converter fed integrated inverter grid connected PV system has been proposed.A perturb and observe MPPT for zeta converter has been proposed for optimal power point tracking. The proposed system integrates optimum power point tracking, dc side buck boost voltage and inverter current injected into the grid. The integrated inverter is controlled by hysteresis current controller. The simulation results have been verified using MATLAB/SIMULINK environment.

KEYWORDS: Grid connected PV system, MPPT, Zeta converter, MATLAB/SIMULINK

I. INTRODUCTION

The fossil fuel and nuclear fission are the energy sources which are needed to produce electric power. The burning of fossil fuel produces the harmful gases and toxic metals to the environment. Renewable energies are playing a vital role in supplying the world's required power demands. The photovoltaic power generation system keeps growing in the last few decades to produce promising source of energy. The present PV systems are not very efficient and having 12-20% efficiency to convert solar power to electrical power [1-3]. The drop in efficiency of solar array is due to the variable irradiance and ambient temperature. In order to extract the optimal power from solar array it is important to operate the solar array at its optimal power point. Hence Maximum Power Point Tracking algorithms are required to extract optimum power from the PV Array at variable irradiance level and environmental temperature[4-6]. In this paper a perturb and observe based MPPT has been proposed due to fast and easy computational analysis. The proposed Zeta converter gives low voltage ripple compared to other conventional dc-dc converter. The integrated inverter has been controlled by hysteresis current control which gives fast dynamic response, high efficiency and low THD compared to other conventional current control.

II. RELATED WORK

The structure of the proposed system is shown below in Fig.1.The block diagram shows the proposed zeta buck boost converter is controlled by P&O MPPT control,on the other hand the Three phase inverter has been controlled by hysteresis current controller.

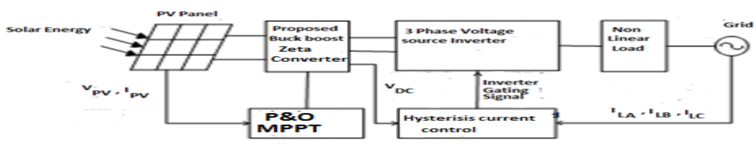

Fig.1 Proposed system structure

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A. **Mathematical modelling of PV system**

The PV cell model is developed using equivalent circuit equations as shown in Fig.2,of the Photovoltaic cells including the effects of temperature and solar insolation.

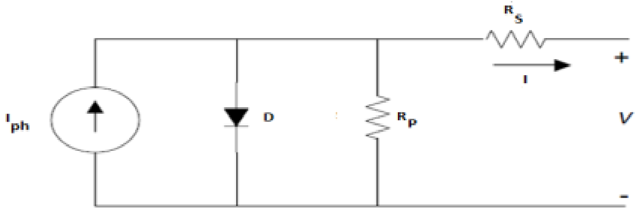

Fig.2 Equivalent circuit of a PV cell

For obtaining the V-I characteristics of a PV cell, the equation is expressed as:

$$I = I_{Ph} - I_0 \left\{ \exp\left[\frac{q}{AK\,T_C} \left(V + IR_S \right) \right] - 1 \right\} - \frac{V + IR_S}{R_P} \qquad \ldots\ldots.(1)$$

Where,

Iph is the photocurrent, I_0 is the reverse saturation current of the diode, *q* is the electronic charge, *V* is the output voltage across the cell, *K* is the Boltzmann's constant, T_c is the operating cell temperature, *A* is the ideality factor of the diode, and *Rs* and R_P are the series and shunt resistors of the cell, respectively.

B.Zeta buck boost converter

The proposed zeta converter has been used as a MPPT tracker due to least output voltage ripple. It includes two capacitors and two inductors as dynamic storage elements and able to amplify and reduce the input voltage levels without inverting the polarities. Zeta converter works in two modes of operation. In first mode of operation, when switch is closed, the current flows through inductor Land L_1 while diode is reversed biased. In second mode of operation when switch is opened, the diode is conducting and all the energy stored in inductor L_1 is transferred to Load RL as shown in Fig3.

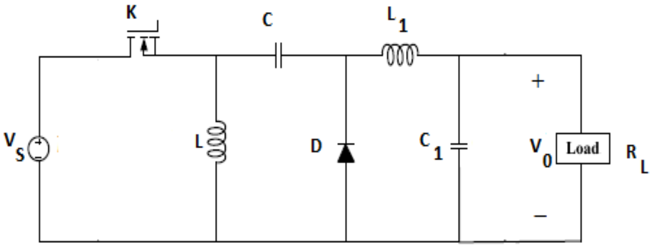

Fig.3 Circuit of zeta converter

C.Purturb and observe (P&O) MPPT

In perturb & observe method, the array voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous output power. In this method a small perturbation is introduce to the system. This perturbation causes the power of the solar array various. If the output power increases due to the perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses . This process is repeated until the MPP is reached .Fig4.shows the matlab/simulink implementation of P&O method.

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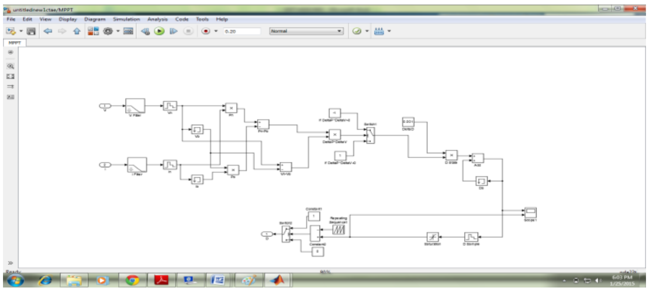

Fig 4 P&O method using Matlab/simulink

D.Integrated inverter control

The integrated inverter is controlled by shunt active filter scheme.

***1. Generation* of reference current for each phase of inverter**

The proposed system used instantaneous reactive power (IRP) theory for the Generation of reference current for each phase of inverter. The Instantaneous Reactive Power theory s describes the Clarke transformation of the three phase input voltages and the three phase load currents in the a-b-c coordinates to the α-β-0 reference frame followed by the calculation of the real and reactive instantaneous power components. From figure it is clear that the input voltage and load current are transformed, and processed to generate reference current commands as a input to a hysteresis current controller to generate the gating signal for inverter, shown in Fig.5.

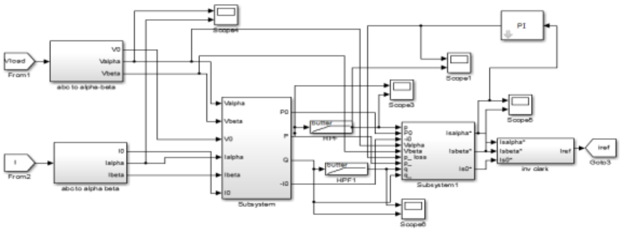

Fig.5 MATLAB/SIMULINK implementation of the generation of the reference current

2. Generation of gating pulses for inverter

The proposed system used nonlinear control based hysteresis current controller for generation of gating pulses to the inverter. It generates the switching pattern for current controlled voltage source inverters which gives precise and quick response, as shown in Fig6.

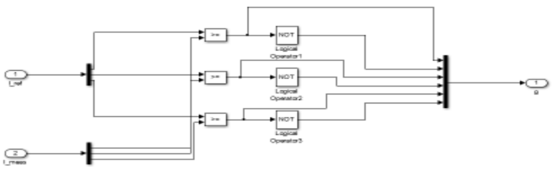

Fig.6 MATLAB/SIMULINK implementation of the hysteresis current control

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III. SIMULATION RESULTS

The proposed system has been implemented using Matlab/Simulink as shown in Fig 7.

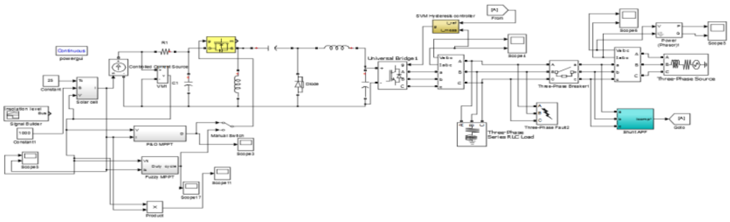
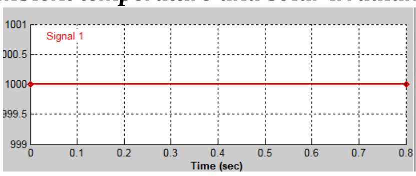
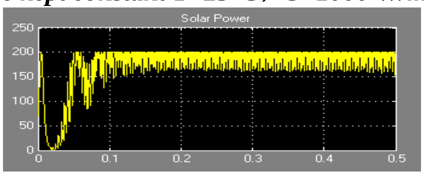


Fig.7 Simulink model zeta fed of Integrated Inverter with P&O MPPT

The simulation is implemented in MATLAB/SIMULINK environment with P&O algorithm as shown in Fig7. Under the same irradiation and temperature conditions, the PV array continued to generate around 200 Watts. In this case the power obtained by the PV array at the load side is found to be around 200 Watts. Under different weather conditions fuzzy logic based MPPT shows better performance in MPPT applications. The above simulation results show tracking capability of the proposed system at different insolations.

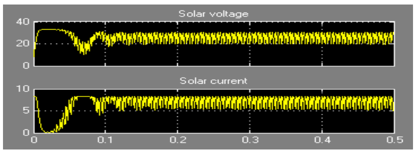
Case I: When the ambient temperature and solar irradiance kept constant $T=25^0$C, S=1000 W/m2.

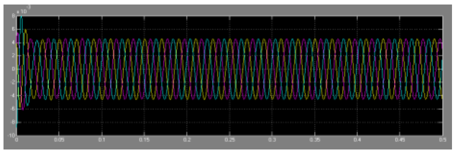




(a) (b)

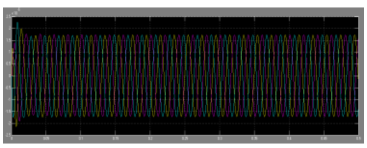
Fig (a) shows the constant irradiance level and (b) shows the solar power at constant irradiance and constant temperature i.e at $T=25^0$C, *S=1000 W/m2.*

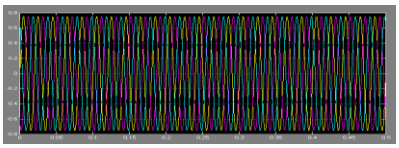




(b) (d)

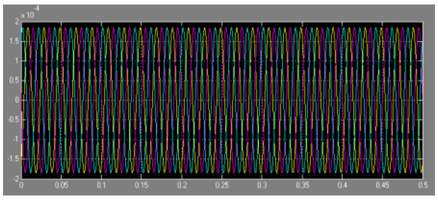
Fig(b) and (c) show the solar voltage,solar current and inverter current at standard irradiance and ambient temperature respectively. The MATLAB/SIMULINK results of Integrated Inverter for grid connected PV system with MPPT are shown in Figure. It can be conclude from the above figure that the system reaches the maximum power point at time t=0.15 sec. Time t=0 to t=0.02sec is a period for the system to initialize its state. At time t=0.02 sec, the PV cell has output voltage, on the other hand solar power and solar current is zero. From period t=0.02sec to t=0.15sec, the simulated MPPT based P&O method waveform has overshoot. After t=0.15sec, the waveform are constant throughout.





(e) (f)

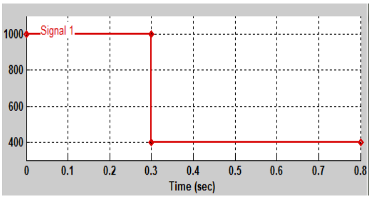
The above simulation results show that the inverter current is purely sinusoidal in nature and it is the current injected into the grid as shown in fig 8(d).From figure 8(f) and (g), it is clear that grid voltage is also purely sinusoidal in nature.



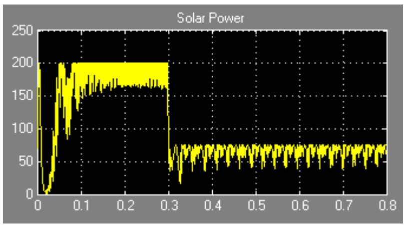
(g)

Fig.8 (a) Constant solar irradiance (b) Solar power(c) Solar voltage and current(d)Inverter current(e) Inverter voltage(f) Grid voltage (g) Grid current

Case II: When the ambient temperature kept constant （25^{0}C）, and the solar irradiance varies from 1000 W/m2 to 400 W/m2 at time t=0.3s.

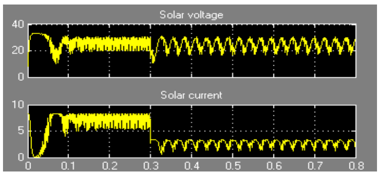


(a)

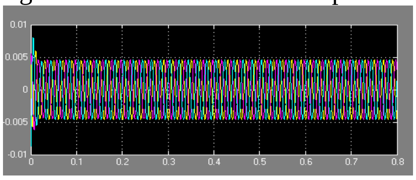


(b)

The above simulation results are shown, when cell temperature remains constant and solar irradiance level changes. It is clear from the figure that at time t=0.3s the output solar power decreases due to sudden reduction in irradiance level at 0.3 sec .On the other hand the solar output voltage increases and the solar output current increases.

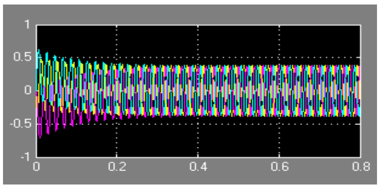


(c)

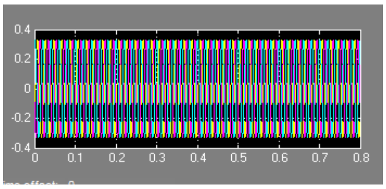


(d)

After t=0.5ecs the waveforms of solar power, solar voltage and solar current shakes up and down regularly. From above simulation results 9 (b) &(c), it is clear that the proposed system always run at maximum power, no matter what the operating condition is.

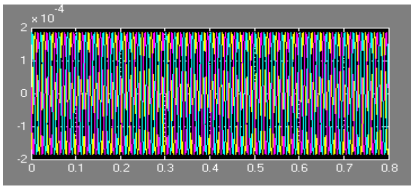


(e)



(f)

The simulation results show that due to variation in irradiance level also the proposed system has purely sinusoidal waveform of inverter current, as shown in fig9(d).the sinusoidal grid voltage and grid current are also shown in fig9 (f) & (g).



(g)

Fig.9 (a) variable solar irradiance (b) Solar power(c) Solar voltage and current(d)Inverter current(e) Inverter voltage(f) Grid voltage (g) Grid current

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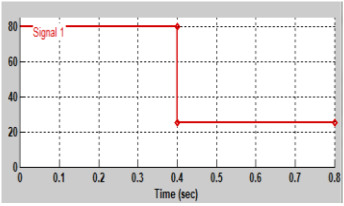
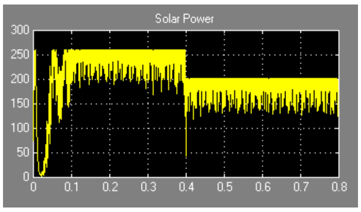
Case III: When the solar irradiance kept constant at 1000 W/m2, the ambient temperature varies at t=0.4s from 80 to 25^{0}C.

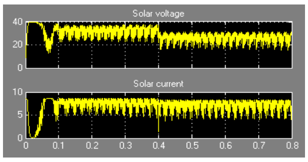


(a)

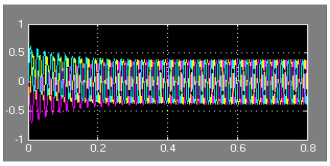


(b)

The simulation results are shown, when solar insolation kept constant and cell temperature changes. It is clear from the figure that at time t=0.4sec, the output solar power, solar voltage and solar current increase due to sudden change in environment temperature.

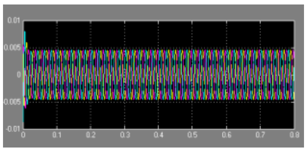


(c)

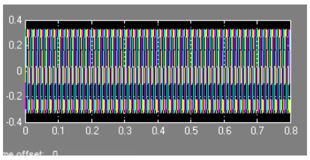


(d)

After time t=0.4sec, the solar power, solar voltage and solar current waveforms shake up and down regularly. This P&O based MPPT can work effectively when environmental temperature changes suddenly. The above simulation results show tracking capability of the proposed system at different insolations.

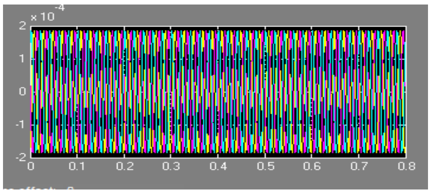


(e)



(f)

Simulation results show that fig10 (b) &(c), due to variation in ambient temperature also the proposed system works at maximum power. From figure 10 (d), (f) & (g), it is clear that inverter current, grid voltage and grid currents are sinusoidal in nature. The inverter current is in phase with the grid voltage.



(g)

Fig.10 (a) variable solar irradiance (b) Solar power(c) Solar voltage and current(d)Inverter current(e) Inverter voltage(f) Grid voltage (g) Grid current

IV. CONCLUSION

The zeta based integrated inverter for grid connected PV system has been proposed. Through the proposed modelling and controller design, the proposed system can track the peak power of the PV modules and feed power to the grid. The P&O MPPT method is able to track the optimal power from solar array at different irradiation level and variable ambient temperature. Simulation results show that the proposed system always runs at maximum power and giving better dynamic response even at variable atmospheric conditions.

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